Int Ophthalmol (2020) 40:943–949
https://doi.org/10.1007/s10792-019-01266-7

ORIGINAL PAPER

# Complications of femtosecond laser-assisted cataract surgery combined with vitrectomy

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Received: 16 May 2019 / Accepted: 28 December 2019 / Published online: 8 January 2020


**Abstract**
*Purpose* To evaluate the safety of femtosecond laser-assisted cataract surgery (FLACS) combined with 25- or 27-gauge vitrectomy.
*Methods* This retrospective study included patients who underwent FLACS combined with 25- or 27-gauge vitrectomy at the Jikei University School of Medicine in Tokyo, Japan, between August 2016 and April 2018 and were followed up for $\geq$ 3 months postoperatively. In all cases, anterior capsulotomies and fragmentations of crystalline lenses were performed using a femtosecond laser. After FLACS, 25- or 27-gauge vitrectomy was performed. All intraoperative and postoperative complications due to FLACS and vitrectomy were examined.
*Results* A total of 34 eyes from 34 patients were included. In 33 cases, complete coverage of the intraocular lens (IOL) by the anterior capsular edge was achieved. One case had posterior capsule rupture due to mis-suction during emulsification and aspiration of a fragment of the nuclear lens after capsulotomy. The IOL was fixed at the sulcus. Postoperative complications included endophthalmitis and macular edema in one eye, epiretinal membranes in two eyes, and postoperative capsular opacification in two eyes. The femtosecond laser caused no postoperative complications. There were no cases of intraoperative or postoperative iris capture or IOL subluxation.
*Conclusions* In most cases, FLACS provided good IOL fixation in the capsule without affecting the intra- or extraocular pressure and good vision during or after the operation. FLACS combined with 25- or 27-gauge vitrectomy should be performed considering the advantages and disadvantages of femtosecond laser usage.
*Clinical trial registration* Japan Clinical Trials Register; number: UMIN000021814.

**Keywords** FLACS · Vitrectomy · Capsulotomy · Femtosecond laser · Complication

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## Introduction

Femtosecond laser-assisted cataract surgery (FLACS) has recently become popular worldwide [1]. Femtosecond laser methods provide some advantages in cataract surgery [2–4]. Laser anterior capsulotomy, fragmentation of the crystalline lens, and corneal incisions can be performed easily during operations with the aid of optical coherence tomography images of the anterior segment in FLACS [5]. These steps have led to improvements in the accuracy and reproducibility of cataract surgery.

One of the advantages of FLACS is that it is possible to accomplish an accurate anterior capsulotomy in the center of the crystalline lens, ensuring proper intracapsular fixation of the intraocular lens (IOL). This reduces the risks of dislocation and decentration of the IOL after surgery [6, 7]. Well-centered and appropriately sized anterior capsulotomy is essential to maximize the performance of the IOL, and this is even more critical for premium IOLs (i.e., toric, multifocal, and accommodating IOLs) [8].

In addition to considerations relating to procedural accuracy, another advantage of FLACS pertains to lens fragmentation. Phacoemulsification energy damages corneal endothelial cells [9]. Nucleus fragmentation decreases the energy and duration of phacoemulsification, thus reducing the risk of altering corneal transparency [10, 11].

The third advantage of FLACS is the creation of a wound in the cornea. A constant repeatable corneal incision renders the length of the tunnel constant, in contrast to a manually created wound. Furthermore, by creating arcuate corneal incisions, it is possible to reduce corneal astigmatism [12], resulting in earlier recovery of vision after surgery.

FLACS has recently been used in combination with vitrectomy [13–16]. Bali et al. [13] have published a series of eight cases with 25-gauge vitrectomy, and Gómez-Resa et al. [14] have published 21 cases with 23-gauge vitrectomy. They concluded that FLACS is an effective technique for vitrectomy combined cataract surgery. However, few reports have discussed about the effect of femtosecond laser to combination surgery with 25- or 27-gauge vitrectomy. Here, we investigated the advantages of each step of FLACS with vitrectomy. Additionally, we described the intra- and postoperative complications of FLACS and vitrectomy.

