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OPTICAL COHERENCE TOMOGRAPHY OF PSEUDOPHAKIC EYES AFTER PRIMARY POSTERIOR CAPSULORHEXIS IN PSEUDOEXFOLIATION SYNDROME

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✧ ***Purpose*** to study vitreolenticular interface (VLI) and central retinal thickness after primary posterior capsulorhexis (PPC) in pseudoexfoliation syndrome (PEX).

Material and methods. We conducted a dynamic OCT-evaluation of the macular morphology (47 cases) and of the VLI (39 cases) in patients with PEX in early and long term period after uncomplicated cataract surgery with PPC. In the long term period a comparative OCT-evaluation of the macula was performed in 129 patients with PEX (159 eyes) in different groups: after phacoemulsification with and without PPC, after Nd:YAG laser capsulotomy for secondary cataract, and in the control group of non-operated eyes.

Results. The OCT-evaluation made it possible to visualize two significant features of VLI after PPC – intact anterior hyaloid and restoration of the capsule barrier. It took 3–8 days for full adhesion. Secondary cataract in the PPC area was detected in one case in the long-term period. Dynamic OCT-evaluation of the macula in the main group revealed a statistically unreliable increase in the macular thickness (3.4%) in post-op period at 1–3 months with subsequent regression. Such changes were within the limits of physiological norm. In the remote period, comparative OCT-evaluation of the macula in different groups did not reveal statistically significant differences with the control group.

Conclusion. OCT-evaluation at different post-op terms revealed the formation of stable vitreolenticular relationships and absence of clinically significant macular edema. Secondary cataract in the PPC area was detected only in one case.

✧ ***Keywords:*** posterior capsulorhexis; cataract; macular edema; vitreolenticular interface.

ОПТИЧЕСКАЯ КОГЕРЕНТНАЯ ТОМОГРАФИЯ АРТИФАКИЧНЫХ ГЛАЗ ПОСЛЕ ВЫПОЛНЕНИЯ ПЕРВИЧНОГО ЗАДНЕГО КАПСУЛОРЕКСИСА ПРИ ПСЕВДОЭКСФОЛИАТИВНОМ СИНДРОМЕ

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✧ ***Цель работы*** — изучить состояние витреолентикулярного интерфейса и толщины центральных отделов сетчатки после выполнения первичного заднего капсулорексиса (ПЗКР) при псевдоэксфолиативном синдроме.

Материал и методы. Проведено динамическое ОКТ-исследование морфологии макулы (37 человек, 47 глаз) и витреолентикулярного интерфейса (35 человек, 39 глаз) у пациентов с псевдоэксфолиативным синдромом в раннем и отдалённом периоде после неосложнённой хирургии катаракты с ПЗКР. В отдалённом периоде выполнено сравнительное ОКТ-исследование макулы у 129 пациентов с псевдоэксфолиативным синдромом (159 глаз) в различных группах: после факоэмульсификации катаракты с ПЗКР и без него, после YAG-лазерной дисцизии вторичной катаракты и в контрольной группе неоперированных глаз.

Результаты. ОКТ-исследование дало возможность визуализировать две существенные особенности витреолентикулярного интерфейса после ПЗКР — интактный передний гиалоид и восстановление капсульного барьера. Для полной адгезии требовалось от 3 до 8 дней. В отдалённом периоде вторичная катаракта в зоне ПЗКР была выявлена в одном случае. Динамическое ОКТ-исследование макулы у пациентов основной группы выявило статистически незначимое увеличение толщины макулы на 3,4 % в сроки 1–3 мес. с последующей регрессией. Данные изменения находились в пределах физиологической нормы. В отдалённые сроки сравнительное ОКТ-исследование макулы в различных группах не выявило статистически значимых различий с контрольной группой.

Заключение. ОКТ-исследование в различные послеоперационные сроки показало формирование стабильных витреолентикулярных взаимоотношений и отсутствие клинически значимого макулярного отёка. Вторичная катаракта в зоне ПЗКР выявлена только в одном случае.

✧ ***Ключевые слова:*** задний капсулорексис; катаракта; макулярный отёк; витреолентикулярный интерфейс.

