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Enlargement of Phimotic Capsulorhexis Using Plasma Energy: A Case Series

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ABSTRACT **Ophthalmology in Russia. 2021;18(4):972–980**

Purpose: to evaluate the effectiveness and safety of the plasma ablation technique of Fugo blade system to enlarge phimotic capsulotomies in the management of anterior capsule contraction syndrome. **Patients and methods.** Results of the enlargement of phimotic capsulotomies using the plasma ablation technique in 17 patients with anterior capsule contraction syndrome (10 men and 7 women, 18 eyes; average age — 73.8 ± 9.6 years) were retrospectively analyzed. Surgically, after pupil dilation, the anterior chamber was irrigated with a viscoelastic device (1.4 % solution of hyaluronic acid), and the tip of the Fugo blade was inserted through a 2.0–2.2 mm wide corneal incision. After slightly touching the anterior capsule, the apparatus was activated, and its tip was moved in a concentric manner, excising the required size of the fibrosed anterior capsule in a resistance-free fashion. Finally, the viscoelastic material was aspirated, and the incisions were hydrated. **Results.** Phimotic capsulotomies were enlarged in all cases. Except for three cases where the bimanual technique was required to ablate the anterior capsule, all other cases were managed single-handedly. The use of cohesive viscoelastic device (1.4 % solution of hyaluronic acid) made it possible to perform this procedure with minimum trauma and under visual control. No serious complications were encountered during surgery or in the early postoperative period. Patients were discharged 1–2 days after surgery. Corneal edema, which was observed in six eyes, resolved within 3–4 days. Visual acuity improved in all cases, except for 2 patients with complete glaucomatous optic atrophy. IOP remained under control in all cases. No negative effect on the hypotensive results of previous glaucoma surgeries was observed. **Conclusion.** The plasma-generating Fugo blade system is an effective and safe tool to enlarge phimotic capsulorhexis in a resistance-free fashion. It is easy to use, mastering of new surgical skills is not required, surgical trauma is minimal, the surgical time is reduced, and the patient's rehabilitation period is significantly shortened.

Keywords: anterior capsule contraction syndrome, Fugo blade, anterior capsule phimosis, plasma energy

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Опыт применения плазменной энергии для расширения капсулорексиса при контракционном капсулярном синдроме (клинические случаи)

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РЕЗЮМЕ

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Цель: оценить эффективность и безопасность применения плазменной энергии Фуго-лезвия в расширении капсулорексиса при контракционном капсулярном синдроме. **Пациенты и методы.** Ретроспективно проанализированы результаты расширения капсулорексиса с применением плазменной энергии Фуго-лезвия у 17 пациентов с контракционным капсулярным синдромом (10 мужчин и 7 женщин, 18 глаз; средний возраст 73,8 ± 9,6 года). Хирургическая техника: после расширения зрачка переднюю камеру заполняли вискоэластиком, через роговичный разрез 2,0–2,2 мм вводили наконечник Фуго-лезвия и, слегка прикасаясь к поверхности передней капсулы, активировали аппарат, далее плавно передвигали кончик наконечника по кругу, разрезая фиброзированную переднюю капсулу, формировали вторичный круговой капсулорексис нужного размера. Последним этапом операции являлась эвакуация вискоэластика из передней камеры и герметизация разреза. **Результаты.** Капсулорексис удалось расширить во всех случаях. В трех случаях потребовалась бимануальная техника. Использование когезивного вискоэластика позволило выполнить данную процедуру щадяще и под визуальным контролем. Серьезных осложнений в раннем послеоперационном периоде не наблюдали, и все пациенты выписались из стационара в течение 1–2 дней после операции. Нарушение прозрачности роговицы вследствие легкой складчатости десцеметовой мембраны, которую наблюдали у шести пациентов, купировалось через 3–4 дня. Острота зрения увеличилась во всех случаях, кроме 2 пациентов, у которых имела место полная глаукомная атрофия зрительного нерва. Повышение ВГД в раннем и позднем послеоперационном периоде и в отдаленные сроки не наблюдали. Данная процедура не оказывала отрицательного воздействия на гипотензивную функцию ранее проведенных антиглаукомных операций. **Заключение.** Плазма, генерируемая Фуго-лезвием, является эффективным и безопасным инструментом для расширения капсулорексиса при контракционном капсулярном синдроме, способ прост в применении, не требует освоения новых хирургических навыков, хирургическая травма минимальна, сокращается время проведения операции и сроки реабилитации пациентов.

Ключевые слова: контракционный капсулярный синдром, Фуго-лезвие, фимоз передней капсулы, плазменная энергия

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INTRODUCTION

Phacoemulsification with implantation of a foldable intraocular lens (IOL) is the method of choice in modern cataract surgery. Creation of continuous curvilinear capsulorhexis (CCC) of appropriate size is an integral part of this technique. It enables the successful completion of all surgical steps of cataract surgery [1]. Unfortunately, this procedure sometimes causes fibrosis of the anterior capsular opening [2–5].

In anterior capsular contraction syndrome (ACCS), shrinkage of the anterior capsule may lead to concentric stenosis of the CCC, deformation and contracture of the capsular bag and IOL haptics, tilting of the IOL optic, changes in refraction, damage to Zinn's ligaments, and dislocation of the IOL-capsular bag (IOL-CB) complex into the vitreous body [6–8].

Various techniques have been proposed for ACCS management. Most authors use Nd:YAG laser to perform either radial or circular relaxing capsulotomies [9, 10]. Some authors use bimanual technique to enlarge the CCC size with the help of a microsurgical instrument [11, 12], whereas others give preference to vitrector-cut capsulotomy [13].

The Fugo blade system (named after its inventor Richard J. Fugo, Medisurg Research & Management, Norristown, PA, USA) generates plasma energy and concentrates it around a thin stainless-steel filament to make an incision in the tissue-plasma ablation technique (PAT). Among other applications, the instrument has been cleared for human applications to perform anterior capsulotomies in cataract surgery [14]. It has been proposed that this technique may be useful to enlarge phimotic capsulotomies in ACCS [15].

The purpose of this study was to evaluate the effectiveness and safety of the plasma ablation technique of Fugo blade system to enlarge phimotic capsulotomies in the management of ACCS.

