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Outcomes of Sutureless Small Incision Descemet's Stripping Automated Endothelial Keratoplasty: A Retrospective Study

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Abstract: Background: This study evaluated the outcomes of sutureless small incision Descemet's Stripping Automated Endothelial Keratoplasty (DSAEK-SI) for treating corneal endothelial decompensation. Methods and Analysis: This retrospective study reviewed patients with corneal endothelial decompensation who underwent DSAEK-SI between January 2018 and June 2021 at the Vietnam National Eye Hospital. All patients were followed for at least one year postoperatively. The endothelial graft was inserted into the anterior chamber through a 2.8 mm main corneal incision using a Busin glide. The normal pressure air tamponade of the anterior chamber was applied to attach the graft to the recipient bed. The small incision required no sutures, and no need to remove part of the air from the anterior chamber. This ensured that the surgery ended immediately after the air tamponade, without having to wait for 15 min like with regular DSAEK. The patients were instructed to lie supine for at least 6 h postoperatively. Patients with cataracts underwent combined phacoemulsification and intraocular lens implantation with DSAEK-SI. Results: Sixty eyes from sixty patients were enrolled. The success rate of the surgery was 93.3%. Postoperatively, the best spectacle-corrected visual acuity (BSCVA) improved from 20/3600 to 20/400 at discharge and reached 20/100 at 12 months. Mild astigmatism (0.5D to 2D) was observed in 91.8% of patients, with a mean cylinder of 0.9 ± 0.4D at 12 months. The endothelial cell loss rate after 12 months was 34.6 ± 16%. No graft dislocations or detachments were recorded. Conclusions: The sutureless DSAEK-SI technique with a 2.8 mm incision is a modified technique that achieves high success rates and potentially reduces surgical manipulation and complications.

Keywords: sutureless DSAEK; small incision DSAEK; DSAEK-SI

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1. Introduction

In recent years, corneal transplantation for the treatment of corneal endothelial diseases has developed rapidly, leading to significant improvements in outcomes. However, Descemet's Stripping Automated Endothelial Keratoplasty (DSAEK) remains the preferred method and yields ideal results in treating corneal endothelial damage, especially in complex cases where Descemet's Membrane Endothelial Keratoplasty (DMEK) surgery is not indicated [1].

The conventional DSAEK procedure involves incisions ranging from 3 to 5 mm, depending on the surgeon. With the advent of improved graft insertion tools, the DSAEK technique has evolved, allowing for smaller incisions and reduced surgical times, laying the foundation for sutureless small-incision endothelial keratoplasty. In 2017, Titiyal [1] and colleagues introduced a 3.8 mm sutureless technique in which the corneal tunnel was long

enough to self-seal without the need for sutures. This technique employed air tamponades with a 30 G needle for 12–14 min, similar to conventional DSAEK surgeries, to help the graft adhere to the recipient bed. At the end of the surgery, the air tamponade was reduced and replaced with a balanced salt solution (BSS). These advancements improved outcomes by minimizing astigmatism and reducing operative time.

In our study, we further refined this technique by utilizing a 2.8 mm sutureless incision and applying an air tamponade with a 26 G cannula at normal pressure. The surgery was completed without the prolonged high-pressure air tamponade of 10–15 min commonly used in DSAEK methods.

2. Materials and Methods

2.1. Study Design and Patients

This retrospective study reviewed the medical records of patients who underwent DSAEK-SI surgery performed by a single corneal surgeon at the Vietnam National Eye Hospital from January 2018 to June 2021. Patients with bullous keratopathy without stromal scarring, who completed at least one year of postoperative follow-up, were included. For cases with coexisting cataracts, combined DSAEK-SI and cataract surgery with intraocular lens implantation was performed.

This study was approved by the Ethics Committee of the Vietnam National Eye Hospital. All patients and their families provided informed consent for the use of their data in this research.

2.2. Inclusion and Exclusion Criteria

The inclusion criteria were patients diagnosed with bullous keratopathy without stromal scarring who completed at least one year of postoperative follow-up. Patients who declined participation or were lost to follow-up were excluded.

