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*Original Article*

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ENDOTHELIAL-PRESERVING PENETRATING KERATOPLASTY (ENDO-PK):  
TECHNIQUE AND EARLY CLINICAL OUTCOMES.Elkadam, M.<sup>(\*)</sup>, Allam, W. & Nasef, M.

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**Abstract**

**Purpose:** to describe technique and evaluate early outcomes of penetrating keratoplasty with preserved recipient peripheral endothelium. **Methods:** Prospective case series included five eyes with central full thickness corneal opacity and underwent endothelial preserving penetrating keratoplasty (Endo-PK). Outcome measures assessed at least six months after surgery included: Average keratometric reading (average K), keratometric astigmatism (KA), manifest refractive astigmatism (RA), spectacle best corrected visual acuity (BCVA) and complications. **Results:** The mean follow up period was  $7.8 \pm 2.1$  months. The mean BCVA (decimal) was  $0.46 \pm 0.17$  (range: 0.3 – 0.7). The mean RA was  $1.85 \pm 1.14$  diopters (range: 0-3 diopters). The mean KA was  $2.1 \pm 1.15$  diopters (range: 0.5 -3.5 diopters). The average keratometric reading (average K) was  $44.5 \pm 1.6$  diopters and ranged from 42 to 46 diopters. As regard late postoperative complications, there was persistent peripheral double anterior chamber encountered in one eye (20%). **Conclusions:** Endothelial preserving penetrating keratoplasty (Endo-PK) represents a promising step forward in optimizing corneal transplantation in eyes with full thickness corneal scars and healthy peripheral endothelium.

**Keywords:** Endothelium, Graft survival, Keratoplasty, Endo-PK**1. Introduction**

Despite the development of deep anterior lamellar keratoplasty (DALK) techniques selectively addressing the diseased anterior layer of the cornea, penetrating keratoplasty (PK) is still indicated when deep stromal scars affect the descemet membrane and endothelium particularly in its optical zone [1]. Penetrating keratoplasty has several challenges that can lead to graft failure, including immunologic rejection of the donor endothelium—especially in eyes with

vascularized corneal scars—, progressive endothelial cell loss, and suboptimal graft quality [2]. If a suboptimal -quality graft is used in penetrating keratoplasty (PK) for a recipient with healthy peripheral endothelium; endothelial migration from the intact peripheral bed is expected to help compensate for the progressive loss of donor endothelial cells [3]. This highlights the crucial importance of preserving any healthy recipient endothelial cell during the proce-

ture. This can be achieved by performing a small-diameter penetrating keratoplasty addressing only the opacity in the visual axis or, ideally, a mushroom-shaped PK. Long-term survival of small grafts, with successful outcomes reported up to 30 years after PK for keratoconus [4]. However, the challenge with small grafts is the risk of poor visual outcomes, primarily due to high postoperative astigmatism [5].

## **2. Methods**

This was a prospective case series conducted at a tertiary care university hospital (Tanta University hospital; Tanta; Egypt) and included five eyes of five patients presented with central full thickness corneal opacity in the period from December 2023 to March 2024. The study followed the tenets of the 2013 Declaration of Helsinki and was approved by the local Institutional Ethics Committee of Tanta Faculty of Medicine (approval number

### **2.1. Preoperative evaluation**

Demographic data were recorded, and each patient underwent a complete preoperative ophthalmological evaluation including slit-

### **2.2. Surgical technique**

All operations were performed under general anesthesia by a single surgeon (ME). The surgical technique was a hybrid approach that integrated steps of both deep anterior lamellar keratoplasty (DALK) peripherally and penetrating keratoplasty (PK) centrally. The procedure commenced with donor preparation using 8 mm punch. Then the recipient bed was partially trephined using a 7.75–8 mm suction trephine to a depth of 300–450  $\mu$ m (5–8 quarter turns with Barron suction trephine), followed by gentle dissection with insulin needle down to reach a clear plane in the peripheral part of pre-Descemet's layers. Similar to a manual dissection DALK, the recipient cornea is then debulked by removing approximately 80% of the anterior stroma above the reached plane with the help of a

The mushroom PK technique, though more advanced, often requires specialized tools such as a microkeratome or femtosecond laser for graft and bed preparation [6]. The aim of this study was to describe an innovative technique, Endothelial-Preserving Penetrating Keratoplasty (Endo-PK), and evaluate its early outcomes, offering a promising solution to the challenges faced in full-thickness corneal transplants.