## Materials and methods

We reviewed the medical records of the patients who underwent FLACS combined with 25- or 27-gauge vitrectomy for vitreoretinal disease performed by four surgeons at the Jikei University School of Medicine in Tokyo, Japan, between August 2016 and April 2018. The study adhered to the tenets of the Declaration of Helsinki, and institutional review board approval was obtained. All participants provided written informed consent to participate in the study.

All participants underwent comprehensive ophthalmological examinations such as slit lamp examination, fundus examination, and optical coherence tomography (OCT) before and after surgery.

### Surgical technique

In all cases, anterior capsulotomy and fragmentation of the crystalline lens were performed with a femtosecond laser (CATALYS®, Abbott Medical Optics Inc., Santa Ana, CA, USA). The intended anterior capsulotomy diameter was from 5.1 to 6.0 mm, and the lens was to be fragmented into four or six segments. Hydrodissection was not performed in cases with fragmentation. The incision for cataract surgery was performed manually using a 2.4-mm slit knife, and after removal of the crystalline lens, IOLs of 6.0 mm, 6.5 mm, or 7.0 mm diameter were inserted into the capsule. In all cases, 25- or 27-gauge vitrectomy (Alcon Constellation Vision System, Fort Worth, TX, USA) was performed using a Resight (Carl Zeiss Meditec AG, Germany) wide-angle viewing system. Sutures were used in cases in which the port did not self-seal. Fluid-gas exchange was performed if necessary for treatment.

### Postoperative outcomes

Postoperative follow-up was performed every day for 1 week after surgery and then at 2 weeks, 1 month, and 3 months. Subsequent follow-up visits were decided at the discretion of the surgeon. Only patients with a minimum of 3 months of follow-up were included. Preoperative and postoperative visual acuity, deviation from the predicted refraction value, axial length, and intraoperative and postoperative complications due to the combined FLACS and vitrectomy were evaluated.

## Results

The preoperative characteristics of the selected patients are shown in Table 1. A total of 34 eyes of

34 patients were included. Vitrectomy was performed with a 25-gauge needle in 33 eyes and with a 27-gauge needle in one eye. The mean age was 64.8 ± 0.7 years (range, 52–79 years) and the male: female ratio was 23:18. The mean follow-up period was 10 months (range, 3–31 months). There were no moderate or severe cataracts that affected best-corrected visual acuity.

### Surgical outcomes

The mean preoperative best-corrected visual acuity was LogMAR 0.51 ± 0.51, and the mean postoperative best-corrected visual acuity at the end of follow-up was LogMAR 0.1 ± 0.33. The mean ocular axial length was 24.49 ± 1.39 mm. The mean difference between predicted refraction and postoperative refraction was 0.49 ± 0.65. Macular hole closure and retinal laser application were achieved in all patients. The forms of postoperative tamponade applied to the eyes are shown in Table 2.

**Table 1** Patient characteristics

| Characteristics | Values |
|---|---|
| No. of patients | 34 |
| Gauge | |
| 25 | 33 |
| 27 | 1 |
| Age (years) | 64.8 ± 0.7 |
| M/F | 23/18 |
| Diagnosis | |
| ERM | 15 |
| MH | 10 |
| PDR (VH) | 6 |
| RRD | 3 |
| AL (mm) | 24.49 ± 1.39 |
| Pre-op BCVA | 0.51 ± 0.51 |
| Post-op BCVA | 0.1 ± 0.33 |
| Refraction error (D) | 0.49 ± 0.65 |

*AL* axial length, *BCVA* best-corrected visual acuity, *D* diopter, *ERM* epiretinal membrane, *F* female, *M* male, *MH* macular hole, *PDR* proliferative diabetic retinopathy, *Post-op* postoperative, *Pre-op* preoperative, *RRD* rhegmatogenous retinal detachment, *VH* vitreous hemorrhage

### Intraoperative complications

Laser capsulotomy and IOL sizes are shown in Table 3. There were no complications during FLACS, such as suction loss, incomplete capsulotomy, capsular tags, femtosecond laser-induced miosis, or anterior or posterior capsular tears.

Complete coverage of the IOL by the anterior capsular edge was possible in 33 eyes in which the IOL could be fixed inside the capsule, and there were no cases in which the IOL moved out of the capsule or captured the iris during or after the vitrectomy.

