DOI: https://doi.org/10.17816/OV630019

Endothelial keratoplasty in patients with endothelial dysfunction of various etiologies, combined with abnormality of the iris-lens diaphragm

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ABSTRACT
The article presents a description of a modified method of transplantation of the endothelium on descemet membrane and of a method of femtosecond laser-assisted posterior lamellar keratoplasty in patients with corneal endothelial dysfunction combined with severe defects of the iris-lens diaphragm integrity. During surgery, in both cases, a banded stromal flap was used. There were no complications in the early postoperative period. The air resorption in the anterior chamber in both cases lasted no more than 2 days. After air resorption, the stromal flap occupied an intermediate position between the iridolens diaphragm remnants and the endothelial graft. On day 3, the bandage stromal flap was removed in the operating room. It was shown that the use of a bandage stromal flap during surgical procedures for extensive defects of the iris-lens diaphragm allows minimizing the risk of dislocation of the endothelial graft into the vitreal cavity. Proposed technique is an universal solution for DMEK and Fs-DSAEK in patients with an abnormality of the iris-lens diaphragm. The preliminary insertion of banded stromal flap into the anterior chamber makes it possible to block the defects of the iris-lens diaphragm and provides conditions for prolonged air tamponade of the anterior chamber and primary graft adhesion.

Keywords: endothelial transplantation with descemet's membrane; femto-assisted posterior automated lamellar keratoplasty; intraoperative optical coherence tomography; aniridia; aphakia; iris coloboma; banded stromal flap.

To cite this article
Tereshchenko AV, Trifanenkova IG, Demianchenko SK, Bulatova YuD, Gelyastanov AM. Endothelial keratoplasty in patients with endothelial dysfunction of various etiologies, combined with abnormality of the iris-lens diaphragm. *Ophthalmology Reports*. 2025;18(1):63–73. DOI: https://doi.org/10.17816/OV630019

Received: 05.04.2024 **Accepted:** 11.09.2024 **Published online:** 31.03.2025

ECO•VECTOR

DOI: https://doi.org/10.17816/OV630019

Эндотелиальная кератопластика у пациентов с эндотелиальной дисфункцией различной этиологии, сочетанной с нарушениями целостности иридохрусталиковой диафрагмы

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АННОТАЦИЯ

В статье представлено описание модифицированного способа проведения трансплантации эндотелия на десцеметовой мембране и методики фемтолазер-ассистированной задней послойной кератопластики у пациентов с эндотелиальной дисфункцией роговицы, сочетанной с грубыми нарушениями целостности иридохрусталиковой диафрагмы. В обоих случаях в ходе хирургии использовали бандажный стромальный лоскут. В раннем послеоперационном периоде осложнений не наблюдалось. Резорбция воздуха в передней камере в обоих случаях длилась не более 2 суток. После резорбции воздуха стромальный лоскут занимал промежуточное положение между остатками иридохрусталиковой диафрагмы и эндотелиальным трансплантатом. На третьи сутки бандажный стромальный лоскут был удалён в условиях операционной. Показано, что его применение в ходе операций при обширных дефектах иридохрусталиковой диафрагмы позволяет минимизировать риск дислокации эндотелиального трансплантата в полость стекловидного тела. Предлагаемая методика является универсальным решением для трансплантации эндотелия с десцеметовой мембраной и для задней автоматизированной послойной кератопластики с использованием фемтосекундного лазера у пациентов с патологией иридохрусталиковой диафрагмы, предварительное введение бандажного стромального лоскута в переднюю камеру позволяет блокировать дефекты иридохрусталиковой диафрагмы и обеспечивает условия для длительной воздушной тампонады передней камеры глаза и первичной адгезии трансплантата.

Ключевые слова: трансплантация эндотелия с десцеметовой мембраной; задняя автоматизированная послойная кератопластика с использованием фемтосекундного лазера; интраоперационная оптическая когерентная томография; аниридия; афакия; колобома радужки; бандажный стромальный лоскут.

Как цитировать

Терещенко А.В., Трифаненкова И.Г., Демьянченко С.К., Булатова Ю.Д., Гелястанов А.М. Эндотелиальная кератопластика у пациентов с эндотелиальной дисфункцией различной этиологии, сочетанной с нарушениями целостности иридохрусталиковой диафрагмы // Офтальмологические ведомости. 2025. Т. 18. № 1. С. 63–73. DOI: https://doi.org/10.17816/OV630019

Рукопись получена: 05.04.2024 **Рукопись одобрена:** 11.09.2024 **Опубликована online:** 31.03.2025

INTRODUCTION

A multicenter study published in 2016 was based on data from eye banks from 148 countries and included an analysis of 184,576 corneal transplantations performed between August 2012 and August 2013; the main indications for keratoplasty were Fuchs endothelial corneal dystrophy (39%), keratoconus (27%), and inflammatory corneal opacities (20%) [1].