Evaluation Parameters

Preoperative assessments included:

Data on visual acuity (VA), intraocular pressure (IOP), corneal thickness, corneal astigmatism, and endothelial cell density (ECD). VA was measured using a Snellen chart at a 6 m distance under standardized lighting conditions. IOP was assessed using the iCare IC100 tonometer (iCare Finland Oy, Model TA011, Vantaa, Finland). Corneal thickness was evaluated with anterior segment optical coherence tomography (Visante OCT 4000, Carl Zeiss Meditec, Jena, Germany). Corneal astigmatism was measured using the KR-1W Wavefront Analyzer (Topcon, Tokyo, Japan). ECD was provided by the eye bank, with cell counts documented prior to transplantation.

Postoperative evaluations:

Data on VA, IOP, corneal thickness, corneal astigmatism, graft condition, and complications were recorded at 1, 3, 6, and 12 months. Measurements were conducted using the same methods and devices as those employed preoperatively, except for ECD, which was assessed with the SP-3000P specular microscope (Topcon, Japan).

- **Graft Condition** was documented for clarity, adherence, position, and any complications.
- **Success** was defined as the resolution of symptoms such as photophobia, tearing, glare, and foreign body sensation, a clear cornea, and a well-adhered graft within four weeks.
- **Graft Failure** was defined by persistent graft detachment, corneal edema with epithelial bullae, and the recurrence of symptoms.

2.3. Surgical Technique

Anesthesia: The surgery was performed under either general anesthesia or peribulbar anesthesia.

Recipient bed preparation: The patient's corneal diameter was measured, and a trephine was used to mark the recipient bed's circumference on the epithelial surface. The graft diameter was typically 3 mm smaller than the patient's corneal diameter. In cases of thick epithelial edema, epithelial removal was necessary to achieve optimal anterior chamber visualization. A main incision, 2.8 mm wide and 2 mm long, was created at the 10 o'clock position for the left eye or the 8 o'clock position for the right eye. Two secondary incisions were made: one opposite the main incision to allow forceps insertion for pulling the graft into the anterior chamber, and a second oblique incision between the main and the first secondary incision for inserting the anterior chamber maintainer. Viscoelastic was injected to stabilize the anterior chamber. A reversed Sinskey hook was used to strip the Descemet's membrane along the marked recipient bed circumference. Finally, the viscoelastic was completely removed from the anterior chamber.

Graft preparation: Donor tissue was prepared using a microkeratome from the SightLife Eye Bank (Seattle, WA, USA). The donor corneal lenticule was cut with a trephine of the desired diameter and loaded onto the Busin glide.

Graft insertion and air tamponade: The donor lenticule was pulled into the anterior chamber using the "pull through" technique with forceps and the Busin glide, allowing it to unfold naturally. The incisions were closed by hydration without the need for sutures. Air was then introduced into the anterior chamber, and a reverse 27 G needle attached to a 10 mL syringe was used to center the graft. The graft was attached to the posterior surface of the recipient stroma by injecting a normal-pressure air bubble through the main incision. Unlike conventional DSAEK, no air-fluid exchange was needed, and the surgery was finished without 10–15 min waiting time. The patient was required to remain supine for at least 6 h postoperatively (Figure 1).