Intraoperatively, there was one case in which the posterior capsule ruptured due to mis-suction during emulsification and aspiration of the nuclear lens after performing the anterior capsulotomy with the femtosecond laser. The lens cortex was removed from the vitreous side using a cutter after making three 25-gauge ports, and then, a 7-mm IOL was fixed in the sulcus.

### Postoperative complications

Clinical data and postoperative complications are shown in Table 4. There was one case of postoperative endophthalmitis after vitrectomy for epiretinal membrane (ERM) that developed within 1 week after surgery, in which the patient underwent vitrectomy again immediately. Macular edema occurred 2 months after reoperation. The edema was not treated because visual acuity was not decreased.

Two cases of postoperative ERM were observed in two cases of proliferative diabetic retinopathy (PDR). One was diagnosed at 2 months, and one was diagnosed at 8 months after surgery. In one case,

**Table 2** Forms of intraocular tamponade applied

| Diagnosis | BSS (*n*) | Air (*n*) | SF6 (*n*) | Oil (*n*) |
|---|---|---|---|---|
| ERM | 11 | 4 | 0 | 0 |
| MH | 0 | 1 | 9 | 0 |
| PDR (VH) | 5 | 0 | 0 | 1 |
| RRD | 0 | 0 | 3 | 0 |
| Total (%) | 16 (47%) | 5 (15%) | 12 (35%) | 1 (3%) |

*BSS* balanced salt solution, *ERM* epiretinal membrane, *MH* macular hole, *Oil* silicone oil, *PDR* proliferative diabetic retinopathy, *RRD* rhegmatogenous retinal detachment, *SF6* sulfur hexafluoride, *VH* vitreous hemorrhage

**Table 3** Intraocular lenses and laser capsulotomy sizes

| Intraocular lens | Laser capsulotomy size (mm) | | | | | | | Total (*n*) |
|---|---|---|---|---|---|---|---|---|
| | 5.1 | 5.3 | 5.4 | 5.5 | 5.6 | 5.8 | 6.0 | |
| X70 | | | 1 | 2 | 27 | 5 | 1 | 36 |
| YA65BB | | 2 | | | | | | 2 |
| W60 | 1 | 1 | | | | | | 2 |
| PCB00V | | 1 | | | | | | 1 |

X70 = Eternity X70, Santen Corporation, Osaka, Japan; YA65BB = YA65BB Hoya Corporation, Tokyo, Japan; W60 = Eternity Natural Uni W60, Santen Corporation, Osaka, Japan; PCB00V = TECNIS PCB00V, Amo Japan Corporation, Tokyo, Japan

ERM was resolved after a second operation to remove ERM and recurrence was not observed. In the other case, the patient did not want to undergo an additional operation.

There were two cases of postoperative posterior capsular opacification (PCO) in two cases with PDR and RD. One case of PCO required yttrium aluminum garnet (YAG) laser treatment 16 months after the first vitrectomy and recovered the visual acuity, and another did not require YAG laser treatment because the affected eye showed good visual acuity (LogMAR 0).

## Discussion

There are some reports describing FLACS surgery combined with vitrectomy, and the associated potential advantages and disadvantages [13–16]. There have been few detailed investigations of complications in 25- or 27-gauge vitrectomy combined with FLACS; therefore, in the present study, we sought to investigate the advantages of FLACS with 25- or 27-gauge vitrectomy. Additionally, we assessed the intra- and postoperative complications of FLACS with vitrectomy.

The results of our study show that laser capsulotomy has the greatest advantage of the combined FLACS and vitrectomy surgery. In some cases of vitrectomy, fluid–gas exchange is performed for treatment and scleral indentation is performed for visualization of the peripheral fundus. Even if the IOL is in the correct position at the end of cataract surgery, there are risks of IOL dislocation in the capsular bag and out of the capsule. Further, iris capture caused by pressure from gas or scleral indentation may occur. In the current study, seven sizes of capsulotomies were used to insert three different IOL sizes. There was no incidence of iris capture or dislocation of the IOL after vitrectomy. Previous reports also indicated that one advantage of laser capsulotomy is a reduced risk of IOL prolapse into the anterior chamber in eyes to which gas tamponade is applied [13–15].