Other studies have also demonstrated that endothelial corneal dystrophy of various etiologies is the leading indication for keratoplasty. In 2021, Dunker et al. published an analysis of corneal transplants in the European Union, Switzerland, and the United Kingdom [2]. Of 12,913 corneal transplants performed, 41% (5325) were performed to treat Fuchs endothelial corneal dystrophy; indications for the remaining procedures were repeated keratoplasty in 16% (2108) of cases, pseudophakic bullous keratopathy in 12% (1594) of cases, and keratoconus in 12% (1594) of cases [2].

For many decades, penetrating keratoplasty has been considered the main method of surgical treatment of endothelial corneal dystrophy of various etiologies. The advantages of this type of corneal transplantation were the relative technical ease and no need for expensive tools, whereas the disadvantages included a high risk of intra- and postoperative complications, prolonged visual rehabilitation, and postoperative astigmatism.

To minimize risks and optimize the results of corneal transplantation, state-of-the-art ophthalmology technologies helped to develop lamellar keratoplasty techniques, in particular various modifications of endothelial keratoplasty [3, 4]. They allowed surgeons to achieve high clinical and functional results as soon as in the early postoperative period with significantly lower risks of complications at all procedure stages compared with penetrating keratoplasty. Endothelial keratoplasty has significantly affected the keratoplasty methods worldwide. For example, the Eye Bank Association of America reported that the proportion of penetrating keratoplasty performed from 2005 to 2014 decreased by half from 94.9% to 41.5%, whereas the proportion of endothelial keratoplasty increased from 3.2% to 55.9% [5]. Dunker et al. [2] stated that out of 12,913 transplantations, 5918 (46%) were Descemet stripping automated endothelial keratoplasty (DSAEK).

Endothelial keratoplasty has been widely used not only for rapid visual rehabilitation, but also partially for a lower risk of graft rejection and subsequent immunization [6]. However, various endothelial keratoplasty techniques are largely limited in case of extensive defects of the lens-iris diaphragm, as they are associated with a high risk of the intra-operative endothelial graft migration into the vitreous cavity, extensive marginal diastases and complete graft dehiscence in the early postoperative period, as it is impossible to perform complete air tamponade of the anterior chamber, necessary for adhesion endothelial graft to the posterior corneal surface of the recipient [7–13].

This study is based on search of surgical approaches to provide permanent endothelial graft attachment during Descemet membrane endothelial keratoplasty (DMEK) and femtosecond laser-assisted Descemet stripping automated endothelial keratoplasty (FS-DSAEK) in patients with lens-iris diaphragm defects by creating a temporary barrier between the anterior and posterior chambers.

The *study aimed* to describe a modified technique of DMEK and FS-DSAEK in patients with endothelial corneal dystrophy combined with severe lens-iris diaphragm defects.

CASE REPORT No. 1

A 27-year-old male patient with a history of penetrating corneal injury in 2016. During primary surgical treatment, the cornea was sutured, traumatic cataract was removed without implantation of an intraocular lens (IOL). Post-traumatic best corrected visual acuity (BCVA) was 0.05 until 2019. In 2019, penetrating keratoplasty was performed with implantation of hydrophilic IOL RSP3 (Scientific Experimental Production Eye Microsurgery LLC, Russia) and iris surgery. BCVA was 0.2 at postoperative year 1. At postoperative year 2, graft endothelium was decompensated (Fig. 1, *a*), therefore endothelial keratoplasty was recommended. In 2022, endothelial keratoplasty was performed. Severe iris coloboma of about a quarter of the iris area required modified Descemet membrane endothelial keratoplasty using a bandage stromal flap (BSF) to prevent intraoperative endothelial graft dislocation into the vitreous cavity, air migration to the posterior segment, and hydrophilic IOL opacification.