INTRODUCTION

Background: Primary posterior capsulorhexis (PPC) has been used in lens surgery to prevent secondary cataracts for over 25 years [1, 2]. The efficacy and safety of this method, which, according to modern concepts, are due to the preservation of the barrier between the anterior and posterior segments of the eye, have been investigated in several studies [3–6]. The advent of optical coherence tomography (OCT) enabled to expand our understanding of the morphology of the retinal macular region and vitreolenticular relationships after posterior capsulorhexis, and to assess the consequences of this method's use [5–10]. However, this issue remains poorly understood in situations where the vitreolenticular barrier is initially compromised, for example, in pseudoexfoliation syndrome (PEX).

This study *aimed* to evaluate the state of the vitreolenticular interface (VLI) and the thickness of the central retinal areas using optical coherence tomography after PPC in PEX.

MATERIALS AND METHODS

In the early and late postoperative periods, patients with stages I–II PEX were examined after uncomplicated cataract surgery with PPC and implantation of various models of flexible hydrophobic intraocular lenses, namely Acrysof (Alcon), Hoya (HSO), Basis Z (First Q), AquaFree (Rumex), Tecnis (Abbott), and MIOL (Reper-NN) [11]. A dynamic OCT evaluation of the macular morphology was performed in 37 patients (47 eyes) aged 56–83 years ($M \pm \sigma$; 73.2 ± 7.3) with eye length of 23.62 ± 3.12 mm, and that of the vitreolenticular interface in 35 patients (39 eyes) aged 66–83 years with eye length of 23.56 ± 3.28 mm. OCT examination of the macula was performed before surgery and at various times after surgery (2–4 weeks, 1–3 months, and 6–12 months). The dynamics of the postoperative transformation of the vitreolenticular interface was assessed in the period from 1 day to 5 years.

Comparative OCT examination of the macular region of the retina in 129 patients (159 eyes) was performed to assess the long-term consequences of the PPC method. The macular morphology was studied in various groups of patients with grade II PEX [11], namely 36 cases after standard phacoemulsification (PE) with intraocular lens (IOL) implantation (PPC group); 31 cases after YAG-laser posterior capsulotomy for secondary cataract with uncomplicated primary cataract surgery; and 62 cases after uncomplicated PE with IOL implantation and PPC (PPC+ group). The control group consisted of 30 contralateral non-operated eyes of same patients. In a comparative study of macular thickness, the time after cataract surgery or YAG-laser posterior capsulotomy ranged from 1 to 7 years. The study included only patients with an unchanged baseline macular profile.

Posterior capsulorhexis was performed after IOL implantation both in primary fibrosis and on a transparent posterior lens capsule (PLC) to prevent the appearance of secondary cataracts in the optical area. Microperforation in the central part of the posterior capsule was performed using a 30G needle; afterwards, a circular hole with approximately 3.5 mm diameter was formed in it using 25G coaxial forceps. Manipulations on the posterior lens capsule were performed taking into account the involutional manifestations of PEX in the vitreolenticular interface area such as incompetence of the zonules, dystrophic changes of the

capsular bag, weakening of the Wiger's ligament, expansion of Berger's space, and destruction of the anterior hyaloid (AH). The technique used to perform the PPC was characterized by preliminary implantation of the intracapsular ring and partial filling of the capsular bag with a viscoelastic solution that was sufficient only to expand the posterior capsule. The viscoelastic solution under the posterior capsule was not administered or it was administered in a micro dose only in the perforation area, and there was therefore no need in the stage of the viscoelastic solution removal from under the capsular bag [12].

Statistical analysis of the variation series including the calculation of the arithmetic mean values and standard deviations was performed using SPSS11.0 and STATA application statistical software package. To compare abnormally distributed (according to the Shapiro-Wilk test) data across the groups, nonparametric criteria were used, namely Mann-Whitney test for comparing independent nonparametric samples, and Wilcoxon test for comparing dependent samples.

RESULTS

The proposed surgical technology allowed performing PPC without complications in all cases. The IOL was fixed in the capsular bag of the lens in correct position, and the IOL's optic completely covered the round opening in the posterior capsule. The OCT examination enabled to visualize two essential aspects of VLI after PPC, namely the intact anterior hyaloid and the restoration of the capsular barrier by adhesion of the edges of the capsulorhexis to the IOL.