36264MS919-4-25); Informed consent was taken from all patients before surgery. Patients with full thickness corneal opacity involving visual axis were included. Exclusion criteria were: Patients with corneal edema (endothelial dysfunction), poor retinal and optic nerve function as detected by electrophysiological study, the presence of uncontrolled glaucoma, or previous failed corneal graft.

lamp examination, ultrasonography, retinal and optic nerve electrophysiological study.

blunt tipped Vannas scissor. This dissection was typically interrupted near the cornea center by full thickness scaring, then a paracentral perforation was made in the bed and the inferior branch of the Vannas scissor was inserted into the anterior chamber to complete the excision of the central scarred deep stroma and endothelium over the pupillary area (central 4–6 mm area), leaving a peripheral rim of clear descemet's membrane and predescmet's layer (peripheral DALK and central PK). Ocular viscoelastic device (OVD) was used to reform the collapsed anterior chamber. The graft was then sutured in place as usual; notably, the peripheral endothelium of the graft was compressed against the retained peripheral portion of the recipient's posterior lamellae. The preserved peripheral

posterior lamellae had to be unaffected by scarring, otherwise a deeper layer by layer dissection was performed down to a clear descemet's membrane. If the scarring involves the entire descemet's membrane in the trephined area, the surgery was converted to conventional PK and if the clear plane could be dissected in the central area, the surgery was continued as manual dissection DALK. Bandage soft contact lens was applied after suturing.

### **2.3. Follow up**

All patients were seen daily during hospital admission (2-3 days), weekly for the first 2 months then monthly thereafter. A thorough eye evaluation was scheduled and performed in all patients between 6 and 9 months postoperatively, that is, after the first selective suture removal performed 3-6 months postoperatively guided by keratoscopic finding. Any post-operative complications were recorded. Early outcome measures assessed at least one month after the first selective suture removal included: refractive astigmatism (RA), spectacle best-corrected visual acuity (BCVA) measured

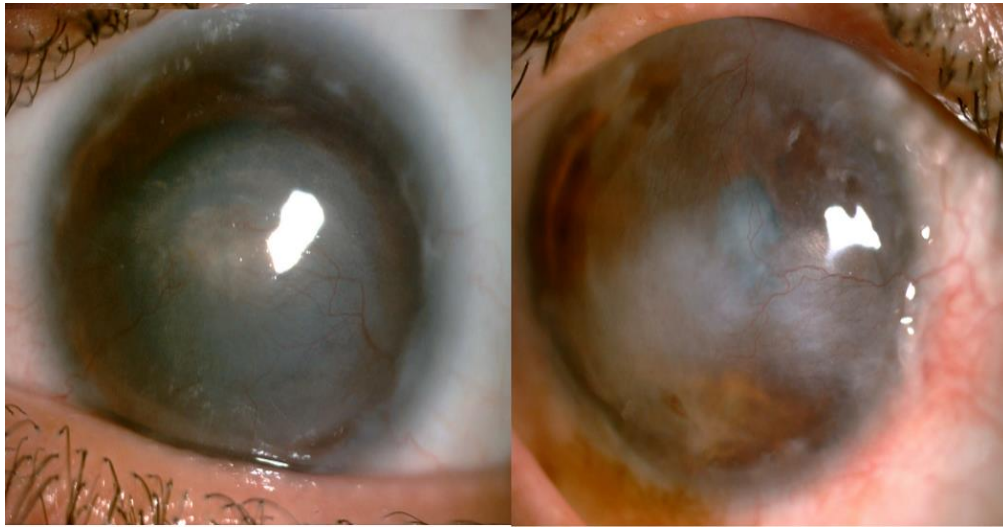
Postoperative medications included topical Moxifloxacin hydrochloride ophthalmic solution 0.5 % (Vigamox®, Alcon Inc., Fort Worth, TX, USA) five times daily for ten days, Topical Prednisolone acetate 1% eye drops (Pred-Forte®, Allergan Inc., Irvine, CA, USA) hourly then gradually decreased in the follow up to reach once daily, cyclopentolate (Plegica®, EPCI., Cairo, Egypt) three times daily for 3 days.

using Landolt's broken ring chart, keratometric astigmatism (KA) and average keratometric reading (average K) were evaluated using autorefracto-keratometer Accuref K 900 (Shin-Nippon, Osaka, Japan). All data collected in the study were entered into an electronic database via Microsoft Excel 2007 (Microsoft Corp., Redmond, WA). Statistical analysis was performed using SPSS Statistics Version 16 (IBM, Armonk, New York, USA). Numerical variables were described as mean  $\pm$  standard deviation.