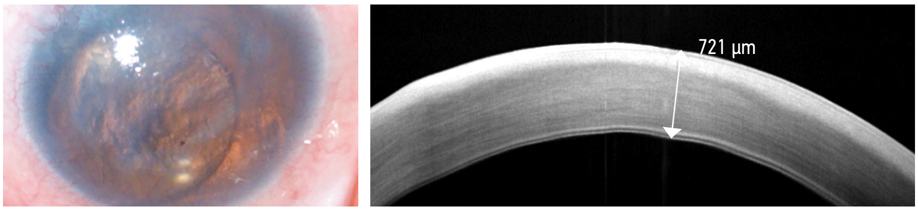
Pre-operative uncorrected visual acuity was 0.01; intraocular pressure (IOP) was 19 mmHg. Corneal optical coherence tomography (OCT) on topical hypotensive therapy revealed central corneal thickness of 814 μm (Fig. 1, *b*); endothelial cell density (ECD) was not determined. ECD of the donor cornea was 2587 cells/mm^2.

CASE REPORT No. 2

A 52-year-old female patient with congenital aniridia had bilateral lens-iris diaphragm implantation with cataract removal 20 years ago. After 1 year, secondary glaucoma required bilateral lens-iris diaphragm removal with implantation of a posterior chamber IOL in the left eye. She was followed-up in the Kaluga Branch of the Fyodorov Eye Microsurgery Federal State Institution over the past 5 years. At presentation, OS subclinical corneal edema was observed, central corneal thickness was

a *b*

Fig. 1. Clinical case 1: *a*, photo of the anterior segment of the eye before surgery; *b*, OCT of the cornea before surgery, central thickness of the penetrating corneal graft is 814 µm
Рис. 1. Клинический случай № 1: *a* — фото переднего отрезка глаза перед операцией; *b* — ОКТ роговицы до операции, центральная толщина сквозного трансплантата роговицы 814 мкм



a *b*

Fig. 2. Clinical case 2: *a*, photo of the anterior segment of the eye before surgery, aniridia, bullous keratopathy, intraocular lens dislocation; *b*, OCT of the cornea before surgery, central thickness of the cornea is 721 µm
Рис. 2. Клинический случай № 2; *a* — фото переднего отрезка глаза перед операцией, аниридия, буллёзная кератопатия, дислокация интраокулярной линзы; *b* — ОКТ роговицы до операции, центральная толщина роговицы 721 мкм

598 µm, and BCVA was 0.2. In 2022, OS bullous keratopathy, decreased vision, anterior dislocation of the posterior chamber IOL, and IOL contact with the posterior corneal surface (Fig. 2, *a*) required endothelial keratoplasty with IOL explantation. To prevent the endothelial graft migration into the vitreous cavity and air migration into the posterior segment, modified posterior lamellar keratoplasty using a BSF was performed.

Pre-operative uncorrectable visual acuity was 0.05, IOP was 21 mmHg, with hypotensive therapy, OCT revealed central corneal thickness of 721 µm (Fig. 2, *b*). ECD was not determined.

SURGICAL TECHNIQUE

During both procedures, a temporary barrier was created between the anterior and posterior chambers using a BSF. It prevents air migration into the vitreous cavity and allows for complete air tamponade of the anterior chamber and increase in initial adhesion of the endothelial graft. Moreover, the BSF protects the IOL surface from contact with air or a gas-air mixture, which prevents hydrophilic IOL opacification and allows for endothelial keratoplasty without the need to replace a hydrophilic IOL with a hydrophobic one.

An intra-operative OCT system (iOCT, surgical microscope with integrated iOCT module, Hi-R NEO 900, Haag Streit Surgical, Germany) was used to view the relative position of the BSF and endothelial graft in the anterior chamber during surgery and to verify the orientation of the graft endothelial surface. The BSF was created from the used corneoscleral button immediately after endothelial graft preparation. A femtosecond laser was used to form a 200 µm flap of 9.4 mm (clinical case No. 1) and 8.5 mm (clinical case No. 2) in diameter, consisting of the Bowman layer and surface stromal layers.

Preoperatively, all patients received standard retrobulbar anesthesia (3.0 mL of 0.75% ropivacaine) and anesthetic eye drops (0.4% oxybuprocaine) 3 times 5 minutes apart.

Modified Descemet membrane endothelial keratoplasty using a bandage stromal flap (clinical case No. 1)

The first step was to mark the cornea using an 8 mm circular ring (individual corneal parameter) centered by the edge of the penetrating keratoplasty scar. Then, the Descemet membrane graft with an endothelial layer was prepared using a banked donor corneoscleral button and placed in a container with a preservation solution. The Descemet membrane graft with an endothelial layer matched the recipient's corneal mark. When the endothelial graft was prepared, the donor corneoscleral button was transferred to a Petri dish with 0.9% balanced sodium chloride solution and stored for further BSF creation. Then, a 3 mm tunnel incision was made at 10 o'clock, and two 1.2 mm paracenteses were made at 2 and 8 o'clock.