PATIENTS AND METHODS

The results of enlargement of phimotic capsulorhexis in 17 patients with ACCS (10 males and 7 females; 18 eyes) were retrospectively analyzed. Patients were admitted and operated on between October 2009 and January 2020. The average age of the patients was 73.8 ± 9.6 years. In all cases, the capsulorhexis was enlarged using PAT with the Fugo blade system. The study was approved by the Institutional Review Board and Ethics Committee of the Medical Institute of People's Friendship University of Russia (protocol № 102 dated 04 September 2009). The study adhered to the Declaration of Helsinki. Written informed consent was obtained from all participants in the study.

From the medical records of patients, the following information was gathered: demographic data of the patients, time of the 1st surgery, pre, peri- and postoperative observations including visual acuity and tonometry, time interval between the 1st surgery and development of ACCS, type of IOL implanted, whether a capsule tension ring (CTR) was implanted and prevalent risk factors.

Before surgery, a comprehensive ophthalmological examination was carried out. Visual acuity was checked using Snellen's chart, and IOP was measured by Maklakov's method (using a 10.0 gm weight). In all patients, slit-lamp biomicroscopy, ophthalmoscopy, gonioscopy, ultrasound biomicroscopy and b-scan ultrasonography were performed. The score of anterior capsule opacification was noted. In the case of IOL-CB complex dislocation, the degree of dislocation was verified. If previous attempts were made to manage ACCS, details of the surgical technique used and the outcome were noted, and peri- and postoperative observations were recorded. Anterior capsule opacification and dislocation of the IOL-CB complex were classified as per Werner L. [16] and Lorente R. et al [17], respectively.

The effectiveness and safety of the procedure were assessed based on changes in visual acuity and IOP dynamics, intra- and postoperative complication rates and decreases in the rehabilitation period.

The Fugo blade system consists of a portable, battery-operated electronic console, an ergonomic hand piece, an activation foot pedal, disposable cutting tips and a charging unit (Fig. 1а, б, в). The level of plasma energy to be generated can be controlled by a regulator located on the front panel. The device provides ten cutting regimes, switchable by a knob at the front panel. Upon activation, the console generates plasma and concentrates and focuses it around the thin stainless-steel filament of the cutting tip (Fig. 1г). The apparatus resonates this energy to completely transfer it to the molecular lattice of the tissue. Plasma is completely absorbed by the molecular lattice, and when this energy level exceeds the energy level of molecular bonds, the molecules shatter into small fragments. In this way an incision is made. Although the temperature of the plasma cloud at the tip is approximately 4500 °C, its area is very small and equals 25 microns if low power energy is selected and 50 microns if medium power is selected; in the case of high power selection, it is equal to 75 microns. Thanks to the complete absorption of plasma energy by the molecular lattice, its thermal effect on tissue is nil or very low [14]. The plasma cloud is surrounded by photons, whose temperature equals the temperature of the surrounding area. These photons do not possess cutting properties.

SURGICAL TECHNIQUE

Surgically, after pupil dilation, the anterior chamber was irrigated with a viscoelastic device (1.4 % solution of hyaluronic acid), and the tip of the Fugo blade was inserted through a 2.0–2.2 mm wide corneal incision. After slightly touching the anterior capsule, the apparatus was activated, and its tip was moved in a concentric manner, excising the required size of the fibrosed anterior capsule in a resistance-free fashion. Finally, the viscoelastic material was aspirated, and the incisions were hydrated.

Fig. 1. Fugo blade system: a — plasma generating battery-operated electronic console with an activation foot pedal and charging unit; б — an ergonomic electronic hand piece; в — disposable cutting tips; г — the activated tip of the Fugo blade; in close proximity to the thin stainless-steel filament is the "plasma cloud" surrounded by photons

Рис. 1. Плазменное лезвие Фуго: а — плазма генерирующий электронный аппарат; б — рукоятка аппарата с одноразовым наконечником; в — одноразовые наконечники с кончиками разных диаметров; г — наконечник плазменного лезвия Фуго в работе: непосредственно вокруг стального волокна определяется «плазменное облачко», окруженное фотонами

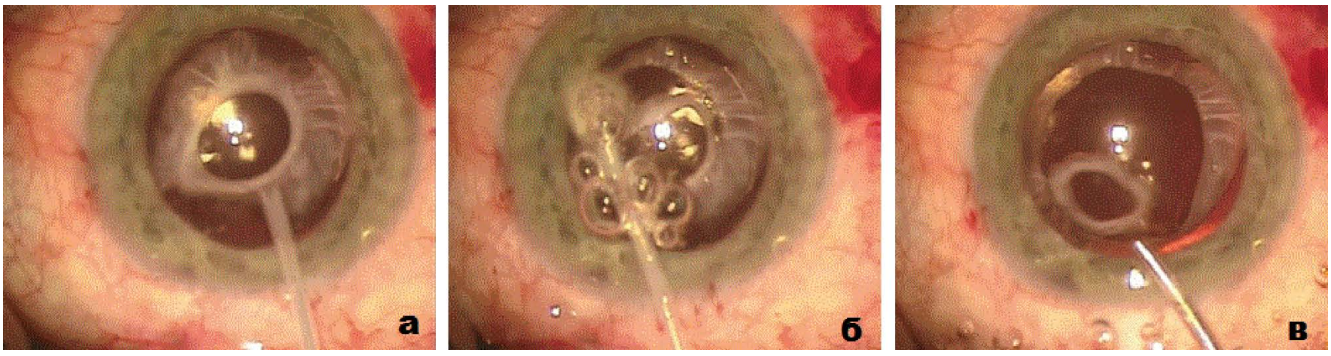

Fig. 2. Surgical steps of capsulorhexis enlargement: a — the pupil is dilated with instillation of mydriatics, the anterior chamber is irrigated with the cohesive viscoelastic device, and the tip of the Fugo blade is inserted through 2.0–2.2 mm wide corneal incision; б — a portion of the phimosed capsulotomy is excised, and cavitation bubbles can be identified in proximity to the tip; в — the procedure of capsulorhexis enlargement is completed, the excised ring of the anterior capsule lies freely on the IOL surface, which is removed by forceps

