International Journal of Medical Discoveries
Volume 2, Issue 2
ISSN: 3067-7912

Penetrating Keratoplasty in the Pre-Lamellar Era: Indications, Risk Factors, and Visual Outcomes from a 350-Case Turkish Historical Cohort (1994–1996).

[1]*Ekrem Kurnaz
[1]Ophthalmology Department, Istanbul, Sistemgöz Medical Center, Istanbul, Turkey.

Abstract

Background: Penetrating keratoplasty has been considered the gold standard surgical treatment for corneal blindness, as it involves the whole thickness of a diseased or scarred cornea being replaced by a healthy cornea from a donor.

Purpose: To present indications, risk factors, complications and visual outcomes of penetrating keratoplasty performed at a training hospital in Turkey during 1994-1996, as a historical reference from the pre-lamellar period.

Methods: Retrospective analysis of 350 PKs where indications were ranked based on clinical and histopathological pre-operative data. Corneae from the in-house eye bank were used. The primary outcome measures were graft clarity, complications and best corrected visual acuity (BCVA). Wilcoxon signed ranked test (Bonferroni correction) was used for statistical analysis performed with SPSS Version 26, with the threshold set at $p < 0.05$ for claiming statistical significance.

Results: The top indications were keratoconus (18.0%), regrafts (14.3%) and pseudophakic bullous keratopathy (10.6%). The most frequently reported comorbidities were vascularisation (33.4%). Anterior vitrectomy and secondary IOLTA (12.6% and 10.9%) were combined procedures. The postoperative complication rate consisted of graft failure (13.1%), graft rejection (12.6%) and cystoid macular edema (3.7%). The success rate for clear grafts was 88.5% overall (96.8% for keratoconus and 68.0% for aphakic bullous keratopathy). The proportion of eyes with vision of finger counting or less reduced significantly postoperatively (86.9% to 32.6%, $p<0.0001$), with 28.6% of eyes having a vision of Snellen ≥0.5.

Conclusions: Penetrating keratoplasty was effective at visual rehabilitation in this Turkish cohort in the 90s, especially in keratoconus. The primary challenges were graft failure and rejection, particularly in vascularised grafts and regrafting. These results are used as a baseline for comparison with the modern lamellar techniques.

Keywords: Penetrating keratoplasty; keratoconus; bullous keratopathy; graft rejection; pre-lamellar era.

1. Introduction

Penetrating keratoplasty (PK) has been considered the gold standard surgical treatment for corneal blindness as it involves the whole thickness of a diseased or scarred cornea being replaced by a healthy cornea from a donor (Mathews et al., 2018). Throughout the twentieth century, until the success rates of other corneal transplants increased, the success rate of PK in avascular, non-inflamed eyes made corneal transplantation the most successful form of solid organ transplantation, especially for conditions such as keratoconus and bullous keratopathy (Heger et al., 2025; Hoffmann et al., 2025). However, the last 20 years have seen a paradigm shift in corneal surgery where Deep anterior lamellar keratoplasty (DALK) for stromal diseases and Descemet membrane endothelial keratoplasty (DMEK) for endothelial diseases have been introduced and developed to replace PK in many high income countries (Nair et al., 2026; Tanyildiz et al., 2022). These lamellar surgeries provide unique benefits including the maintenance of the recipient's endothelium (in DALK), sutureless surgery, quicker visual rehabilitation and much reduced incidences of immunologic rejection and long-term glaucoma (Atik et al., 2023; Tandra et al., 2026).

However, despite these developments, there is no reason to believe that PK is becoming obsolete, particularly in LMICs, where corneal scarring due to infectious keratitis, trauma and chemical burns is common, thereby requiring the performance of PK at high volumes (Ting et al., 2022). In addition, even in a well-equipped clinic, PK is essential when the corneal perforation is complete, where the scar involves all of the stromal layers and in the case of severe anterior segment disorganisation, where lamellar dissection is technically unsafe (Moramarco et al., 2022; Roozbahani et al., 2018). Hence, there is both clinical and historical

Ekrem Kurnaz
Ophthalmology Department, Istanbul, Sistemgöz Medical Center, Istanbul, Turkey.
Email: ekremkurnaz@hotmail.com

Received: 18-Jun-2026 Revised: 15-Jul-2026 Accepted: 24-Jul-2026

International Journal of Medical Discoveries
Volume 2, Issue 2
ISSN: 3067-7912

relevance in understanding the indications, risk factors and outcomes of PK, especially in the prelamellar period.