In the first days after surgery, the relationship between the IOL and the PLC ranged from complete adhesion to its subtotal absence with a sagging edge of the capsulorhexis. However, in all cases, there was a contact of the posterior capsule with the IOL along its optical edge (Fig. 1). This fact could conventionally be considered as the restoration of the capsular barrier. In the following days, the edge of the capsulorhexis was pulled up to the IOL, the contact between the posterior capsule and the lens optic always progressed from the periphery to the center, and the capsule adjoined the IOL without forming folds (Fig. 2). It took 3–8 days for the PLC to fully adhere to the lens.

In subsequent periods, the relationship between the posterior capsule and the IOL remained, and the size of the posterior capsulorhexis also remained the same. The AH integrity was noted at all follow-up periods, and its state was determined by the degree of involution and was expressed in varying degrees of contour reflectivity and profile irregularities. In the early stages, the profile of the anterior hyaloid was also determined by its relationship to the movable edges of the posterior capsule and the remnants of the viscoelastic solution. After resorption of the viscoelastic solution and adhesion of the posterior capsule edges, the final vitreolenticular relationship formed. In all cases,

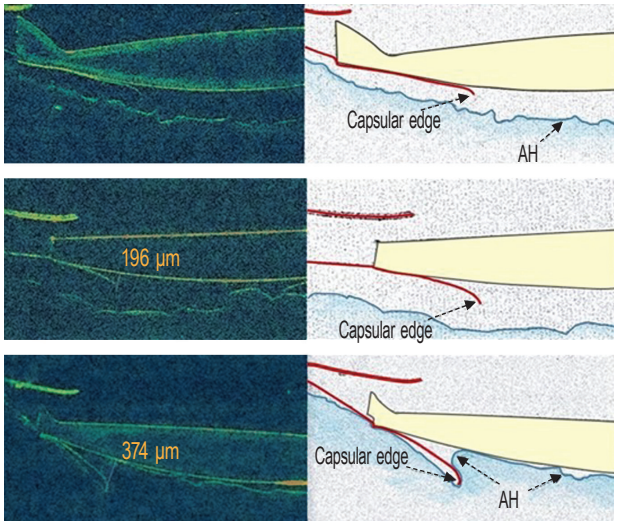

Fig. 1. OCT image / scheme with symbols. Pseudophakia, pseudoexfoliative syndrome, primary posterior capsulorhexis. Variants of adhesion of posterior capsule to IOL (total, partial, along the optical edge of the lens) in the early postoperative period (1–2 days). AH – anterior hyaloid

Рис. 1. Оптическая когерентная томограмма. Артифакия, псевдоэксфолиативный синдром, первичный задний капсулорексис. Различные варианты адгезии задней капсулы хрусталика к интраокулярной линзе (тотальная, частичная, по оптическому краю линзы) в раннем послеоперационном периоде (1–2-е сутки).

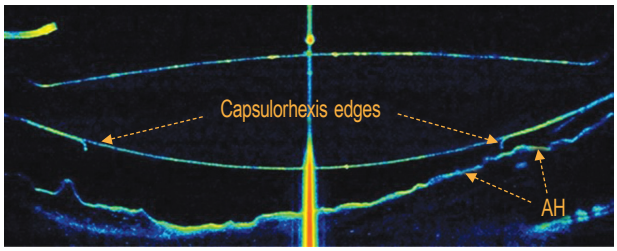

Fig. 2. OCT image. Pseudophakia, pseudoexfoliative syndrome, primary posterior capsulorhexis. The postoperative period – 8 days. Full adhesion posterior capsule-IOL. AH – anterior hyaloid

Рис. 2. Оптическая когерентная томограмма. Артифакия, псевдоэксфолиативный синдром, первичный задний капсулорексис. Послеоперационный период — 8 дней. Полная адгезия задней капсулы хрусталика к интраокулярное линзе.