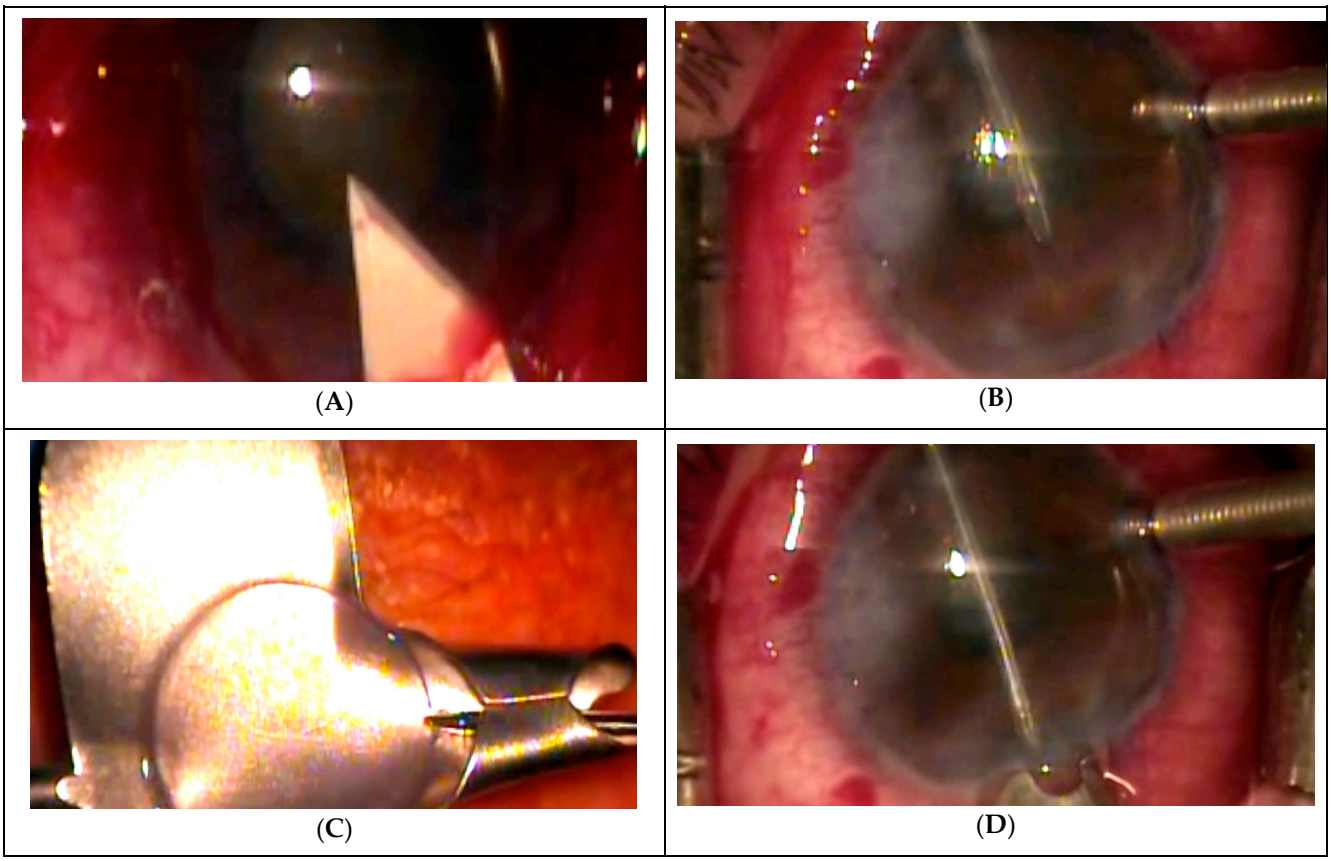
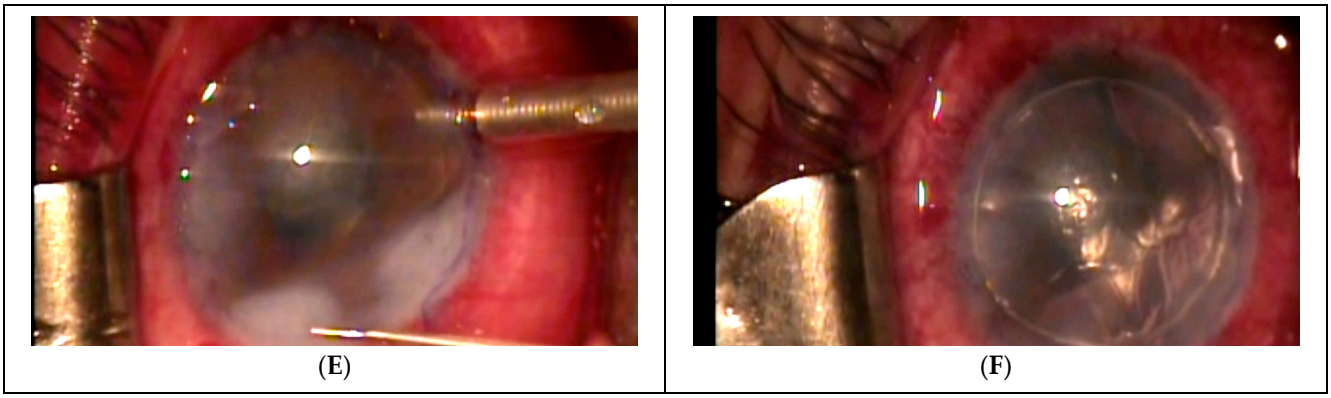