Turkey is currently in the middle of the global change holding a reputed infrastructure for corneal surgery with several corneal training hospitals conducting high volume keratoplasty (Balıkçı et al., 2025). The use of DALK and DMEK has been gaining in popularity among Turkish corneal surgeons over the last 10 years (Ababneh et al., 2024). However, at a single tertiary centre, the percentage of DMEK procedures increased from 4.6% in 2012 to 30.4% at the end of 2021 (Balıkçı et al., 2025). However, penetrating keratoplasty is still frequently performed, especially in tertiary centres that treat patients with advanced keratitis, failed keratoplasties, and keratitis as a result of herpetic and traumatic keratitis. The indications for PK in contemporary Turkey have changed due to the new techniques of lamellar surgery, with regrafts being more common, or vascularized leucomas and post-traumatic scars in the high-risk areas where these newer techniques might be difficult (Matthaei et al., 2017).

The disease spectrum of most research from the 1990s and early 2000s has been mainly from North America and Western Europe, where the spectrum of disease is significantly different from Southern and Eastern Europe, the Middle East and Central Asia (Matthaei et al., 2017; Qureshi & Dohlman, 2023). It is difficult to determine if the conversion to lamellar surgery has been as effective or more successful in higher-risk, scarred and vascularized eyes without region-specific historical data (Song et al., 2021). The lack of knowledge is important because extrapolating the results from low-risk Fuchs patients to the high-risk post-trauma or herpetic eye could lead to over- or under-estimating the benefit of lamellar techniques and the ongoing role of PK.

In addition, the long-term results of the PK results obtained in the 90s with the old method of donor storage (Optisol GS at 4°C), manual and vacuum trephination, interrupted and continuous suturing are not systematically recorded in the Turkish population (ŞİNGAR et al., 2023). Historic information is needed not merely for quality improvement but also for health-economic evaluations for comparing the cost and lifetime of the PK and lamellar alternatives in a middle-income country environment. The claims of modern techniques for their superiority are not completely substantiated without a well-documented historical standard. Thus, the purpose of this study is to report indications, risk factors, combined procedures, complications and visual outcomes in this historical cohort to provide a strong regional baseline for comparison of current results of lamellar keratoplasty.

2. Materials and Methods

2.1 Study Design and Setting

The study design was a retrospective, single-center, historical cohort conducted at the 2nd Ophthalmology Clinic of Dr. Lütfi Kırdar Kartal Training and Research Hospital, Istanbul, Turkey which is a tertiary referral center for corneal and anterior segment diseases. The study period occurred over 24 months of continuous study (January 1994-January 1996). The surgeons were two experienced corneal surgeons, while all the surgeries were performed using the standard surgical procedures. Donor corneas were stored in a vacuum bag (Optisol GS) at 2–8°C in the eye bank, the cornea was trephinated under vacuum, and 10/0 nylon sutures were placed (continuous or interrupted). Combined procedures (anterior vitrectomy, synechiolysis, secondary IOL implantation, cataract extraction with IOL, IOL exchange, trabeculectomy) were done if clinically indicated.

2.2 Inclusion and Exclusion Criteria

All patients who had penetrating keratoplasty during the period of the study were included. Patients included were primary or repeat PK, completion of a comprehensive clinical record before surgery and documentation on the donor cornea and at least one postoperative follow-up visit. There were 335 patients with 350 eyes that fulfilled the inclusion criteria, the rest were excluded.