Рис. 2. Этапы расширения капсулорексиса: а — зрачок медикаментозно расширен, передняя камера заполнена когезивным вискоэластиком, на рисунке определяется контракционный капсулярный синдром, наконечник лезвия находится в передней камере; б — выполнена часть вторичного кругового капсулорексиса, в передней камере определяются кавитационные пузыри; в — вторичный круговой капсулорексис полностью выполнен, срезанное кольцо передней капсулы свободно лежит на поверхности искусственного хрусталика, которое удаляли пинцетом

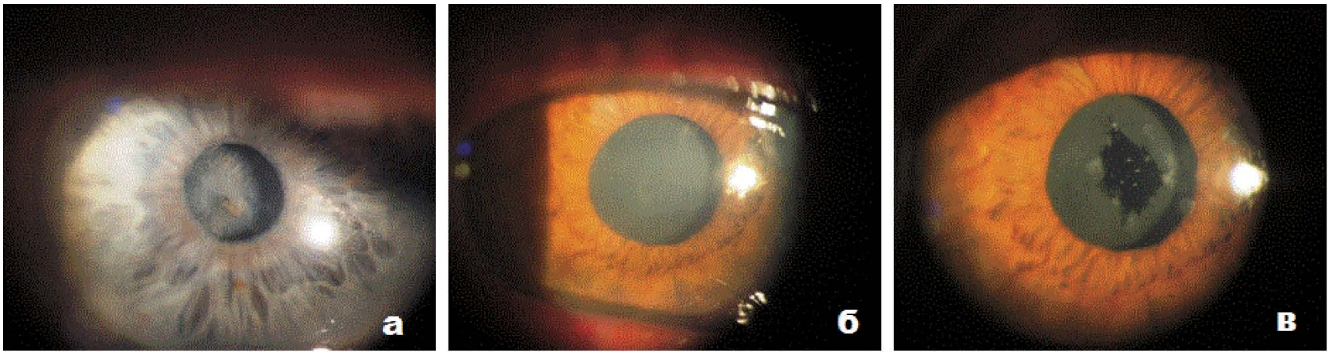

Fig. 3. Complete closure of the capsulorhexis opening in anterior capsule contraction syndrome; a — first patient, no capsulorhexis opening is visible, and the anterior capsule is highly fibrosed; б — second patient, also with complete closure of the capsulorhexis opening; в — the patient in b, after unsuccessful Nd:YAG laser radial capsulotomies, laser-induced damage can be identified on the surface of the IOL

Рис. 3. Полное закрытие отверстия в передней капсуле при контракционном капсулярном синдроме: а — первый пациент с полным закрытием отверстия передней капсулы, передняя капсула сильно фиброзирована; б — второй пациент с полным закрытием отверстия передней капсулы; в — состояние глаза пациента «б» после попытки устранения фиброза с помощью Nd:YAG-лазера, на поверхности ИОЛ видны повреждения от лазерного воздействия

Patients were evaluated daily during their hospital stay and then again at 1 week, 1 month, 3 months, 6 months and 1 year after surgery. Postoperative evaluation included visual acuity assessments, tonometry, biomicroscopy, ophthalmoscopy, and gonioscopy. Wherever possible, findings were documented via photography and videography.

RESULTS

The mean preoperative visual acuity was 0.3 ± 0.1, and the mean IOP was 20.7 ± 2.8 mm Hg. ACCS was prevalent in all cases, with 4th degree of anterior capsule opacification [16].

In ten patients, ACCS was associated with dislocation of the IOL-CB complex of the 1st degree. As a result of previous cataract surgery, the pupil margins were almost completely fused with fibrosed anterior capsules in two patients (three eyes). In three patients, ACCS led to complete closure of the capsulorhexis opening (Fig. 3а-в). Among these, in one patient, Nd:YAG laser relaxing radial capsulotomies were tried unsuccessfully. In this patient, damage to the anterior IOL surface by laser was observed (Fig. 3в). In the second patient, Nd:YAG laser circular capsulotomy was tried, but the procedure was unsuccessful. Four patients had previously undergone various successful glaucoma procedures (trabeculectomy-1 patient, transciliary filtration-1 patient, segmental dilation of Schlemm's canal with implantation of Kumar's stainless-steel spiral Schlemm's canal expander-1 patient, and implantation of Kumar's metallic drainage device into the anterior chamber under scleral flap-1 patient).

The baseline characteristics of the eyes at the time of the 1st and 2nd surgeries, and the time interval between the 1st surgery and the development of ACCS are presented in Table 1.

The time interval between the 1st surgery and ACCS development varied from 2 to 120 months. At the time of the 1st surgery, PEX was prevalent in all cases; ten patients had phacodonesis, and six patients had a capsule tension ring (CTR) implanted in the capsular bag to stabilize it before IOL implantation.

The type of operative procedure(s) to be performed to enlarge the phimotic capsulorhexis was selected individually for each patient depending upon the preoperative condition of the eye. Data are presented in Table 2.

Table 1. Baseline characteristics of the eye at the time of the first and second surgeries