The next step was to fill the anterior chamber with a cohesive viscoelastic. Using a reverse Sinskey hook,

DOI: https://doi.org/10.17816/OV630019

the Descemet membrane was separated from the posterior surface of the penetrating graft and removed. Then, the viscoelastic was removed from the anterior chamber, which was filled with 0.9% balanced sodium chloride solution. Next, a femtosecond laser was used to create the BSF from the outer stromal layers of the donor corneoscleral button. BSF diameter was calculated by subtracting 2 mm from the minimum diameter of the recipient's cornea (9.4 mm). BSF thickness was 200 μm. Suture (silk 8–0) was fixed to the BSF periphery. The resulting BSF was folded in half and implanted into the anterior chamber through the primary incision using forceps so that the BSF Bowman membrane faced the posterior surface of the recipient's cornea. One suture end was fixed to the BSF edge facing the primary incision, and the other end exited the anterior chamber through the primary corneal incision. The Descemet membrane graft with an endothelial layer was placed in a glass injector (Gueder AG, Germany) connected to a syringe with 0.9% balanced sodium chloride solution. The injector was inserted into the anterior chamber through the primary incision so that the tip was between the posterior surface of the recipient's cornea and BSF. The endothelial graft was implanted into the anterior chamber between the posterior surface of the recipient's cornea and BSF.

The next step was to close the primary incision and paracenteses with single interrupted sutures (nylon 10-0) and to fill the anterior chamber with 0.9% balanced sodium chloride solution. The iOCT system was used to assess the endothelial graft position relative to the recipient's corneal stroma and BSF together with correct orientation of the graft endothelial layer relative to the posterior corneal surface. Then, the graft was unfolded and positioned by the marked Descemet membrane incision area using in a standard for DMEK manner. Under iOCT guidance, a 27 G cannula was inserted through one of the paracenteses between the endothelial graft and BSF, and air tamponade of the anterior chamber was performed. Then, the primary incision was closed with two additional interrupted sutures using nylon 10-0. The BSF was removed on day 3, when the air bubble dissipated, and the Descemet membrane graft with an endothelial layer completely adhered to the posterior surface of the recipient's corneal graft. The surgery was performed in the operating room after standard preoperative procedures (retrobulbar anesthesia with 3.0 mL of 0.75% ropivacaine) and instillation of anesthetic eye drops (0.4% oxybuprocaine 3 times 5 minutes apart). First, the central interrupted suture (nylon 10-0) was removed from the primary incision. The BSF was removed from the anterior chamber through the primary incision using the suture fixed to the BSF and exiting the eye through the primary incision. The anterior chamber was filled with 0.9% balanced sodium chloride solution, and the primary incision was closed with an additional nylon 10-0 suture.

Modified femtosecond laser-assisted posterior lamellar keratoplasty using BSF (clinical case No. 2)

To improve visualization, the corneal epithelium was delaminated. The cornea was marked using an 7 mm circular ring (considering individual parameters of the recipient's cornea). A temporal corneal incision of 4 mm was made. Paracenteses of 1.2 mm were created opposite to the primary incision and at 12 o'clock. The incision at 12 o'clock was used for an irrigation cannula. Then, the anterior chamber was filled with a cohesive viscoelastic. Using a reverse Sinskey hook, a 7 mm Descemet membrane incision was made along the corneal marking, then the Descemet membrane was separated from the posterior surface of the corneal stroma and removed.

The next step was to remove the viscoelastic from the anterior chamber, which was then filled with 0.9% balanced sodium chloride solution. A femtosecond laser was used to create a 120 μm and 7 mm posterior lamellar corneal graft on the endothelial surface, then it was transferred to a container with a preservation solution. The femtosecond laser was used to create 200 μm thick and ∅8.5 mm BSF. A suture (silk 8-0) was fixed to the BSF periphery, which was then implanted into the anterior chamber so that the BSF Bowman membrane faced the recipient's iris. One suture end was fixed to the BSF edge facing the primary incision, and the other end exited the eye through the primary corneal incision. Next, the posterior lamellar graft was placed into a Busin spatula and implanted into the anterior chamber through the primary corneal incision using serrated forceps so that the endothelial graft was between the posterior surface of the recipient's cornea and the BSF. The posterior lamellar graft was implanted under constant irrigation with 0.9% balanced sodium chloride solution to support the anterior chamber and press the BSF downwards.