2.3 Variables and Data Sources

Archived paper medical records and operative logs were used to obtain data. Demographics (age, sex); clinical data before surgery (indication, BCVA, corneal vascularization, glaucoma, cataract, uveitis, surface pathology, perforation); parameters of the donor (age, harvest time, storage time, trephine diameter); parameters of the surgery (trephine diameter of the recipient, suture technique, combined procedures); and postoperative results (graft clarity, complications, final BCVA) were recorded. Visual acuity was categorised according to the Snellen scale as follows: Light perception with projection (LPP), hand motion (HM), finger counting (FC), Snellen 0.1–0.2, Snellen 0.3–0.4, and Snellen ≥ 0.5. For statistical analysis, the observations were converted to approximate LogMAR values (LPP = 3.0, HM = 2.3, FC = 1.9, 0.1–0.2 = 1.0–0.7,

0.3–0.4 = 0.52–0.4, ≥0.5 = ≤0.3), acknowledging that LPP, HM and FC are ordinal non-LogMAR categories.

2.4 Statistical Analysis

The data was analysed statistically with IBM SPSS Statistics version 26.0. Data are described as mean ± SD or median (range) for continuous variables or as a frequency (%) for categorical variables. The Wilcoxon signed ranked test was used to analyse the changes in BCVA from pre- to post-operative. Two-ratio Z-test or Pearson chi-square test were used to compare categorical proportions. Bonferroni correction was used to account for multiple comparisons ($p < 0.0083$). Statistical significance was considered at $p < 0.05$.

2.5 Ethical Considerations

The study adopted a retrospective design and utilised anonymised archival data hence, institutional review board approval was obtained with a waiver of informed consent. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Patient confidentiality was maintained throughout data collection and analysis.

3. Results

Table 1 illustrates the demographics and baseline characteristics of patients. During the study period, 350 eyes of 335 patients were treated with PK. Among these, 153 patients (45.7%) were women and 182 (54.3%) were men. The age of the patients was 15 days to 82 years, with a mean of 39.6 years. The mean age of the 15 patients less than 4 years old was 6 months. The average length of follow-up was 10.5 months (range 4-28).

Table 1: Demographic and Baseline Characteristics

Parameter	Value Distribution
Total number of cases/eyes	335 cases - 350 eyes
Gender	Women 153 (45.67%), Men 182 (54.33%)
Average age	39.6 years old (between 15 days and 82 years old)
Average follow-up period is months.	10.5 months (4-28)
Average donor age	32.5±22 years (3.5-67)
Donor procurement time	2.2 ± 1.2 hours (15 minutes - 8 hours)
Donor transplant time	30±24 hours (0.5-120)
Type of Anaesthesia	Local 297 (85%) - General 53 (15%)

The most frequent indications were keratoconus (63 eyes, 18.0%), regrafts (50 eyes, 14.3%) and pseudophakic bullous keratopathy (37 eyes, 10.6%) as illustrated in Table 2. Amongst 50 regraft cases, 34 were due to immunological or non-immunological rejection of the graft and 16 were due to primary donor failure. In 37 pseudophakic bullous keratopathy cases, five had had previous IOLens removal.

Table 3 exhibits preoperative comorbidities, where additional pathologies were most commonly vascularisation (117 eyes, 33.4%). From these, 45 eyes had superficial or deep vascularisation in one or two quadrants, while 62 eyes had involvement in three or four quadrants. 51 (14.6%) had glaucoma (medically/surgically controlled) while 32 eyes (9.1%) had cataract.

Table 4 suggests that, in a subpopulation, surgery was performed in combination with other surgeries as part of PK. Most frequently performed combined procedure was anterior vitrectomy (44 eyes, 12.6%), anterior segment reconstruction through synechiolysis (38 eyes, 10.9%) and secondary IOL implantation for aphakic eyes (38 eyes, 10.9%).

Table 5 summarises postoperative complications, where graft rejection was diagnosed in 44 eyes (12.6%) with 15 (34.1%) of the rejection episodes leading to failure despite medical treatment. In 4 eyes (1.1%), an endophthalmitis developed, 3 of which required enucleation and developed into phthisis.