Таблица 1. Исходное состояние глазного яблока во время первой и второй операции

Patient	Age/sex	1st surgery	Baseline characteristics of the eye at the time of the 1st surgery	Time interval between the 1st surgery and ACCS (in months)	Baseline characteristics of the eye at the time of the 2nd surgery
1	80/F	Phaco + IOL	PEX, Phacodonesis	26	ACCS, 1st degree disloc. of the IOL-CB complex
2	75/M	Phaco + IOL + CTR +TCF	Lens subluxation	36	ACCS, 1st degree disloc. of the IOL-CB complex
3	76/M	Phaco + IOL + CTR	PEX, Phacodonesis	108	ACCS, 1st degree disloc. of the IOL-CB complex
4	74/M	Phaco + IOL + CTR	PEX, Phacodonesis	5	ACCS, 1st degree disloc. of the IOL-CB complex
5	58/M	Phaco + IOL	PEX	8	ACCS (complete occlusion of the capsulorhexis), after Nd:YAG laser radial capsulotomies
6	63/F	Phaco + IOL + CTR	PEX, Phacodonesis	2.5	ACCS, 1st degree disloc. of the IOL-CB complex
7	54/F	Phaco + IOL	PEX	2	ACCS
8	79/F	Phaco + IOL	PEX, Phacodonesis, high myopia, OAG surgically treated with a metallic drainage device	5	ACCS, 1st degree disloc. of the IOL-CB complex
9	71/M	Phaco + IOL	PEX, Phacodonesis	48	ACCS (complete occlusion of the capsulorhexis), after Nd:YAG laser circular capsulotomy
10	64/M	Phaco + IOL + CTR	PEX, Phacodonesis	24	ACCS, 1st degree disloc. of the IOL-CB complex
11	75/M	Phaco + IOL	PEX	1,5	ACCS, 1st degree disloc. of the IOL-CB complex
12	71/M	Phaco + IOL	PEX, Phacodonesis, rigid pupil, use of iris retractors, trauma to the pupil margin	60	ACCS, posterior synechiae, pupil deformation
13	82/M	Phaco + IOL OD	PEX, rigid pupil, use of iris retractors, trauma to the pupil margin	108	ACCS, posterior synechiae, pupil deformation
		Phaco + IOL OS		120	
14	64/M	Phaco + IOL + CTR	PEX, Phacodonesis	24	ACCS
15	79/F	Phaco + IOL + Trab.	PEX, Phacodonesis	7	ACCS, 1st degree disloc. of the IOL-CB complex
16	85/M	Phaco + IOL + SDSC	PEX, Phacodonesis	84	ACCS, 1st degree disloc. of the IOL-CB complex
17	91/F	Phaco + IOL	PEX	6	ACCS

Note: ACCS — anterior capsule contraction syndrome; CTR — capsular tension ring; PEX — pseudoexfoliation; disloc. — dislocation; SDSC — segmental dilation of Schlemm's canal; F — female; IOL-CB — intraocular lens — capsular bag; M — male; Nd:YAG — neodymium-doped yttrium aluminum garnet laser; OAG — open angle glaucoma; Phaco — phacoemulsification; TCF — transciliary filtration; Trab — trabeculectomy.
Примечание: Дис. — дислокация; Ж — женщина; ИОЛ-КМ — интраокулярная линза — капсульный мешок; КК — капсульное кольцо; ККС — контракционный капсулярный синдром; М — мужчина; МВС — миопия высокой степени; OD — правый глаз; OS — левый глаз; ПЭС — псевдоэксфолиативный синдром; СДШК — сегментарная дилатация Шлеммова канала; СТЭК — синусотрабекулэктомия; ТЦФ — трансцилиарная фильтрация; ФД — факодонез; ФЭ — факоэмульсификация.

INTRAOPERATIVE OBSERVATIONS

The phimosed capsulorhexises could be enlarged in all cases. In some of the earlier cases, a dispersive viscoelastic device (2 % solution of hydroxypropylmethylcellulose) was used to maintain the anterior chamber during surgery. This viscoelastic material is less viscous; as a result, the anterior chamber had the tendency to collapse during surgery, and the cavitation bubbles merged into each other, making it difficult to visualize the ongoing procedure. Repeat irrigation of the anterior chamber with the viscoelastic material was required to complete the procedure. This resulted not only in an increase in the surgical time but also in multiple insertions and exertions of the Fugo blade tip into the anterior chamber. This viscoelastic material was discarded from further use, and a cohesive viscoelastic material (1.4 % solution of hyaluronic acid) was chosen, which allowed the surgery to be performed in a less traumatic manner and under visual control. Moreover, the overall surgical time was reduced significantly. In three eyes, a bimanual technique was required to excise the anterior capsule under the main incision area. The second instrument was inserted through a side port. In two cases, when the artificial pupil was created, some blood oozed from the pupil margins, but this bleeding stopped spontaneously after some time.

POSTOPERATIVE OBSERVATIONS

The average hospitalization period was 2.6 ± 0.6 days. In the early postoperative period, serious complications were not observed. Corneal edema that was noticed in six eyes disappeared after 3–4 days. The visual acuity improved in all cases, except for 2 cases with complete glaucomatous atrophy of the optic nerve. The IOP remained under control throughout the postoperative follow-up. The hypotensive effect of previously performed glaucoma procedures remained unaffected after this procedure.

A few case reports are presented below.

Case 1. A 79-year-old female patient (patient 8 in Table 1) attended the outpatient department (OPD) with complaints of decreased vision in her only functional (left) eye. Several years ago, her right eye had lost vision due to glaucoma. Previously, the patient's left eye had undergone two glaucoma surgeries. The first surgery was trabeculectomy, which failed after some time, and the second surgery was performed using Kumar's metallic drainage device. After the second surgery, the IOP normalized. Five months earlier, the patient had undergone cataract surgery by phacoemulsification with implantation of a hydrophilic IOL in the capsular bag. The postoperative period was uneventful. At five months after cataract surgery, the patient noticed a progressive decrease in vision. At the time of examination, ACCS blocking the visual axis, PEX, rigid pupil and dislocation of IOL-CB of the 1st degree were diagnosed. At the 11 o'clock position, a metallic glaucoma device was seen at the peripheral basal iridectomy site (Fig. 4. Case 1a). Using the PAT, the constricted capsulorhexis was enlarged up to 5 mm with restoration of vision (Fig. 4.1в–г). The postoperative period was uneventful.

Case 2. An 82-year-old male patient attended the OPD with complaints of decreased vision in both eyes. The patient had noticed progressive loss of vision in both eyes for over one year. Ten years ago, the patient had undergone cataract surgery by phacoemulsification with implantation of a hydrophilic IOL, first in the right eye and then, one year later, in the left eye. From his medical records of both surgeries, it was noted that the surgeon had to use iris retractors to enlarge rigid pupils. As a result, trauma occurred to the pupil margins. In the postoperative period, the patient was placed on anti-inflammatory medication for a considerable period. At the time of consultation, the patient had severe ACCS in both eyes and posterior synechiae with nearly complete fusion of the pupil margin with the opacified anterior capsule. The visual axis was blocked by the opacified anterior capsule (Fig. 4. Case 2a, в). By using PAT, first in the right eye and then, after six months, in the left eye, the pupil was reformed along with enlargement of the constricted capsulorhexis. During pupil formation, some hemorrhage occurred from the iris, and this bleeding stopped spontaneously after some time. The postoperative period was uneventful. Because of unequal trauma