Figure 1. *Cont.*



(**E**) (**F**)

Figure 1. Surgical steps: (**A**) Create a main incision of 2.8 mm (compared to other methods using 3–5 mm). (**B**) Insert an anterior chamber maintainer and create a secondary incision opposite the main incision for graft insertion. (**C**) Prepare the graft and load it onto the Busin glide. (**D**) Pull the graft into the anterior chamber through the 2.8 mm incision. (**E**) Hydrate the incision. (**F**) Inject air at normal pressure into the anterior chamber and complete the surgery.

For patients undergoing combined surgery of DSAEK-SI and cataract extraction with IOL implantation, DSAEK was performed after IOL implantation.

Postoperative care: Patients received oral antibiotics and topical eye drops, including moxifloxacin 0.5% four times daily for the first month, prednisolone acetate 1% four times daily for the first month with subsequent tapering, and artificial tears.

A video demonstrating the surgical technique is provided in Supplementary Materials.

2.4. Statistical Analysis

The Wilcoxon *t*-test was used to compare visual outcomes, corneal astigmatism, and endothelial cell loss. Statistical analysis was performed using SPSS software, version 21.0 (SPSS Inc., Chicago, IL, USA). The threshold for significance was $p = 0.05$.

3. Results

3.1. Patient and Surgical Characteristics

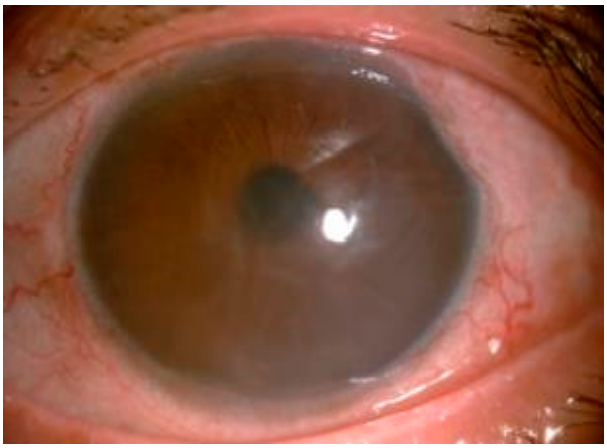
This study included 60 eyes from 60 patients with complete one-year follow-up data. The average age was 63.6 ± 13.5 years (range: 29 to 86). Of the participants, 54.7% were male and 45.3% were female. Among the 60 eyes, seven (11.6%) eyes underwent a combined procedure of DSAEK-SI and phacoemulsification with IOL implantation to address coexisting cataracts. The remaining 53 eyes (88.4%) underwent standalone DSAEK-SI; among these, four had clear lenses that did not require cataract surgery, while the rest had previously undergone cataract extraction with IOL implantation. Some surgical characteristics are detailed in Table 1.

Table 1. Surgical characteristics.

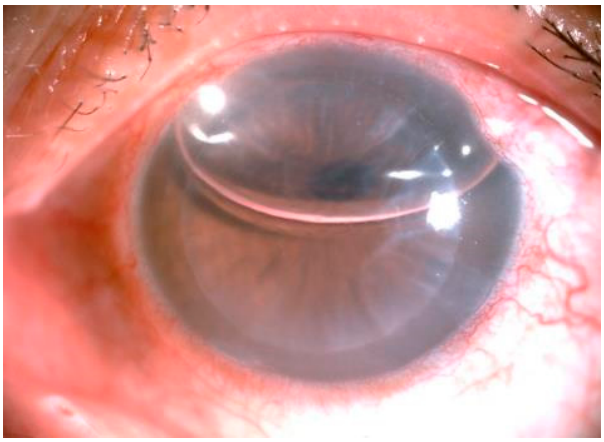
Indications	Bullous keratopathy	75%
	Fuchs' dystrophy	15%
	ICE syndrome	3.3%
	Other (graft failure, glaucoma, viral endotheliitis)	6.7%
Graft diameter	7.5 mm	11.3%
	8.0 mm	88.7%