The next step was to remove the irrigation cannula and close the paracenteses and primary incision with single nylon 10-0 interrupted sutures and two nylon 10-0 interrupted sutures, respectively. The iOCT system was used to assess the posterior lamellar graft position relative to the recipient's corneal stroma and BSF together with orientation of its endothelial layer. Then, using iOCT, a 27 G cannula was inserted between the posterior lamellar graft and BSF, and air tamponade of the anterior chamber was performed.

Next, the posterior lamellar graft was centered relative to the previously marked Descemet membrane incision, and the posterior lamellar graft adhesion to the posterior surface of the recipient's stroma was verified using OCT. Postoperatively, a soft contact lens was inserted to reduce the corneal syndrome symptoms until complete epithelialization. The BSF was removed on day 3, when the air bubble dissipated, and the endothelial graft completely adhered to the posterior surface of the recipient's cornea. The surgery was performed in the operating room after standard preoperative procedures (retrobulbar anesthesia with 3.0 mL of 0.75% ropivacaine) and instillation of anesthetic eye drops (0.4% oxybuprocaine 3 times 5 minutes apart). First, the nylon 10-0 interrupted suture was removed from the primary incision, the suture was at the incision edge, where the silk 8-0 suture, fixed to the BSF edge, exited the eye. The BSF was removed from the anterior chamber through the primary incision using the suture fixed to the BSF and exiting the eye through the primary incision. The anterior chamber was filled with 0.9% balanced sodium chloride solution, and the primary incision was closed with an additional nylon 10-0 suture.

In both cases, patients were transferred to the ward at the supine position. In addition, supine head rest without a pillow was recommended for both patients on day 1.

In the postoperative period, both patients received in-hospital antibacterial, anti-inflammatory, and corneal protective therapy with 1 drop of 0.5% levofloxacin and 0.1% dexamethasone solutions and 5% dexpanthenol gel 4 times a day in clinical case No. 1 and with 1 drop of 0.5% levofloxacin and 0.1% dexamethasone solutions and artificial tears 4 times a day in clinical case No. 2.

RESULTS

Both patients had no complications characteristic of endothelial keratoplasty, including graft dehiscence, early graft failure, significant and progressive local diastases, and pupillary block, in the early postoperative period. It took no more than 2 days for the air to dissipate in the anterior chamber in both cases. When the air bubble dissipated, the stromal flap located between the remaining lens-iris diaphragm and endothelial graft (Fig. 3, 4). On day 3, the BSF was removed in the operating room. Intraoperative OCT control showed no endothelial graft dehiscence during the BSF removal from the anterior chamber.

Case report No. 1

Penetrating graft edema completely resolved at postoperative month 3 (Fig. 5, *a*). BCVA was 0.1, IOP was 22 mmHg on hypotensive therapy (brinzolamide + timolol and brimonidine), central thickness of the penetrating graft based on OCT data was 576 μm (Fig. 5, *b*), and ECD was 1648 cells/mm^2.

At postoperative month 12, an IOP increase to 35 mmHg on hypotensive therapy (brinzolamide + timolol, brimonidine, and travoprost) required glaucoma surgery (Ahmed valve implantation).

At postoperative month 24, the penetrating graft remained transparent (Fig. 6, *a*), and BCVA was 0.16. Central corneal thickness based on OCT data was 613 μm (Fig. 6, *b*). ECD was 873 cells/mm^2; IOP was 19 mmHg on hypotensive therapy (brinzolamide + timolol).

Case report No. 2

Corneal edema completely resolved at postoperative month 3 (Fig. 7, *a*). BCVA was 0.2, IOP was 21 mmHg on hypotensive therapy (dorzolamide + timolol). OCT showed central corneal thickness of 605 μm (Fig. 7, *b*), endothelial graft thickness of 76 μm, and ECD of 1759 cells/mm^2.

At postoperative month 18, the cornea was stable (Fig. 8, *a*), BCVA was 0.2, IOP was 19 mmHg on hypotensive therapy (2% dorzolamide + 0.5% timolol). OCT demonstrated central corneal thickness of 622 μm, endothelial graft thickness of 75 μm, and ECD of 1104 cells/mm^2 (Fig. 8, *b*).