Table 2. Baseline characteristics of the eyes and type of surgery performed by using the plasma ablation technique

Таблица 2. Исходное состояние глазного яблока и выполненное хирургическое вмешательство с применением плазменной энергии Фуго-лезвия

Baseline characteristics of the eyes	Operative procedure(s) performed to enlarge the capsulorhexis	Number of eyes
ACCS without IOL-CB complex dislocation	Enlargement of the capsulorhexis up to 5–5.5 mm	3
ACCS with IOL-CB complex dislocation		10
ACCS with complete occlusion of the capsulorhexis		2
ACCS, posterior synechiae, pupil margins completely fused with the opacified anterior capsule, visual axis blocked by anterior capsule opacification	Pupil formation, enlargement of the capsulorhexis, PBI	3

Note. ACCS — anterior capsule contraction syndrome; IOL-CB — intraocular lens-capsular bag; PBI — peripheral basal iridotomy.
Примечание: ККС — контракционный капсулярный синдром; ПКХ — передняя капсула хрусталика; ИОЛ-КМ — интраокулярная линза — капсульный мешок.

to the pupil that was caused by iris retractors during the 1st surgery, the size of the reformed pupils varied in size (Fig. 4, case 2в, г).

Case 3. A 64-year-old male patient attended the OPD with decreased vision in his right eye (patient 14 in the table). Two years earlier, the patient had undergone cataract surgery by phacoemulsification with implantation of a hydrophilic IOL in the capsular bag. Because of PEX and phacodonesis, the patient had an unstable capsular bag; to stabilize it, a CTR was implanted before IOL implantation. The postoperative period was uneventful. Because of degenerative changes in his macula, the patient's visual acuity after surgery improved by only up to 0.4. Six months later, the patient noticed a decrease in visual acuity, which progressed further. At the time of consultation, the patient's visual acuity was hand movement, and there was 4th degree ACCS with severe constriction of capsulorhexis, PEX and pseudophacodonesis. The pupil could be dilated well by mydriatics. The patient was admitted for surgical correction of ACCS. Using PAT, the capsulorhexis was enlarged up to 5 mm (Fig. 4. Case 3а–г). The 5th cutting regimen was insufficient to excise the thick opacified anterior capsule, and the 7th cutting regimen was used to complete the surgery. Both the surgery and the postoperative period were uneventful. At one week, the patient's visual acuity improved from hand movement to 0.4.

DISCUSSION

ACCS is a serious postoperative complication of CCC. Several conditions have been identified as risk factors for ACCS. These include advanced age with poor zonular support and comorbidities (poor general health, myotonic dystrophy, Marfan syndrome), glaucoma, pseudoexfoliation syndrome, uveitis, diabetic retinopathy, high myopia, retinitis pigmentosa and small size of the CCC [18–22]. Capsulorhexis shrinkage may cause ciliary body detachment, choroidal hemorrhage, hypotony or IOL decentration and tilt [23–25].

Most commonly, Nd:YAG is used to treat ACCS. Various types of capsulotomies have been proposed, such as relaxing radial capsulotomies [2, 26], circular capsulotomy [10, 27, 28], parabolic capsulotomy [29] and combined capsulotomies [30]. A multimodal therapeutic approach has also been proposed to treat ACCS, which is divided into three complementary and following phases. The first phase includes the creation of holes into the fibrotic material using a Nd:YAG laser. The second and third phases are performed in the operation theatre. In the second phase, a dispersive ophthalmic viscosurgical device is injected between the anterior capsule and the IOL optic to increase the space between them. In the third phase, a 3.7 mm to 4 mm circular-shaped cut of the pathological fibrosis is created using a femtosecond laser, which is removed with 23-gauge microforceps [31].

Although the safety and effectiveness of laser methods in treating ACCS have been proven, there are reports where these procedures were complicated by unpredictable capsule tears and dislocation of IOLs in the vitreous cavity [32, 33]. Recurring ACCS with contracture of the capsular bag and IOL decentration have also been reported in the literature [9, 34]. There are case reports in which free capsular remnants after circular capsulotomies were in close contact with the corneal endothelium, causing decompensation or freely changing positions with different head postures, obscuring vision during reading [35, 36].

Therefore, it can be concluded that Nd:YAG laser methods are not very safe to treat ACCS, and their use is limited. They are not suitable for every patient, especially if the anterior capsule is highly fibrosed and thick or if a combined procedure is needed, for example, surgical intervention on the fibrosed anterior capsule and iris.

Surgical methods are more invasive. To treat ACCS, the fibrosed anterior capsule is cut in a circular fashion with the help of micro instruments using a bimanual technique. The anterior capsule is held in place by micro forceps and is cut by micro scissors to enlarge the capsulorhexis opening [12, 37]. These methods are difficult to perform, and it is not always possible to create a complete secondary capsulorhexis. These drawbacks apply to the mechanical widening of capsulorhexis with a vitrector.

In the presented case series, resistance-free cutting of the fibrosed anterior capsule by using the plasma ablation technique made it possible to enlarge the constricted capsulorhexis in all cases, including with dislocation of the IOL-SC complex of the 1st degree without further dislocation. There was no damage to the IOL surface because of plasma energy use. It was also possible to perform surgical maneuvers on the iris. PAT was successfully applied to perform peripheral iridotomies and to excise irises to create artificial pupils. "Autostasis" provided hemorrhage-free surgery. Some hemorrhage that occurred while creating new pupils stopped simultaneously.

Our experience with PAT of Fugo blade system shows that this technique is safe and effective for resistance-free incision of tissue. It effectively incises the fibrosed anterior capsule in ACCS cases even with poor zonular support, which was prevalent in most of our cases. This technique not only ablates tissue in the incision line but also provides hemostasis, which makes this technique suitable for surgical maneuvering of vascular tissues. The Fugo blade minimizes trauma and allows complex surgical steps to be completed; as a result, the rehabilitation period is shortened.