3.2. Successful Rate

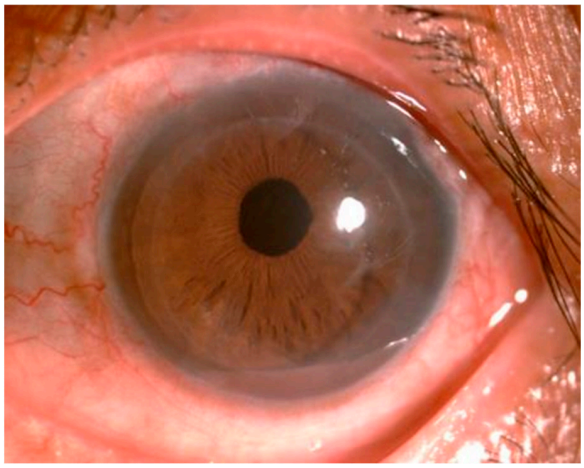
The surgical success rate after one year was 93.3%. Graft failure occurred in four eyes, including one eye with unexplained graft failure, one eye with graft rejection, one eye with CMV endothelial keratitis, and one eye with Iridocorneal Endothelial (ICE) syndrome. Representative cases with successful outcomes are presented in Figures 2 and 3.



A. Bullous keratopathy



B. One day Post-DSAEK-SI



C. One year Post-DSAEK-SI

Figure 2. Post-DSAEK-SI results: (**A**) Eye with bullous keratopathy and pseudophakic IOL. (**B**) One-day post-DSAEK-SI. (**C**) One-year post-op: the endothelial graft remained clear, centered, and well-attached.