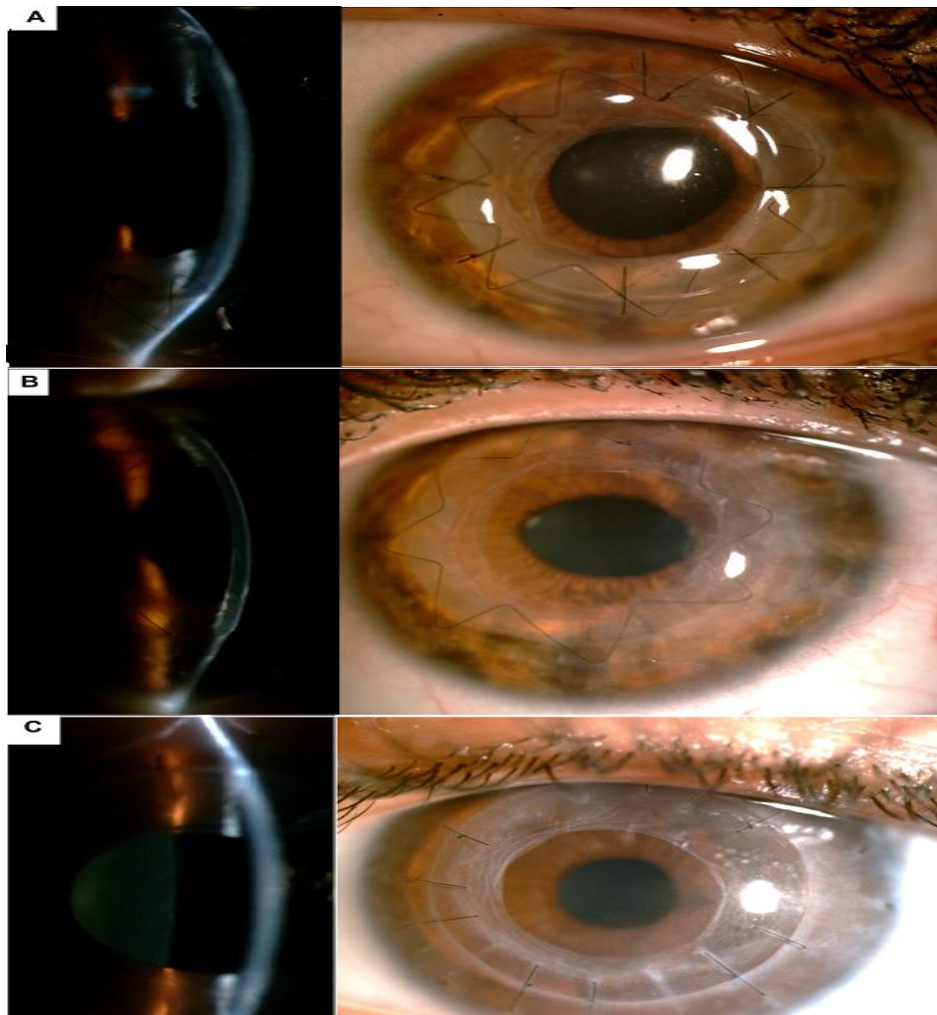
## **3. Results**

The mean age of patients was  $27.2 \pm 13.6$  years (range: 17- 51 years). The mean follow up period was  $7.8 \pm 2.1$  months (range: 6-11 months). Preoperative diagnosis was post-infection corneal scar in four patients (80%) and one patient had central corneal scar after acute hydrops in advanced keratoconus. One patient had cataract surgery and posterior chamber intraocular lens implantation with keratoplasty (Triple Endo-PK) and the remaining 4 cases had only Endo-PK, fig. (1). Immediate postoperative examination revealed excellent wound closure and coaptation of edges were achieved in all cases, figs. (2 & 3). Transient corneal edema occurred in all eyes; however, it improved within one month without intervention. Two eyes (40

%) had peripheral double anterior chamber; in one eye the peripheral recipient rim became attached after 2 months follow up. One month after the first partial selective suture removal, the mean BCVA (decimal) was  $0.46 \pm 0.17$  (range: 0.3–0.7). The mean refractive astigmatism was  $1.85 \pm 1.14$  diopters (range: 0-3 diopters). The mean keratometric astigmatism was  $2.1 \pm 1.15$  diopters (range: 0.5-3.5 diopters). The average keratometric reading (average K) was  $44.5 \pm 1.6$  diopters and ranged from 42 to 46 diopters. As regard late postoperative complications, the only complication was persistent peripheral double anterior chamber encountered in one eye (20%), the details of studied cases are listed in tab. (1)