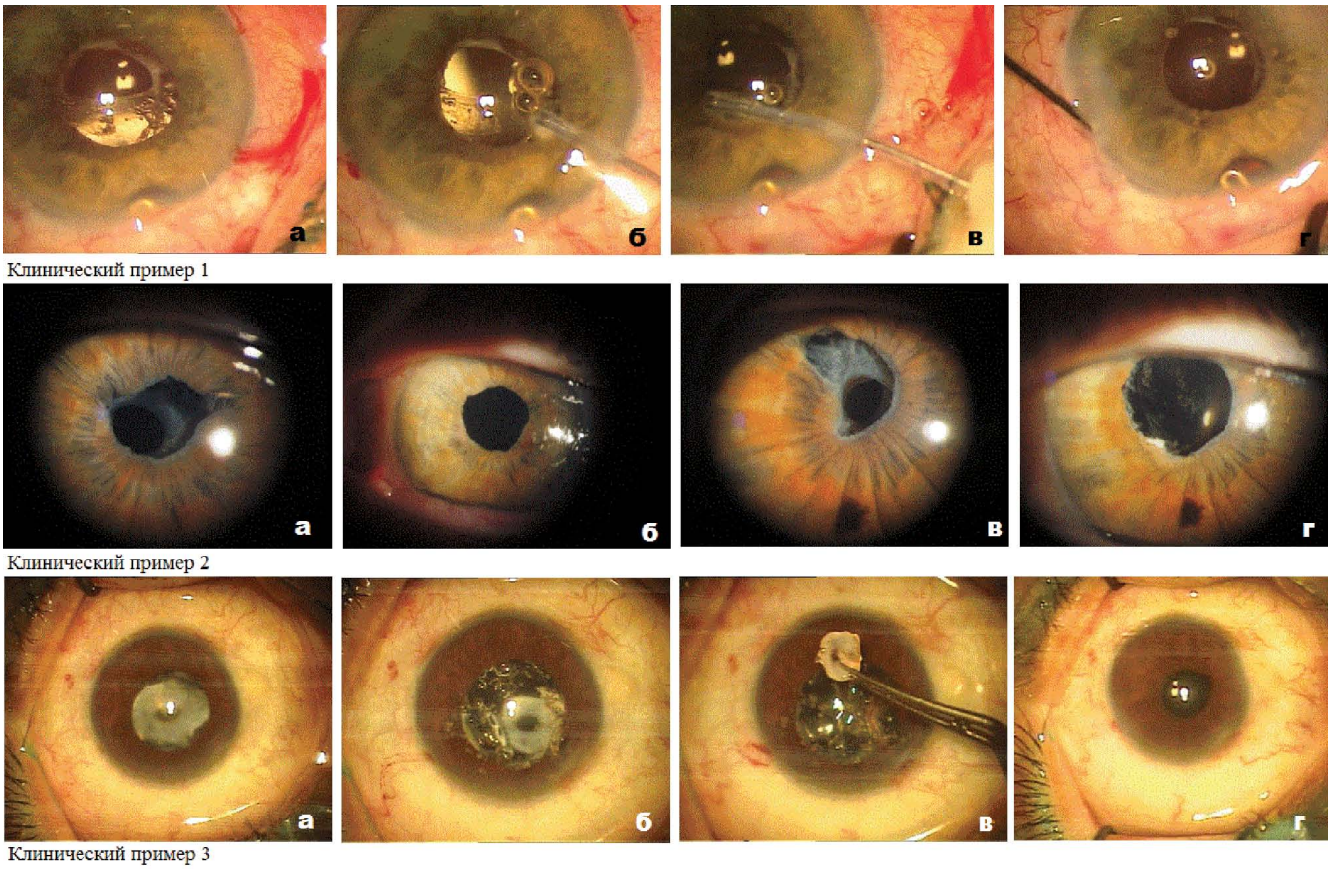

Fig. 4. *Case 1* (patient № 8 in the table): a — preoperative condition of the eye: the opacified anterior capsule is blocking the visual axis, and the pupil is rigid and can't be dilated well; б — at the start of the capsulorhexis enlargement procedure, the Fugo blade's activated cutting tip is in the anterior chamber and cavitation bubbles are seen in close proximity; в — capsulorhexis is enlarged without using bimanual technique; г — at the end of the surgery, the pupil area and visual axis are free from the opacified anterior capsule. *Case 2* (patient № 13 in the table): in the figure, the right eye (а, б) and left eye (в, г) of the same patient are presented; trauma to the pupil margins because of the use of iris retractors in previous surgeries is identified in both eyesб there is severe capsulorhexis phimosis in both eyes; using the plasma ablation technique, the capsulorhexises are enlarged, and pupils are created; there is some difference in the pupil size in both eyes. *Case 3* (patient № 14 in the table): a — preoperative condition of the eye, there is severe constriction of capsulorhexis, but the pupil is well dilated; б — the capsulorhexis is enlarged using plasma ablation technique, and there are cavitation bubbles in the anterior chamber; в — the excised thick anterior capsule is extracted from the anterior chamber with the help of forceps; г — end of surgery

Рис. 4. *Клинический пример 1* (в таблице пациент № 8). А — исходное состояние глазного яблока, определяется ККС в области зрачка, зрачок плохо расширяется; б — начальный этап расширения капсулорексиса, дистальный конец Фуго-лезвия находится в передней камере, аппарат активирован, у кончика наконечника определяются кавитационные пузыри; в — капсулорексис расширен без применения бимануальной техники; г — конец операции, область зрачка и зрительная ось освобождены от фиброзированной передней капсулы. *Клинический пример 2* (в таблице пациент № 13): на рисунке представлены правый (а–б) и левый глаз (в–г) пациента, в связи с применением ирис-ретракторов во время первой операции на рисунке (а, в) определяются разрывы зрачкового края в обоих глазах и выраженный фимоз капсулорексиса; с помощью Фуго-лезвия устранен фимоз и формированы зрачки в обоих глазах, размеры вновь созданных зрачков в правом и левом глазу отличаются друг от друга. *Клинический пример 3 (в таблице пациент № 14):* а — исходное состояние глазного яблока, определяется резкое сужение капсулорексиса, зрачок хорошо расширяется; б — расширен капсулорексис с применением плазменной энергии Фуго-лезвия, в области зрачка определяются кавитационные пузыри; в — разрезанная часть фиброзированной передней капсулы удалена из передней камеры пинцетом; г — конец операции

CONCLUSION

The plasma-generating Fugo blade system is an effective and safe tool that allows enlargement of phimotic capsulorhexis in a resistance-free fashion. It is easy to use, mastering of new surgical skills is not required, surgical trauma is minimal, the surgical time is reduced, and the patient's rehabilitation period is significantly shortened.