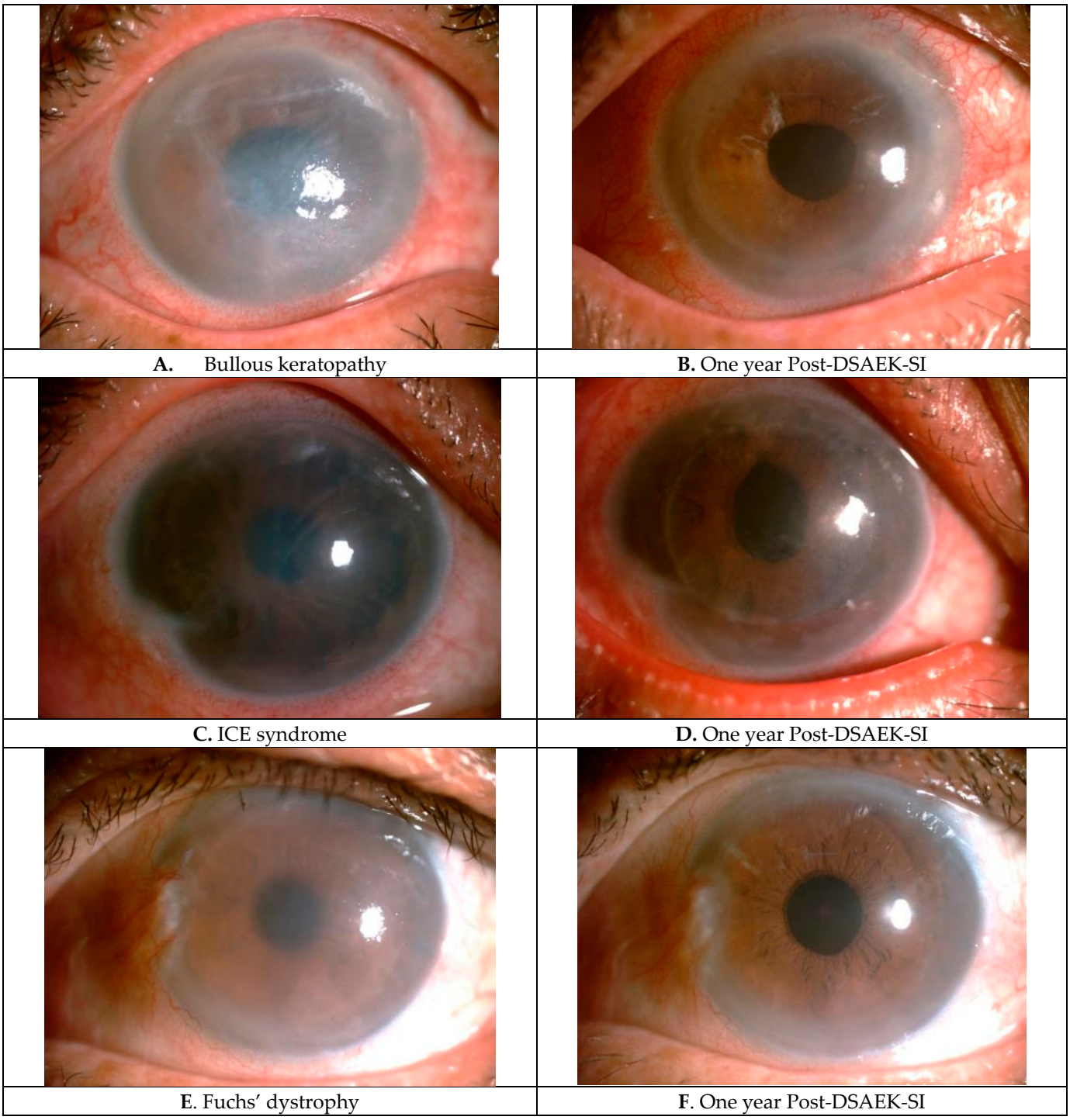


Figure 3. Three cases with successful surgery: Case 1. (**A**) Eye with bullous keratopathy and pseudophakic IOL. (**B**) DSAEK-SI was performed with a good result at one year follow-up. Case 2. (**C**) Eye with ICE syndrome. (**D**) The endothelial graft was clear, centered, and well-attached at one-year follow-up. Case 3. (**E**) Eye with Fuchs' endothelial dystrophy. (**F**) A good result was observed at one-year follow-up.

3.3. Visiual Outcomes

The average preoperative visual acuity was 20/3600, with 90.5% of patients having a visual acuity of less than 20/400. The average best-corrected visual acuity (BSCVA) for all eyes at discharge and at the 12-month follow-up was 20/400 and 20/100, respectively, which was significantly higher than the preoperative visual acuity (p = 0.005). Among the

55 out of 60 eyes with retinal pathologies, 13 patients were diagnosed with age-related macular degeneration accompanied by macular edema, 7 with cystoid macular edema, 10 with diabetic retinopathy, and 9 with hypertensive retinopathy. Additionally, one patient had retinitis, two had glaucoma, three had epiretinal membrane, two had ICE syndrome, and three had myopic retinal degeneration. For patients without retinal pathology (5 eyes), the BSCVA was 20/300 at discharge and improved to 20/45 at the 12-month follow-up ($p < 0.001$).

3.4. Corneal Astigmatism

Preoperative corneal astigmatism was not recorded due to corneal edema. The average corneal astigmatism in 56 eyes with graft survival at the 6- and 12-month follow-up was 0.92 ± 0.5D and 0.9 ± 0.4D, respectively. The difference was not statistically significant ($p = 0.066$). Of these 56 eyes, 91.8% had astigmatism ranging from 0.50 to 2.00D, 8.2% had astigmatism between 2.00 and 3.00D, and no eyes had astigmatism greater than 3D.

3.5. Endothelial Cell Loss

ECD was recorded before and after cutting with a microkeratome at the SightLife Eye Bank (USA) and during follow-up examinations. In the successful group, 53 eyes had measurable ECD at 12 months. The average preoperative ECD was 2645 ± 309 cells/mm^2. At 6 months postoperatively, the average ECD was 1755 ± 457 cells/mm^2, and at 12 months, it was 1668 ± 327 cells/mm^2. The endothelial cell loss rate at 6 and 12 months was 32.7 ± 13.5% and 34.6 ± 16%, $p = 0.322$, respectively.