Another benefit of laser capsulotomy relates to the contraction of the lens capsule after surgery. Friedman et al. [8] compared the strength of the capsule after manual capsulorhexis and after laser capsulotomy in 46 porcine eyes. They argued that laser-created capsulotomies may be over twice as strong as those created manually. Following vitrectomy, fibrin tissue may be affected by forms of postoperative inflammation such as PDR and proliferative vitreoretinopathy. These complications can cause anterior capsule contraction and reduce fundus visibility. Therefore, it is important for the edge of the anterior capsulotomy to be strong after the operation. However, the existing literature fails to mention that the anterior capsulotomy edge strength achievable with FLACS is an important advantage of vitrectomy surgery combined with FLACS.

It is also important to maintain intraoperative visibility during vitrectomy. In vitreous surgery, reduced visibility when treating the parafoveal and peripheral retina may lead to complications, such as macular hemorrhage and iatrogenic tears. FLACS can reduce the energy required during surgery, endothelial cell loss after surgery, and corneal edema during surgery. However, direct incisions into the corneal stroma should be avoided as they can lead to loss of visibility.

When corneal or arcuate incisions are made, gas is generated in the corneal stroma, leading to the

**Table 4** Clinical data and postoperative complications

| Age (year) | R/L | Diagnosis | G | Pre-op BCVA | Pre-op Ref | Post-op BCVA | Post-op Ref | AL (mm) | Complications |
|---|---|---|---|---|---|---|---|---|---|
| 64 | L | PDR | 27 | 1.40 | − 3 | 0.20 | − 0.75 | 24.5 | ERM, PCO |
| 69 | L | PDR | 25 | 1.70 | 0 | 1.70 | − 1.75 | 23.71 | None |
| 57 | R | ERM | 25 | 0.70 | − 0.125 | − 0.10 | 0 | 24.31 | None |
| 65 | L | RD | 25 | 0.10 | − 4.625 | 0.00 | − 4.375 | 25.79 | PCO |
| 53 | L | PDR | 25 | 1.50 | 0 | 0.20 | − 2.875 | 24.65 | None |
| 52 | R | PDR | 25 | 0.70 | − 1.5 | 0.30 | − 0.875 | 23.64 | ERM |
| 75 | R | MH | 25 | 1.50 | 1 | 0.50 | − 0.875 | 22.3 | None |
| 69 | L | MH | 25 | 0.70 | − 1 | 0.70 | − 1.375 | 23.54 | None |
| 73 | L | PDR | 25 | 0.80 | − 2.25 | 0.20 | − 0.75 | 23.61 | None |
| 72 | L | MH | 25 | 0.30 | − 0.625 | 0.10 | − 1 | 23.03 | None |
| 68 | L | MH | 25 | 0.40 | − 0.625 | 0.20 | − 0.75 | 23.24 | None |
| 74 | R | ERM | 25 | 0.20 | 0.5 | − 0.10 | − 0.25 | 23.35 | None |
| 71 | L | PDR | 25 | 1.10 | − 5 | 0.05 | − 2.5 | 25.69 | None |
| 53 | L | ERM | 25 | 0.20 | − 9.625 | − 0.20 | − 5.5 | 27.36 | None |
| 57 | R | ERM | 25 | − 0.10 | − 0.5 | − 0.20 | 0 | 27.44 | None |
| 62 | L | RD | 25 | − 0.20 | − 2 | − 0.20 | − 2 | 24.61 | None |
| 58 | L | MH | 25 | 0.40 | − 3.875 | 0.00 | − 4.5 | 24.61 | None |
| 56 | L | ERM | 25 | − 0.20 | − 2 | 0.05 | − 3.125 | 25.06 | Endophthalmitis, ME |
| 52 | R | MH | 25 | 0.50 | − 8.125 | 0.40 | − 6.125 | 26.57 | None |
| 67 | L | ERM | 25 | 0.20 | − 7.375 | − 0.10 | − 6.375 | 26.38 | None |
| 79 | L | ERM | 25 | 1.00 | 5.125 | 0.50 | − 0.125 | 22.01 | None |
| 62 | R | ERM | 25 | 0.30 | − 2 | − 0.10 | − 1.5 | 24.36 | None |
| 52 | R | RD | 25 | − 0.10 | − 9.5 | − 0.20 | − 5.875 | 27.2 | None |
| 67 | L | ERM | 25 | 0.50 | − 1.5 | − 0.10 | 0.125 | 25.4 | None |
| 63 | R | MH | 25 | 0.50 | − 1.875 | 0.20 | − 2.125 | 23.81 | None |
| 73 | L | MH | 25 | 0.70 | 0.125 | 0.20 | − 0.625 | 23.38 | None |
| 53 | R | MH | 25 | 0.30 | − 4.5 | 0.10 | − 3.375 | 24.85 | None |
| 74 | L | ERM | 25 | 0.00 | − 2.625 | 0.00 | − 2.5 | 25.05 | None |
| 78 | R | ERM | 25 | 0.30 | 1.25 | 0.00 | − 1.5 | 23.47 | None |
| 70 | L | ERM | 25 | 0.30 | − 1.375 | − 0.20 | − 2.25 | 24.25 | None |
| 65 | L | MH | 25 | 0.20 | − 7 | − 0.10 | − 8.375 | 27.39 | None |
| 60 | R | ERM | 25 | 0.30 | 0 | 0.10 | − 0.75 | 24.52 | None |
| 77 | L | ERM | 25 | 0.30 | 1.125 | − 0.10 | 0.125 | 24.88 | None |
| 69 | R | ERM | 25 | 0.20 | 0 | − 0.10 | − 1 | 24.23 | None |