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Kumar Vinod: conception, design, data collection, analysis and interpretation, writing and editing, overall responsibility.

REFERENCES

1. Егорова Э.В., Струсова Н.А., Ронкина Т.И. О роли биомикроскопии в определении показаний к возможности дозированного рассечения передней капсулы и ее использование для фиксации ИОЛ. *Вестник офтальмологии*. 1986;1:7–11. [Egorova E.V., Strusova N.A., Ronkina T.I. On the role of biomicroscopy in determining the indications to the possibility of dosed dissection of the anterior capsule and its use for fixing IOL. *The Russian Annals of Ophthalmology = Vestnik Oftalmologii*. 1986;1:7–11 (In Russ.)].
2. Городничий В.В., Куроедов А.В. Хирургическая тактика при фиброзе капсулярного мешка после факоэмульсификации (клинические случаи). *Клиническая офтальмология*. 2014;3:164. [Gorodnichij V.V., Kuroedov A.V. Surgical tactics in management of capsular sac fibrosis after phacoemulsification (clinical cases). *Russian journal of clinical ophthalmology = Klinicheskaya oftalmologia*. 2014;3:164 (In Russ)].
3. Суркова В.К., Бикбов М.М., Акмирзаев А.А. Возрастные изменения задней сумки хрусталика и сроки развития ее фиброзной гиперплазии после факоэмульсификации катаракты. *Практическая медицина*. 2012;1(59):303–306 [Surkova V.K., Bikbov M.M., Akmirzaev A.A. Age-related changes in the posterior capsule and the timing of the development of its fibrous hyperplasia after cataract phacoemulsification. *Practical medicine = Prakitcheckaya meditsina*. 2012;1(59):303–306 (In Russ)].
4. Тахчиди Х.П., Агафонова В.В., Верзин А.А., Сиденко Т.Н. Передний капсулорексис: история появления, способы выполнения и дозирования (обзор литературы). *Офтальмохирургия*. 2010;5. [Tahchidi H.P., Agafonova V.V., Verzin A.A., Sidenko T.N. Anterior capsulorhexis: the history, techniques and dosing (review of literature). *Fyodorov Journal of Ophthalmic Surgery = Oftalmokhirurgiya*. 2010;5: (In Russ.)]. https://eyepress.ru/article.aspx?8329
5. Фабрикантов О.Л., Михина И.В. Предотвращение фимоза кольца капсулорексиса после факоэмульсификации осложненной катаракты. *Вестник Оренбургского государственного университета* 2011;14:237–238. [Fabrikantov O.L., Mihina I.V. Prevention of phimosis of the capsulorhexis ring after phacoemulsification of complicated cataracts. Annals of Orenburg State University = *Vestnik Orenburgskogo gosudarstvennogo universiteta* 2011;14:237–238 (In Russ.)].
6. Hansen S., Crandall A., Olson R. Progressive constriction of the anterior capsular opening following intact capsulorhexis. *J Cataract Refract Surg.* 1993;19(1):77–82. DOI: 10.1016/s0886-3350(13)80287-8
7. Hayashi K., Hayashi H., Nakao F. Hayashi F. Reduction in the area of the anterior capsule opening after PMMA, silicone, and soft intraocular lens implantation. *Am J Ophthalmol*. 1997;123(4):441–447. DOI: 10.1016/s0002-9394(14)70169-2
8. Kato S., Suzuki T., Hayashi Y., Numaga J., Hattori T., Yuguchi T., Kaiya T., Oshika T. Risk factors for contraction of the anterior capsule opening after cataract surgery. *J Cataract Refract Surg*. 2002;28(1):109–112. DOI: 10.1016/s0886-3350(01)00901-4
9. Deokule S.P., Mukherjee S.S., Chew C.K. Neodymium:YAG laser anterior capsulotomy for capsular contraction syndrome. *Ophthalmic Surg Lasers Imaging*. 2006;37(2):99–105.
10. Elmohamady M.N., Elhabbak A., Abdelazim G.A. Circular YAG laser anterior capsulotomy for anterior capsule contraction syndrome. *Int Ophthalmol*. 2019;39(11):2497–2503. DOI: 10.1007/s10792-019-01094-9. Epub 2019 Mar 11.
11. Reyntjens B., Tassignon M., Van Marck E. Capsular peeling in anterior capsule contraction syndrome: surgical approach and histopathological aspects. *J Cataract Refract Surg*. 2004;30(4):908–912. DOI: 10.1016/j.jcrs.2003.08.034
12. Zinkernagel M., Papazoglou A., Patel C.K. Bimanual anterior segment revision surgery for anterior capsule contraction syndrome associated with anterior flexion of intraocular lens haptics. *Eye* (Lond). 2013;27(12):1388–1390. DOI: 10.1038/eye.2013.206. Epub 2013 Sep 13.
13. Yeh P.C., Goins K.M., Lai W.W. Managing anterior capsule contraction by mechanical widening with vitrector-cut capsulotomy. *J Cataract Refract Surg*. 2002;28(2):217–20. DOI: 10.1016/s0886-3350(01)01031-8
14. Fugo R.J., Singh D. The biophysics and mode of operation of plasma surgery. In: Ocular applications of the Fugo Blade. Eds by Hampton R., Singh S., Richard J. Fugo: Philadelphia, Pa: Lippincott, Williams & Wilkins, 2010. P. 5–14.
15. Fugo R.J. Fugo blade to enlarge phimotic capsulorhexis. *J Cataract Refract Surg*.2006;32 (11):1900. DOI: 10.1026/j.jcrs.2006.06.034
16. Werner L., Pandey S.K., Apple D.J., Escobar-Gomez M., McLendon L., Macky T.A. Anterior capsule opacification: correlation of pathologic findings with clinical sequelae. *Ophthalmology*. 2001;108(9):1675–1681. DOI: 10.1016/S0161-6420(01)00674-1