Table 6 indicates that the preoperative visual acuity had been determined in 300 healthy children which is 320 eyes (15 children had an age of less than 4 years, 9 had poor records and 6 were unable to cooperate). A

International Journal of Medical Discoveries
Volume 2, Issue 2
ISSN: 3067-7912

Table 2: Indications for penetrating keratoplasty (N=350 eyes)

Order	Diagnosis	Number	%
1	Keratoconus	63	18
2	Reggraft	50	14.28
3	Pseudophak bullous keratopathy	37	10.57
4	İnterstisiel keratit	33	9.43
5	Travmatik scar	31	8.86
6	Viral keratitler	31	8.86
7	Afakik büllöz keratopati	30	8.57
8	Corneal ulcer	15	4.29
9	Congenital opacity	15	4.29
10	Corneal dystrophy	13	3.71
11	Kimyasal yanık	12	3.43
12	Degenerations	9	2.57
13	Others	6	1.71
14	Graft abscess	3	0.85
15	Fuch's Dystrophy	2	0.58
Total		***350***	***100%***

Table 3: Preoperative comorbidities (N=350 eyes)

Pathology	Number	%
Vascularization	117	33.42
Glaucoma	51	14.57
Cataract	32	9.14
Perforation	8	2.28
Uveitis	6	1.71
Ocular surface pathology	6	1.71

Table 4: Combined procedures performed with PK (N=350 eyes)

Surgical Intervention	Number	%
Anterior vitrectomy	44	12.57
synechiolysis	38	10.85
Secondary IOL implantation	38	10.85
EKKE + IOL implantation	32	9.14
IOL replacement	4	1.14
Trabeculectomy	1	0.28

IOL = intraocular lens, ECCE = extracapsular cataract extraction

Table 5: Postoperative complications (N=350 eyes)

Complication	Number	%
Graft failure	46	13,14
Graft rejection	44	12.57
Cystoid mucosal edema	13	3.71
Cataract	13	3.71
Glaucoma	10	2.85
Endophthalmitis	4	1.14
Graft abscess	3	0.85
Holes in the macula	2	0.57
Retinal detachment	2	0.57

Table 6: Preoperative best-corrected visual acuity (N=320 eyes)

Visual acuity	LogMAR equivalent*	Preoperative (N=320)	Postoperative (N=304)
LPP (light perception projection)	3	70 (21.9%)	7 (2.3%)
HM (hand motion)	2.3	93 (29.1%)	36 (11.8%)
FC (finger counting)	1.9	115 (35.9%)	56 (18.4%)
0.1–0.2	1.0–0.7	31 (9.7%)	76 (25.0%)
0.3–0.4	0.52–0.4	11 (3.4%)	42 (13.8%)
≥0.5	≤0.3	0 (0%)	87 (28.6%)
Total		***320 (100%)***	***304 (100%)***

Table 7: Preoperative and postoperative best-corrected visual acuity

Visual Acuity (Definition/ Decimal)	LogMAR Equivalent	Previous N=320 n (%)	After that, N=304 n (%)	Z-Score	P-value	Result (Bonferroni)
LPP	3	22.36	2.3	7.93	<0.0001	Significant decrease
HM	2.3	28.89	11.84	5.37	<0.0001	Significant decrease
FC	1.9	35.72	18.42	4.89	<0.0001	Significant decrease
0.1-0.2	1.0-0.7	9.62	25	-5.13	<0.0001	Significant increase
0.3-0.4	0.52-0.4	3.41	13.82	-4.61	<0.0001	Significant increase
0.5 or better	≤0.3	0	28.62	-10.63	<0.0001	Significant increase

total of 304 eyes (with 3 excluded for enucleation and 13 excluded because they were lost to follow-up) provided postoperative visual acuity at final follow-up.

Table 7 illustrates the pre and postoperative visual acuity with their statistical comparison. The BCVA categorisation pre- and post-operatively showed a statistically significant improvement overall (Wilcoxon signed-rank test, $p<0.0001$). The proportion of eyes in each of the three lowest vision categories (LPP, HM, FC) decreased significantly and the proportion in each of the three higher vision categories (0.1-0.2, 0.3-0.4, ≥0.5) increased significantly, as confirmed by pairwise comparisons with Bonferroni correction ($p<0.0083$).