3.6. Complications

In our study, no cases of graft detachment or dislocation were observed postoperatively. All grafts remained well-attached and centered at all follow-up visits. Graft rejection was observed in one eye, leading to graft failure. Early postoperative IOP elevation due to pupillary block by an air bubble was seen in four eyes. These four eyes were treated with cycloplegic eyedrops (Mydrin-P). After 3 h, the air bubble block resolved in two eyes, while the other two required partial air removal through the main incision. All patients experienced resolution of early IOP elevation within one day. Late postoperative IOP elevation occurred in two eyes, both of which were controlled with anti-glaucoma medication. One patient with a history of CMV-related endotheliitis developed persistent endotheliitis immediately after grafting, leading to graft failure.

4. Discussion

Endothelial cells play a crucial role in maintaining corneal transparency. DSAEK surgery for endothelial decompensation offers several advantages over penetrating keratoplasty, including faster visual recovery, less nerve damage, and the preservation of ocular integrity due to the small incision size of only 3–5 mm. In recent years, the development of instruments for graft insertion into the anterior chamber has allowed for refinements in DSAEK, including smaller incision sizes and a sutureless approach. Many authors have made individual modifications to the technique, all aimed at simplifying the surgical procedure, while achieving good postoperative outcomes and minimizing complications. To the best of our knowledge, this is the first study in the literature to use the smallest incision size (2.8 mm) without sutures, along with normal-pressure air injection to adhere the graft to the stromal bed. This technique allows the surgery to be completed immediately after air injection, without the need to wait 10–15 min as in conventional methods.

The success rate of DSAEK-SI surgery in our study was 93.3%, which is comparable to traditional DSAEK surgeries. Shih et al. reported a success rate of 88% [2], while Price et al. conducted a five-year study on 165 eyes, achieving a success rate of 95% [3]. With

experienced surgeons, the success rate can reach up to 100% [4]. In these studies, DSAEK surgery was performed with a 5 mm incision, using sutures or forceps to insert the graft into the anterior chamber. After 8–10 min of air injection, approximately 30% of the air bubble was replaced with balanced salt solution (BSS) [2,3]. Titiyal et al. conducted a study on 27 eyes undergoing sutureless DSAEK with a 3.8 mm incision and Busin glide for graft insertion. After 15 min of air injection, approximately 50% of the air was replaced with BSS, and the results showed no graft failures, with a 100% success rate [1]. Foster et al. reported a 95.2% success rate in a study of 105 eyes undergoing DSAEK with a 3 mm incision [5]. In Foster's study, the graft was inserted into the anterior chamber using forceps, with a 10 min wait after air injection before replacing approximately 40% of the air bubble with BSS [5]. Our improved DSAEK-SI technique, using a sutureless 2.8 mm incision with no waiting after air injection and no replacement of the anterior chamber air bubble with BSS, has achieved a high success rate comparable to traditional DSAEK surgery.

DSAEK-SI surgery replaces only the diseased posterior corneal layer while preserving the anterior corneal layer. The surgery uses an air bubble to adhere the graft to the posterior stromal bed, and a 2.8 mm incision to insert the graft into the anterior chamber. This small incision minimally impacts the anterior corneal curvature, and it can self-seal through hydration. The improvement in surgical technique has helped patients avoid astigmatism caused by sutures. In our study, postoperative astigmatism at 12 months was 0.9 ± 0.4D. Terry reported a mean corneal astigmatism of 1.19D in 100 eyes following DSAEK with a 5 mm incision and sutures [6]. Koenig et al. performed DSAEK with a 4.2 mm incision and sutures on 26 eyes, resulting in a mean corneal astigmatism of 2.26 ± 1.48D [7].