DISCUSSION

Endothelial keratoplasty techniques presented in several publications [11–17] do not restore barrier function of the defected lens-iris diaphragm and do not allow for

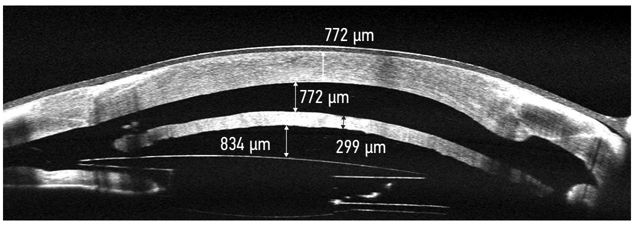


Fig. 3. Clinical case No. 1. OCT of the cornea, day 3 after modified transplantation of the endothelium on descemet membrane with a banded stromal flap. Central thickness of the corneal graft is 772 μm, there are no endothelial graft diastases, the banded stromal flap in the anterior chamber of the eye in a free position, there is no contact of the banded stromal flap with the posterior surface of the penetrating corneal graft, the thickness of the banded stromal flap is 299 μm

Рис. 3. Клинический случай № 1. ОКТ роговицы, 3-и сутки после модифицированной трансплантации эндотелия с десцеметовой мембраной с бандажным стромальным лоскутом. Центральная толщина сквозного трансплантата роговицы 772 мкм, диастазы эндотелиального трансплантата отсутствуют, бандажный стромальный лоскут в передней камере глаза в свободном положении, отсутствие его контакта с задней поверхностью сквозного трансплантата роговицы, толщина бандажного стромального лоскута 299 мкм complete air or gas-air mixture tamponade of the anterior chamber or permanent endothelial graft attachment to the posterior surface of the recipient's cornea, which results in a high incidence of endothelial graft diastases and requires a repeated procedure. Unlike different variations of suture fixation of an endothelial graft to the recipient's cornea, our technique has no direct effects on the endothelial graft, which seems to positively affect postoperative endothelial cell loss.

Several authors have proposed a pathogenetically justified approach aimed at preliminary recovery of the lens-iris diaphragm. Weller et al. [18] used a two-stage

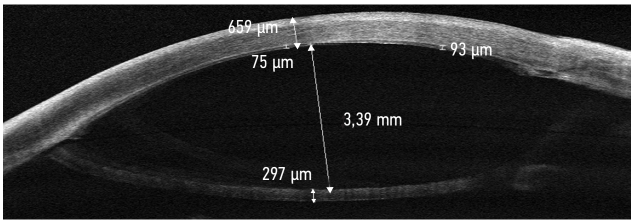
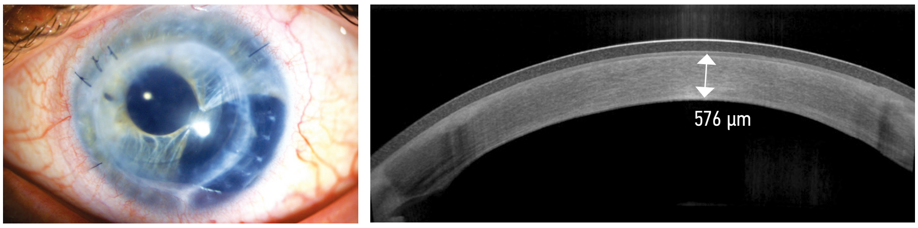


Fig. 4. Clinical case No. 2. OCT of the cornea, day 3 after modified femtosecond laser-assisted posterior automated lamellar keratoplasty with a banded stromal flap. The central thickness of the cornea is 659 µm, there are no diastases of the endothelial graft, the banded stromal flap in the anterior chamber of the eye in a free position, there is no contact of the banded stromal flap with the posterior surface of the endothelial corneal graft, the thickness of the banded stromal flap is 297 µm

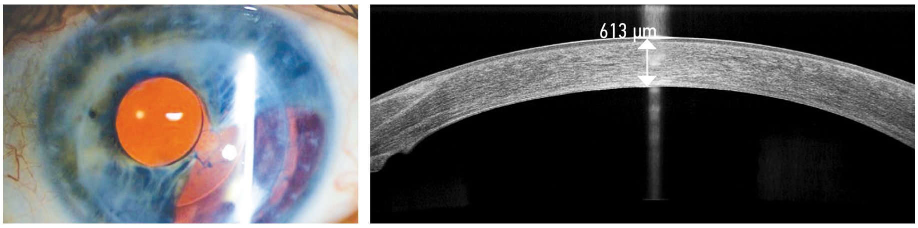
Рис. 4. Клинический случай № 2. Оптическая когерентная томография роговицы, 3-и сутки после модифицированной фемто-ассистированной задней автоматизированной послойной кератопластики с бандажным стромальным лоскутом. Центральная толщина роговицы 659 мкм, диастазы эндотелиального трансплантата отсутствуют, бандажный стромальный лоскут в передней камере глаза в свободном положении, отсутствие его контакта с задней поверхностью эндотелиального трансплантата роговицы, толщина бандажного стромального лоскута 297 мкм