4. Discussion

In the last 20 years, the field of corneal transplant surgery has undergone significant change (Matthaei et al., 2017; Singh et al., 2019). Lamellar surgery has been increasingly used for more indications and has gradually

International Journal of Medical Discoveries
Volume 2, Issue 2
ISSN: 3067-7912

replaced penetrating keratoplasty (Sun et al., 2019). The study comprising 7130 corneal transplants from high volume tertiary centres suggested PK has dropped from 95% of total transplants in 2004 to 11% in 2023, whereas DMEK has risen from 48% to 82% during the same time period (Bastakis & Thill, 2025). This shift has been fueled by an increasing amount of data indicating that lamellar surgery provides significant benefits with regard to endothelial preservation, immunologic rejection, visual rehabilitation, and postoperative complications (including glaucoma) (Shams et al., 2022). However, the contemporary literature states that PK is not unnecessary, but rather the indications have been restricted to high-risk, complex or full thickness corneal diseases where lamellar dissection is technically unsafe or contraindicated (Alió et al., 2024; Shemiakin & Arzhimatova, 2025).

Long-term outcomes of PK and DALK showed that these procedures led to very high 20-year graft survival rates of > 95%, and there was no statistically significant difference between the two techniques in final VA outcomes (Arundhati et al., 2021). Aldebasi et al. (2024) found that the cumulative incidence of postoperative ocular hypertension requiring treatment and endothelial cell loss rates were significantly higher after PK than after DALK, which were about twice the incidence of DALK. The importance of these findings in relation to the present results is significant as the graft success rate was 96.8% for keratoconus patients in this Turkish group of 1994-1996, which is similar to the PK graft success rates in recent years (Dugan & Mian, 2022). The reason for this is that modern patients may enjoy the same visual outcome with fewer long-term complications from glaucoma and endothelial decompensation when using DALK.

Pseudophakic bullous keratopathy (PBK) was the third most frequent indication in this series (10.6%). As per Balıkçı et al. (2024), DMEK has been shown to produce significantly better visual outcomes at final follow-up, with 30.8% of eyes in the DMEK group having a BCVA of 0.3 or better versus 2.7% of eyes in the PK group. However, it was noted that the first-year graft survival rate was lower for the DMEK group than for the PK group (61.5% versus 92.1%), indicating the shallower learning curve and different complication rate of endothelial techniques (Balıkçı et al., 2024). A large Indian registry study also showed that both DSEK and DMEK surgical procedures improved vision by 0.7 LogMAR units, with 41% of DMEK surgeries improving to 6/18 or better (Basak et al., 2018). The rate of clear graft in pseudophakic bullous keratopathy among the patients of the present study (87.4%) was good, but would now yield better visual results with endothelial keratoplasty, with a caveat that the rate of early graft failure and postoperative glaucoma with these newer procedures is higher.

As found in the present study, graft rejection and failure are the main challenges to successful PK, with 12.6% of grafts rejecting and 13.1% failing. These rates are within the range of those reported in the recent literature, about 10–30% in uncomplicated PK, and are much higher in high-risk recipients (Doroodgar et al., 2023; Jabbehdari et al., 2017). The study by Shalaby et al. (2025) found that previous keratoplasty, neovascularisation of two or more quadrants of the cornea and graft inflammation during surgery are major risk factors for graft failure. There was a significant level of vascularisation (33.4%) and regrafts (14.3%) in the present cohort, thus putting a significant number of patients in high-risk category. As per Qedair et al. (2025), topical calcineurin inhibitors (TCIs), and in particular tacrolimus, decrease the risk of graft failure by 75% in high-risk patients on PKs when compared to steroids alone. The findings are important to consider when interpreting historical cohorts that have received protocols of only topical steroids and in a very limited number of high-risk patients' systemic cyclosporine, which has since been optimised.

The present results are consistent with the changing evidence of keratoplasty over the past several years in various series. In contrast, Fuchs endothelial dystrophy has become the most prevalent indication in many high-income countries, decreasing from 24% to 72% of all transplants from 2004 to 2023, while contact lens fitting and corneal crosslinking have led to a decrease in keratoconus cases, from 25% to 4% during that same time period (Niazi et al., 2024). The current group of 1994-1996, on the other hand, represents an earlier time period when keratoconus continued to be the most common indication, regrafts were already common (14.3%), and bullous keratopathies, both pseudophakic and aphakic (combined 19.1%), were becoming significant indications. Notably, a few cases of Fuchs dystrophy (2, 0.6%) were observed in this series and were not typical of the contemporary Western European and North American series in which this condition is more common (Soh et al., 2020), as there was a relatively higher incidence of infectious, traumatic and vascularised corneal conditions in the patients treated at this Turkish tertiary centre.