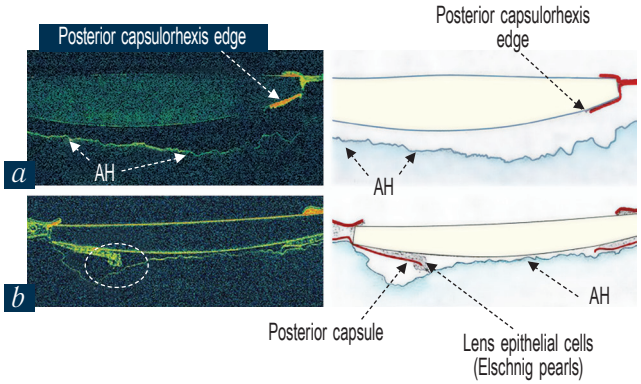

Fig. 3. OCT image. Pseudophakia, pseudoexfoliative syndrome, primary posterior capsulorhexis. Long-term period: *a* – clear optical zone, destruction of the anterior hyaloid membrane; *b* – cell proliferation at the edge of the posterior capsulorhexis. AH – anterior hyaloid

Рис. 3. Оптическая когерентная томограмма. Артифакия, псевдоэксфолиативный синдром, первичный задний капсулорексис. Отдаленный период: *a* — чистая оптическая зона, деструкция передней гиалоидной мембраны; *b* — клеточная пролиферация по краю заднего капсулорексиса

the presence of a retrolental space was observed, and its volume and configuration were determined by the AH profile and the degree of destruction of the Wiger's ligament.

At OCT examination of the state of the VLI structures on the posterior capsule surrounding the capsulorhexis "window" in the long-term period (from 2 to 5 years), various manifestations of fibrosis (41.9%) and cell proliferation (58.1%) were noted; however, the capsule folding and its sagging was not registered in any case, which was probably due to the removal of the thinnest and most destructively altered central part of the posterior capsule at posterior capsulorhexis. In three cases with pronounced cell proliferation on the remaining posterior capsule, a "bend" of the cell mass over the capsulorhexis edge and a "turn" of the migration of the lens epithelium to the outer side of the posterior capsule were noted. The optical zone corresponding to the posterior capsulorhexis area in patients of the main group almost often remained clear, with the exception of one case of retrolental opacity caused by migration of lens epithelial cells along the relatively intact anterior hyaloid membrane (Fig. 3).

Dynamic OCT examination of the macula in main group's patients at various postoperative periods revealed a minor increase in the thickness of the foveolar retina (by 3.4%) within 1–3 months, followed by regression.

These changes were within the range of the physiological norm and were not statistically significant (Table 1).

Comparative long-term OCT examination of the macula in the PPC–, PPC+, YAG-laser posterior capsulotomy for secondary cataract, and control groups revealed an increase in the thickness of the foveolar retina (by 4.2%) in the YAG-laser posterior capsulotomy for secondary cataract group; however, there were no statistically significant differences with the control group (Table 2).

Table 1 / Таблица 1

Dynamic study of the macula morphology after primary posterior capsulorhexis (*n* = 47)
Динамическое исследование морфологии макулы после первичного заднего капсулорексиса (*n* = 47)

Follow-up period	Macular thickness, μm	Wilcoxon's test (*p*)
Before surgery	246.53 ± 19.66	–
2–4 weeks	247.69 ± 19.67	0.57*
1–3 months	254.81 ± 21.18	0.08*
6–12 months	250.97 ± 16.38	0.26*

* Significant at $p < 0.05$.

Table 2 / Таблица 2

Comparative study of the macula morphology in the long-term period
Сравнительное исследование морфологии макулы в отдалённом периоде

Group	*n*	Age, years ($M \pm \sigma$)	Eye length, mm ($M \pm \sigma$)	Macula thickness, μm ($M \pm \sigma$)	Mann-Whitney test (*p*)
Control group	30	73.6 ± 7.1	23.25 ± 0.61	251.13 ± 24.06	–
PPC+ group	62	72.8 ± 8.4	23.52 ± 0.73	254.71 ± 18.85	0.76*
PPC– group	36	74.3 ± 8.4	23.44 ± 0.51	254.42 ± 24.38	0.88*
Group of YAG-laser posterior capsulotomy for secondary cataract	31	73.3 ± 9.0	23.72 ± 0.66	274.19 ± 26.23	0.25*

* Significant at $p < 0.05$.