a *b*

Fig. 5. Clinical case No. 1, 3 months after the modified transplantation of the endothelium on descemet membrane with a banded stromal flap: *a*, photo of the anterior segment of the eye, the corneal graft is transparent, the pupillary model of the hydrophilic IOL is transparent; *b*, OCT of the penetrating graft, central thickness of the penetrating graft is 576 µm

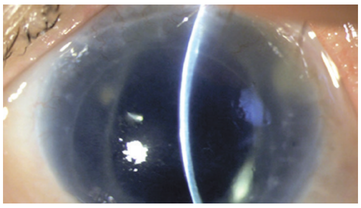
Рис. 5. Клинический случай № 1, через 3 мес. после модифицированной трансплантации эндотелия с десцеметовой мембраной с бандажным стромальным лоскутом: *a* — фото переднего отрезка глаза, сквозной трансплантат роговицы прозрачный, зрачковая модель гидрофильной интраокулярной линзы прозрачная; *b* — ОКТ сквозного трансплантата, центральная толщина сквозного трансплантата 576 мкм



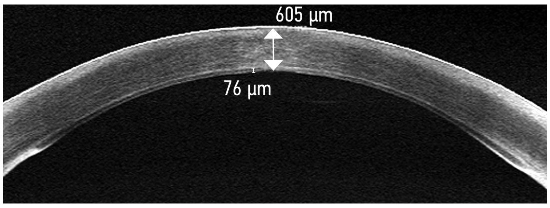
a *b*

Fig. 6. Clinical case No. 1, 24 months after the modified transplantation of the endothelium on descemet membrane with a banded stromal flap: *a*, photo of the anterior segment of the eye, the pupillary model of hydrophilic IOL is transparent; *b*, OCT of the cornea, the central thickness of the penetrating graft is 613 µm

Рис. 6. Клинический случай № 1, через 24 мес. после модифицированной трансплантации эндотелия с десцеметовой мембраной с бандажным стромальным лоскутом: *a* — фото переднего отрезка глаза, сквозной трансплантат роговицы прозрачный, зрачковая модель гидрофильной интраокулярной линзы прозрачная; *b* — ОКТ роговицы, центральная толщина сквозного трансплантата 613 мкм



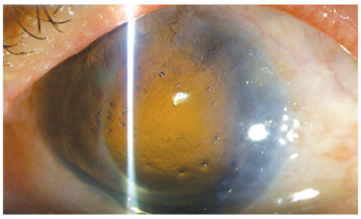
a



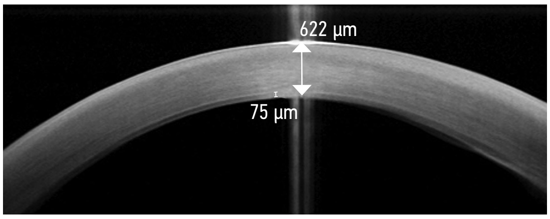
b

Fig. 7. Clinical case No. 2, 3 months after the femtosecond laser-assisted posterior automated lamellar keratoplasty with a banded stromal flap: *a*, photo of the anterior segment of the eye, the cornea is transparent, the remnants of the capsular bag are visible; *b*, OCT of the cornea, the central thickness of the cornea is 605 μm, endothelial graft's thickness is 76 μm

Рис. 7. Клинический случай № 2, через 3 мес. после модифицированной фемто-ассистированной задней автоматизированной послойной кератопластики с бандажным стромальным лоскутом: *a* — фото переднего отрезка глаза, роговица прозрачная, визуализируются остатки капсульного мешка; *b* — ОКТ роговицы, центральная толщина роговицы 605 мкм, толщина эндотелиального трансплантата 76 мкм



a



b

Fig. 8. Clinical case No. 2, 18 months after the femtosecond laser-assisted posterior automated lamellar keratoplasty with a banded stromal flap: *a*, photo of the anterior segment of the eye, the cornea is transparent, the remnants of the capsular bag are clearly visible; *b*, OCT of the cornea, central thickness of the cornea is 622 μm, endothelial graft's thickness is 75 μm