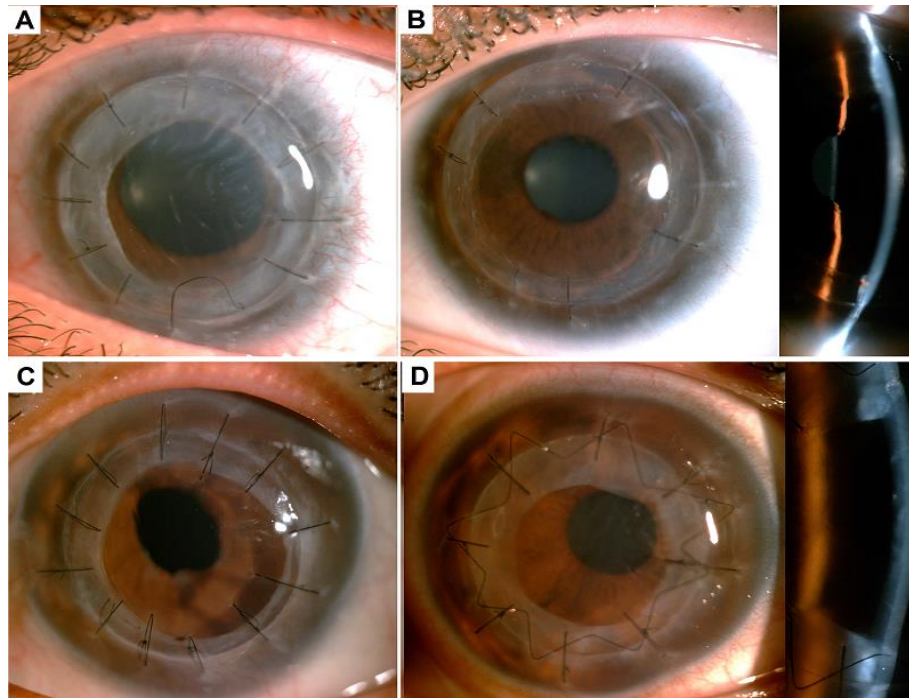


**Figure 1:** preoperative photos of case 1 and case 5 (right); note central full thickness vascularized opacity that is fainter peripheral with rim of clear cornea suggesting healthy peripheral endothelium; note dense cataract in case 5 (right).



**Figure 2:** Two eyes with peripheral double AC; **a.** Immediate postoperative slit and diffuse light photos of case 2 showing double anterior chamber (AC), **b.** six months postoperative slit and diffuse light photos of same case 2 showing disappearance of double AC, **c.** six months postoperative slit and diffuse light photos of case 3 showing persistent double AC.





**Figure 3:** **a.** early postoperative diffuse light photo of case 1 showing graft mild edema, **b.** 6 months postoperative slit and diffuse light photos of same case showing resolved edema, **c.** Early postoperative diffuse light photo of case 5, **d.** Early postoperative slit and diffuse light photos of case 4 showing mild graft edema with no double AC.

**Table (1):** details of the studied cases, age of patients, refractive and visual outcomes and surgical complications of studied cases.

Case	Age (years)	Preoperative diagnosis	KA (D)	RA (D)	DC (D)	BCVA (decimal)	Complications
1	20	Opacity after IK (CL wearer)	0.5	0	-2	0.7	Early mild edema
2	17	Opacity after IK (CL wearer)	1.5	1.75	-5	0.5	Early peripheral double AC + mild edema
3	22	Opacity after IK (CL wearer)	3.5	3	-1.5	0.3	Early mild edema + Persistent peripheral double AC
4	26	Opacity after hydrops	2.5	2.5	-3	0.5	Early mild edema
5	51	Opacity after IK + dense cataract (History of herpetic keratitis)	2.5	2	-1.5	0.3	Early mild edema

*AC: anterior chamber; BCVA: best corrected visual acuity; CL: contact lens; D: diopter; IK: infective keratitis; KA: keratometric astigmatism; RA: refractive astigmatism.*