DISCUSSION

The principle of the PPC method consists in the removal of the central flap of the PLC while maintaining the AH intact [1, 2]. The AH destruction, weakness of the lens zonules and capsule, and enlargement of the retrolental space in PEX necessitate the modification of the surgical technique for PPC in this category of patients in order to adequately expand the PLC, increase control of its dosed opening, and avoid damage to the AH [12]. Our proposed technology enabled to form a circular hole of the required diameter in the PLC and to maintain the AH's integrity in all cases, which was confirmed by the OCT of the vitreolenticular interface.

In an earlier OCT study, we revealed that PPC efficacy depends on the degree of lens epithelium proliferation on the remaining PLC, morphological preservation of the vitreolenticular relationship, and increases with the progression of involutional changes in VLI [13]. In the present study, for the vast majority of PEX patients in the long-term period after cataract surgery with PPC, enlargement of the retrolental space and pronounced destruction of the anterior hyaloid were registered, which excluded the possibility of it being used as a matrix for the lens epithelium migration. In addition, with the accumulation of the proliferative volume at the edge of the capsulorhexis, there was a "bend" and "turn" of cell migration to the outer surface of the lens posterior capsule.

In four patients of the study group, the AH preservation was noted; however, the enlargement of the retrolental space impeded the process of cell migration. Only in one case, the proliferative cell array at the edge of the posterior capsulorhexis reached the AH with continued migration along it to the optical zone.

The most discussed aspect of the PPC method is the degree of preservation and consistency of the vitreolenticular barrier, as its impairment could lead to diffusion of hyaluronic acid into the intraocular fluid, hydration of the vitreous body with a decrease in its "frame" properties, and increased prostaglandin permeability, and the probability of macular edema [14–16]. For a long time, there was no unambiguous interpretation among researchers regarding terminology, role of the constituent structures and functional significance of the barrier between the anterior and posterior segments of the eye, which, in fact, represents a membrane between the intraocular fluid and the vitreous cavity, blocking the penetration of lipids, proteins, hyaluronic acid, and enzymes [3, 4, 8, 15–19].

The study by V. De Groot et al. [3] was of paramount importance in understanding of this problem, as it investigated the permeability of fluorescein from the anterior chamber into the vitreous body one year after uncomplicated phacoemulsification with and without PPC, that is, with preservation of the anterior hyaloid structure, as well as in cases of non-standard cataract surgery with rupture of the posterior capsule and vitreous prolapse. It was revealed that the main factor leading to the impairment of barrier properties is damage to the anterior hyaloid membrane. The authors found a fundamental difference between diffusion processes in the case of an accidental traumatic rupture of the PLC and carefully controlled dosed opening of it in PPC.

A significant contribution in understanding the consequences of lens surgery was made by optical coherence tomography, which appeared in the late 1990s and enabled precisely studying the structure of the central retinal area and determining the two types of macular edema (ME): angiographic (asymptomatic, subclinical) and clinical (with decreased visual acuity) [20, 21]. According to OCT data, in uncomplicated phacoemulsification, the frequency of clinically significant ME is 0–2.35% [22–26]. Subclinical ME with standard PE occurs in 3–41% of cases [27–29]. OCT examination of the macular region morphology after uncomplicated PE with PPC revealed subclinical ME within four weeks to three months in 4.3–10% of cases, and clinical ME prevalence was 0–2%, which correlated with the indices after standard cataract surgery [5–10].

At the same time, the issue of the regulation of the intraocular biochemical and structural balance of the anterior and posterior eye segments after cataract surgery with PPC in pseudoexfoliative syndrome, which is characterized by the failure of the zonular capsule apparatus of the lens and destruction of the anterior hyaloid, remained poorly understood [30, 31].

The present study enabled to analyze the features of the vitreolenticular and vitreoretinal interfaces after PPC in PEX and to note the significant aspects, in particular the AH integrity and restoration of the capsular barrier. The foveolar thickness increased insignificantly within the physiological norm limits within 1–3 months after surgery with subsequent regression, and remained stable in the long-term period.

CONCLUSION

OCT examination at various times after cataract surgery with PPC in patients with PEX revealed intact AH, restoration of the capsular barrier after 3–8 days, formation of stable vitreolenticular relationships, and absence of clinically significant macular edema. Secondary cataract in the posterior capsulorhexis area was detected in just one case.

Conflict of interest. The authors declare no conflict of interest.

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