Рис. 8. Клинический случай № 2, через 18 мес. после после модифицированной фемто-ассистированной задней автоматизированной послойной кератопластики с бандажным стромальным лоскутом: *a* — фото переднего отрезка глаза, роговица прозрачная, чётко визуализируются остатки капсульного мешка; *b* — ОКТ роговицы, центральная толщина роговицы 622 мкм, толщина эндотелиального трансплантата 75 мкм

surgical approach to recover the lens-iris diaphragm (IOL implantation, IOL replacement, and pupil surgery) and perform standard DMEK. However, although the lens-iris diaphragm was pre-recovered, repeated air tamponade was required in 46% of cases, and secondary graft failure was noted in 17% of cases. The authors reported intraoperative complications associated with lens-iris diaphragm defects despite preliminary repair surgery. Jastaneiah presented a similar approach. He was the first to implant a combined IOL + iris prosthesis with scleral fixation and performed standard DSAEK after 6 months [7]. However, these techniques require additional procedure, which poses a risk of intra- and postoperative complications and prolongs patient's rehabilitation.

Several pathogenetically justified techniques with temporary recovery of the lens-iris diaphragm should

DOI: https://doi.org/10.17816/OV630019

be mentioned. For this purpose, a hydrophilic methacrylate sheet of 12.8 mm in diameter with peripheral holes, phakic IOL, 4 mm wide sheets glide can be used. These supportive devices are a temporary intraoperative diaphragm to separate the anterior and posterior chambers, prevent air migration from the anterior chamber to the posterior chamber, and reduce the risks of graft migration and dehiscence [8–10]. These approaches obviously facilitate endothelial graft unfolding in aphakic patients with a deep chamber and allow for complete air tamponade. However, endothelium contact with the polymer seems to be traumatic, and short postoperative follow-up does not allow assessing graft survival and stability of the clinical effect.

Our proposed technique is also based on the temporary intraoperative recovery of the lens-iris diaphragm to create a stable air bubble in the anterior chamber and avoid diastases and graft dehiscence. BSF used as a temporary barrier seems to be less traumatic for the graft endothelium with their inevitable intra-operative contact and is more biologically compatible than artificial materials, which may prevent early endothelial graft failure. Moreover, BSF eliminates the contact of air or a gas-air mixture with the IOL optic surface, which is crucial for hydrophilic IOLs and does not require their preliminary replacement with hydrophobic IOLs, thus reducing surgical trauma.

The presented DMEK-BSF and DSAEK-BSF technique provided stable clinical and functional results at postoperative months 18 and 24 in two clinical cases. This technique is a universal method to compensate lens-iris diaphragm defects during DMEK and DSAEK, which allows for complete permanent endothelial graft attachment to the posterior surface of the recipient's cornea. However, further studies are warranted to support wide use of this technique. They will be aimed at assessing the effect of the stromal flap in the anterior chamber on the severity of the inflammatory reaction and its effect on postoperative loss of graft endothelial cells.

CONCLUSION

The presented clinical cases demonstrated that BSF use in DMEK and DSAEK in patients with severe lens-iris diaphragm defects minimizes the risk of intra-operative dislocation of the endothelial graft into the vitreous cavity. Further studies in a larger sample are warranted to evaluate the long-term functional results of the proposed technique.

ADDITIONAL INFO

Authors' contribution. All authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study. Personal contribution of each author: A.V. Tereshchenko, concept and design of the work, final approval of the version to be published; I.G. Trifanenkova, concept and design of the work, editing; S.K. Demyanchenko, Yu.D. Bulatova, A.M. Gelyastanov, collection, analysis and processing of the material, writing the text.

Funding source. This study was not supported by any external sources of funding.

Competing interests. The authors declare that they have no competing interests.

Consent for publication. Written consent was obtained from the patient for publication of relevant medical information within the manuscript.

ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Вклад авторов. Все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией. Личный вклад каждого автора: А.В. Терещенко — концепция и дизайн работы, окончательное утверждение версии подлежащей публикации; И.Г. Трифаненкова — концепция и дизайн работы, редактирование; С.К. Демьянченко, Ю.Д. Булатова, А.М. Гелястанов — сбор, анализ и обработка материала, написание текста.

Источник финансирования. Авторы заявляют об отсутствии внешнего финансирования при проведении исследования.

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

Информированное согласие на публикацию. Авторы получили письменное согласие пациентов на публикацию медицинских данных.

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DOI: https://doi.org/10.17816/OV630019