#### 4. Discussion

Penetrating keratoplasty using grafts imported from the United States was reported to have five years endothelial cell loss reaching more than 60% [7]. There are many reports in the literature of unhealthy donor tissue escaping the screening processes of eye banks [8]. In such situation, retaining as many functional native endothelial cells as possible becomes a necessity. Endothelial migration from the recipient's peripheral rim could compensate for progressive donor endothelial cell loss, potentially prolonging graft survival [9]. Deep anterior lamellar keratoplasty (DALK) remains the preferred surgical approach

when corneal opacity is confined to the stroma and sparing the endothelium. This preference is attributed to superior graft survival, a significantly reduced risk of immunological rejection, and the avoidance of unnecessary endothelial replacement [10]. Performing a full-thickness PK for a stromal pathology can be considered an overtreatment, akin to amputating a functioning organ (the endothelium) and replacing it with a donor tissue of uncertain function and potential antigenic incompatibility [11]. However, when Descemet's membrane and endothelium are only partially compromised by corneal scarring, a

selective replacement strategy that retains healthy endothelial cells may serve as an intermediate solution between DALK and PK. Endothelial preserving penetrating keratoplasty (Endo-PK) is a novel hybrid surgical technique combining aspects of both penetrating keratoplasty (PK) and deep anterior lamellar keratoplasty (DALK) holding significant promise for the field of corneal transplantation. By preserving the peripheral rim of the recipient's endothelium while performing a central PK, this innovative approach offers a potential solution to the challenges associated with full-thickness corneal transplants. The selective nature of endothelial replacement in this method could be particularly beneficial in cases where the donor endothelium has suboptimal quality. As regard immunological rejection, the less antigenic load offered by minimal endothelial replacement is expected to reduce the risk of endothelial rejection that is a major concern in traditional PK, despite immunosuppressive therapy [12]. The partial endothelial preservation strategy offers a potential solution by decreasing the exposure of the immune system to foreign antigens while maintaining functional endothelial integrity. This is particularly relevant in patients with autoimmune disorders or vascularized corneal scars [12]. Furthermore, Retaining the peripheral posterior lamellae helps maintain the structural integrity of the corneal periphery, in opposition to conventional PK where the surface of contact between the graft and recipient is limited due to vertical wound (graft thickness), this leads to high risk of wound dehiscence and long time is required for the wound to acquire adequate strength before suture removal, also the possibility of poor opposition of internal graft-host junction is associated with high postoperative astigmatism [13]. It's to be noted that this technique could be used in full thickness corneal scars but is contraindicated in patients with corneal endothelial decompensation or bullous keratopathy where maximal endothelial replacement is indicated. The concept of minimal endothelial replacement has been

previously explored in mushroom keratoplasty (MK), which features a two-layer graft configuration, with a smaller, posterior lamella than anterior one [14]. MK has been reported to provide excellent graft survival and visual outcomes, offering improved stability, faster recovery, and reduced postoperative astigmatism compared to conventional PK [4]. However, MK is technically difficult to be performed manually, and usually relies on femtosecond laser or microkeratome, this poses a significant limitation as it increases the operative cost, making it less accessible in low-income regions where cost-effective alternatives are needed. In this study, the early visual and refractive outcomes of Endo-PK were satisfactory. None of the cases had major complications. The persistent peripheral double anterior chamber was the only concern encountered in one case. This problem is expected to be due to poor adherence of the peripheral graft endothelium to the peripheral rim of recipient posterior lamella. The equal pressure of the aqueous on both sides of preserved posterior lamella prevent its adherence. This problem had minimal effect on the results for several reasons. First, the presence of preserved endothelial cells is expected to be beneficial even floating in the anterior chamber, this is the concept of descemet's membrane endothelial cell transplantation surgery [15, 16]. Second, the adherence is expected to occur once needed i.e. when the endothelium of the graft starts to fail and the graft thickness increases this together with remodeling process in the peripheral rim reported as increased thickness of descemet's membrane in cases of persistent double AC. Third, this problem could be prevented by taking the sutures deeper in the recipient side to involve this preserved rim, this deep suture was reported to prevent double AC in cases of top-hat femto-assisted penetrating keratoplasty [17]. This study aim was to report the new technique of Endo-PK and its early clinical results. However, small number of cases and lack of comparison group limits the generalizability of results. Further clinical studies,

long-term follow-up with larger number of cases and specular microscope and anterior segment optical coherence tomographic evaluation are warranted to validate its efficacy, trace corneal remodeling changes and optimize surgical protocols. If

widely adopted, Endo-PK could offer a more refined and individualized approach to corneal transplantation, ultimately improving patient outcomes in complex corneal diseases.

## 5. Conclusion

*Endothelial preserving penetrating keratoplasty (Endo-PK) represents a promising step forward in optimizing corneal transplantation strategies and enhancing long-term outcomes for patients with full thickness corneal opacity and healthy peripheral endothelium.*

## Abbreviations

AC: anterior chamber

DM: descmet's membrane

DALK: deep anterior lamellar keratoplasty

PK: penetrating keratoplasty.

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