17. Lorente R., Rojas V., Parga P.V., Moreno C., Landaluce L., Domı´nguez R., Lorente B. Management of late spontaneous in-the-bag intraocular lens dislocation: Retrospective analysis of 45 cases. *J Cataract Refract Surg*. 2010;36(8):127–1282. DOI: 10.1016/j.jcrs.2010.01.035
18. Davison J.A. Capsule contraction syndrome. *J Cataract Refract Surg*. 1993;19(5):582–589. DOI: 10.1016/S0886-3350(13)80004-1
19. Hayashi H., Hayashi K., Nakao F., Hayashi F. Anterior capsule contraction and intraocular lens dislocation in eyes with pseudoexfoliation syndrome. *Br J Ophthalmol*. 1998;82(12):1429–1432. DOI: 10.1136/bjo.82.12.1429
20. Hayashi H., Hayashi K., Nakao F., Hayashi F. Area reduction in the anterior capsule opening in eyes of diabetes mellitus patients. *J Cataract Refract Surg*. 1998;24(8):1105–1110. DOI: 10.1016/S0886-3350(98)80105-3
21. Hayashi K., Hayashi H., Matsuo K., Nakao F., Hayashi F. Anterior capsule contraction and intraocular lens dislocation after implant surgery in eyes with retinitis pigmentosa. *Ophthalmology*. 1998;105(7):1239–1243. DOI: 10.1016/S0161-6420(98)97028-2
22. Zhang Z.D., Song Z., Chen D., Huang F. Bilateral capsule contraction syn-drome following pathological myopic cataract surgeries. *Int J Ophthalmol*. 2012;5(3):406–408. DOI: 10.3980/j.issn.2222-3959.2012.03.31
23. Lanzl I.M., Kopp C. Ciliary body detachment caused by capsule contraction. *J Cataract Refract Surg*. 1999;25(10):1412–1414. DOI: 10.1016/S0886-3350(99)00213-8
24. Salzmann J., Khaw P.T., Laidlaw A. Choroidal effusions and hypotony caused by severe anterior lens capsule contraction after cataract surgery. *Am J Ophthalmol*. 2000;129(2):253–254. DOI: 10.1016/S0002-9394(99)00319-0
25. Srinivasan S., van der Hoek J., Green F., Atta H.R. Tractional ciliary body detachment, choroidal effusion, and hypotony caused by severe anterior lens capsule contraction following cataract surgery. *Br J Ophthalmol*. 2001 Oct;85(10):1261–1262. DOI: 10.1136/bjo.85.10.1260a
26. Venktesh R., Tan C.S., Veena K., Ravindran R.D. Severe anterior capsular phimosis following acrylic intraocular lens implantation in a patient with pseudoexfoliation. *Ophthalmic Surg Lasers Imaging*. 2008;39(3):228–229. DOI: 10.3928/15428877-20080501-21
27. Moreno-Montane J., Sanchez-Tocino H., Rodiriguez-conde R. Complete anterior capsule contraction after phacoemulsification with acrylic intraocular lens and endocapsular ring implantation. *J Cataract Refract Surg*. 2002;28(4):717–719. DOI: 10.1016/s0886-3350(01)01231-7
28. Kim H.D., Kim J.M., Jung J.J. Complete occlusion of anterior capsulorhexis after uneventful cataract surgery, treated with YAG laser capsulotomy. *BMC Ophthalmol*. 2017;17(1):233. DOI: 10.1186/s12886-017-0630-0
29. Chawla J.S., Shaikh M.H. Neodymium: YAG laser parabolic anterior capsulotomy in extreme capsule contraction syndrome. *J Cataract Refract Surg*. 1999;25(10):1415–1417. DOI: 10.1016/s0886-3350(99)00154-6
30. Гамидов А.А., Аверкина Е.А., Большунов А.В., Федоров А.А. Технология комбинированной лазерной капсулотомии при переднекапсулярном контракционном синдроме в артифакичных глазах. *Вестник офтальмологии*. 2017;6:45–49. [Gamidov A.A., Averkina E.A., Bol'shunov A.V., Fedorov A.A. The technology of combined laser capsulotomy in the anterior capsular contraction syndrome in pseudophakic eyes. *The Russian Annals of Ophthalmology = Vestnik Oftalmologii*. 2017;6:45–49 (In Russ)]. DOI: 10.17116/oftalma2017133645-49
31. Toto L., Viggiano P., Vecchiarino L., Evangelista F., Borrelli E., Mastropasqua L. Anterior capsule contraction syndrome: a successful multimodal therapeutic approach. *Int J Ophthalmol*. 2019;12(8):1356–1358. DOI: 10.18240/ijo.2019.08.20
32. Framme C., Hoerauf H., Roider J., Laqua H. Delayed intraocular lens dislocation after neodymium:YAG capsulotomy. *J Cataract Refract Surg*. 1998;24(11):1541–1543. DOI: 10.1016/S0886-3350(98)80182-X
33. Tuft S.J., Talks S.J. Delayed dislocation of foldable plate-haptic silicone lenses after Nd:YAG laser anterior capsulotomy. *Am J Ophthalmol*. 1998;126(4):586–588. DOI: 10.1016/S0002-9394(98)00124-X
34. Koh J., Song Y., Wee W., Han Y. Recurrent late-onset fibrotic capsular block syndrome after neodymium-yttrium-aluminum-garnet laser anterior capsulotomy: a case report. *BMC Ophthalmology*. 2016;16(1): DOI: 10.1186/s12886-016-0261-x
35. Wilson R.P., Gupta R. Focal corneal decompensation caused by an anterior capsulotomy remnant. *J Cataract Refract Surg*. 1997;23(8):1273–1274. DOI: 10.1016/s0886-3350(97)80328-8
36. Wilde C., Ross A., Awad M., Chen H.C., Dua H.S. Management of anterior capsular contraction syndrome: pitfall of circular capsulotomy technique with the neodymium YAG laser. *Eye*. 2018;32(5):1546–1548. DOI: 10.1038/s41433-018-0125-0
37. Panagopoulos A., Chalioulias K., Kirkby G.R. A new approach in the surgical management of anterior capsular phimosis syndrome. *Ophthalmic Res*. 2009;42(4):221–223. DOI: 10.1159/000232947

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