A concern with DSAEK-SI is the potential for increased endothelial cell (EC) loss due to the higher risk of trauma to the graft when passing through the small incision. However, we observed that using the Busin glide to insert the graft allows it to roll with the endothelial side facing inward, thus protecting the ECs. In our study, endothelial cell loss at 12 months was $34.6 \pm 16\%$, which is comparable to Terry's study and lower than Ishii's, both with the same one-year follow-up period [4,8]. In Titiyal's study on sutureless DSAEK, endothelial cell loss at 6 months was 18.19% [1], which is lower than our results. However, the study only reported on a 6 month period and requires longer follow-up to assess long-term endothelial cell loss.

The graft is inserted into the anterior chamber using the Busin glide, and it unfolds automatically under continuous irrigation through an anterior chamber maintainer. This reduces surgical manipulation and minimizes the risk of endothelial cell loss [9]. The use of the Busin glide has limited endothelial cell loss to 20–30% after 6–12 months, significantly lower than the 61% loss observed with suture or taco techniques [10].

One standout feature of DSAEK-SI surgery is the small incision size (2.8 mm), which can close postoperatively without the need for sutures. This allows for better maintenance of the anterior chamber and reduces suture-induced astigmatism. Consequently, the graft typically adheres and centers fully after air injection, minimizing the need for additional graft adjustments and reducing endothelial cell damage.

A key difference in our improved technique compared to previous methods is the air tamponade step. We inject air into the anterior chamber at normal pressure, allowing the graft to adhere to the stromal bed without maintaining a high-pressure air bubble for 10–15 min, as suggested by other authors. This improvement eliminates the need for air-fluid exchange, simplifies the surgical procedure, shortens operation time, and minimizes damage to endothelial cells caused by high-pressure air bubbles.

Graft dislocation and detachment are common complications after DSAEK surgery. Although anterior chamber air injection is performed to reattach the graft, the risk of graft failure remains high. Graft dislocation or detachment often occurs within the first week

post-surgery but can appear up to six weeks later. In Nahum's study of 1334 eyes, the rate of graft dislocation or detachment was 3.7%, and all grafts were successfully reattached by reinflating the anterior chamber with air [11]. Similarly, Bhalerao reported a graft detachment rate of 3.5% in 80 eyes, with 77 grafts reattached after reinflation, though 25 eyes still experienced graft failure [12]. In Suh's study of 118 eyes post-DSAEK, 23% of eyes experienced graft detachment [13]. In our study, after DSAEK-SI surgery, the graft detachment rate at all follow-up visits was 0%. This improved technique significantly reduced the graft detachment rate compared to traditional DSAEK surgery, where detachment is the most common complication.

Several technical improvements contributed to this success: the small, sutureless incision limits corneal deformation, allowing the graft to adhere more easily to the physiological curvature of the recipient bed; the use of the Busin glide and forceps to pull the graft into the anterior chamber reduces the risk of graft inversion; normal-pressure air tamponade in the anterior chamber; and crucially, maintaining the air bubble in the anterior chamber without replacing it with BSS. We believe that the fluid in the anterior chamber could postoperatively penetrate the interface and cause graft detachment when the patient changes head position. The air bubble remains in the anterior chamber long enough to help the graft adhere firmly to the stromal bed. These improvements have effectively prevented early graft detachment post-surgery.

5. Conclusions

In this study, the improvements in DSAEK-SI surgery offer substantial benefits for both surgeons and patients. For surgeons, the elimination of suturing and waiting time for air-fluid exchange may allow for shorter procedures, though further studies are needed to evaluate this advantage objectively. For patients, this approach supports fast visual recovery, reduces postoperative astigmatism, and minimizes complications, particularly graft dislocation or detachment. The endothelial cell loss rate observed was consistent with traditional DSAEK techniques.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/transplantology6010004/s1, Video S1: DSAEK–SI DR.CUNG.

Author Contributions: Conceptualization, L.X.C.; methodology and writing—original draft preparation: L.T.A.T.; data curation, D.M.N.; writing—review and editing, P.N.D. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was approved by the Ethics Committee of the Vietnam National Eye Hospital as part of the 2020 scientific research projects (Approval No. [423], Date: 13 April 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The relevant data generated or analyzed during this study are included in this article. All data are not publicly available in the interest of patient privacy. Further enquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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