*AL* axial length, *BCVA* best-corrected visual acuity, *ERM* epiretinal membrane, *G* gauge, *L* left, *ME* macular edema, *PCO* posterior capsule opacification, *PDR* proliferative diabetic retinopathy, *Post-op* postoperative, *Pre-op* preoperative, *R* right, *RRD* rhegmatogenous retinal detachment, *VH* vitreous hemorrhage

possibility of reduced intraoperative visibility [16]. In addition, corneal incisions made by femtosecond lasers do not close as well as manual incisions [17]. Nonetheless, when corneal incisions were made with a femtosecond laser, 92.6% were successfully completed, although there were some cases in which it was necessary to create a new incision at another position [5].

Due to the risk of reducing visibility, corneal and arcuate incisions were not made using the laser in the present study. Further, there was no problem with visibility during ERM peeling or inner limiting membrane peeling and cutting the peripheral vitreous cortex in our cases. On the basis of these data, we believe that the application of a femtosecond laser to the cornea should be avoided as much as possible.

Notably, attention to potential complications is required after fragmentation of the nucleus. In FLACS, gas is generated by fragmentation in the capsule. If conventional hydrodissection is not performed, the pressure inside the capsule rises, increasing the risk of posterior capsule rupture by causing capsular block syndrome. Therefore, careful attention must be paid to hydrodissection in FLACS [18]. In the current case series, it is thought that the risk of capsular block syndrome was reduced without increasing the pressure inside the capsule in FLACS from a lack of hydrodissection. Masuda et al. [19] have reported the usefulness of irrigation-assisted hydrodissection in FLACS and argue that it can prevent capsular block syndrome. Although posterior capsule rupture was observed in one eye during surgery in the present series, it was not caused by a complication due to the femtosecond laser such as incomplete capsulotomy, capsular tags, or anterior or posterior tears, but by the mis-suction of the capsule during emulsification and aspiration of the nuclear lens.

The current study had some limitations. It had a retrospective in design and involved a relatively small number of patients who underwent operations with different surgeons. The usefulness of FLACS combined with vitrectomy should be investigated in a prospective study that includes more eyes treated with 27-gauge vitrectomy. Furthermore, we did not examine the total energy at the time of lens removal or the endothelial cell counts. Endothelial cell counts are related to phacoemulsification-related energy use [9, 11], so corneal endothelial cell counts should be measured when using FLACS.

The results of this study provide evidence for the safety and usefulness of FLACS combined with vitrectomy because there were no femtosecond laser-associated complications, such as extracapsular prolapse of the IOL or decreased visibility of the cornea.

**Authors' contributions** AW designed the study and assisted in the preparation of the manuscript. TW and HK have contributed to data collection and interpretation. All other authors critically reviewed the manuscript.

**Funding** No funding was received for this study.

**Compliance with ethical standards**

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee [Japan Clinical Trials Register (http://www.umin.ac.jp/ctr/number, UMIN 000021814)] and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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