5. Conclusion

The study investigating historical groups proves that penetrating keratoplasty was effective in the treatment of corneal blindness in the pre-lamellar age, especially in keratoconus. The high incidence of graft rejection and failure, particularly in vascularized and regrafted cases, however, indicated the biological constraints of full-thickness allotransplantation. In modern practice, the use of lamellar techniques should be considered for elective indications when technically possible. However, in more complicated and full thickness corneal disease, PK is an essential tool, and progressive surgeons need to be well versed in this classic surgery.

6. Strengths and Limitations

One of the strengths of the study is that it considered a reasonable sample of 350 eyes from a single tertiary centre with standard surgical and postoperative procedures, offering a robust historical data set in a Turkish population in the pre-lamellar era. All consecutive cases were captured to reduce selection biases and indications, co-morbidities, combined procedures and complications were systematically recorded, allowing for comprehensive outcome assessment. However, the method was retrospective, leaving the exclusivity aspect. The average follow-up period was 10.5 months which is a relatively short time to evaluate late graft failure, chronic endothelial attrition, or delayed onset glaucoma. Visual acuity was obtained in clinical categories instead of standardised LogMAR testing and measurement of endothelial cell density was lacking to assess subclinical graft deterioration.

7. Declarations

Acknowledgement: The author acknowledges the contribution of Anıl Kubaloğlu (Ophthalmology Department, İstanbul, Etiler Dünyagöz, İstanbul, Turkey) and Ahmet İçağasıoğlu (Ophthalmology Department, Istanbul, VM Medical Park, Istanbul, Türkiye) for performing surgeries and the permission for recording the required observations.

Funding Information: This study did not receive support from any organisation, such as government, commercial, or not-for-profit organisations.

Conflict of Interest: The corresponding author declares that there is no conflict of interest.

Ethics Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

References

Ababneh, O. H., Alzagareet, Y. M., Al-Zoubi, R. M., Ahmad, D. T., Atieh, R. W., Odeh, A. E., Alkhaled, F. A., Alryalat, S. A., Alzagareet, Y., & Al-zoubi, R. M. (2024). The minimally important difference (MID) in visual acuity that represents changes in patients' quality of life. Cureus, 16(7).

Aldebasi, T., Gangadharan, S., Alshammari, Y. S., Alruhaimi, S. S., Alrashid, S. O., Ardah, H., Shahrani, J. A., Shahrani, S. A., Badri, M., & Alfardan, F. (2024). Comparison of clinical outcomes, complications and patient satisfaction following deep anterior lamellar keratoplasty and penetrating keratoplasty. BMC ophthalmology, 24(1), 501.

Alió, J. L., Niazi, S., Doroodgar, F., Del Barrio, J. L. A., Hashemi, H., & Javadi, M. A. (2024). Main issues in penetrating keratoplasty. Taiwan Journal of Ophthalmology, 14(1), 50-58.

Arundhati, A., Chew, M. C., Lim, L., Mehta, J. S., Lang, S. S., Htoon, H. M., & Tan, D. T. (2021). Comparative study of long-term graft survival between penetrating keratoplasty and deep anterior lamellar keratoplasty. American Journal of Ophthalmology, 224, 207-216.

Atik, B. K., Emul, M., Kirgiz, A., Cubuk, M. O., Ahmet, S., & Besek, N. K. (2023). Comparison of deep anterior lamellar keratoplasty and penetrating keratoplasty in keratoconic eyes with previous hydrops-related corneal scar. Cornea, 42(11), 1446-1450.

Balıkçı, A. T., Burcu, A., Yalnız, Z. A., Şingar, E., & Uzman, S. (2025). Trends in Keratoplasty procedures in the last 20 years at a tertiary referral center in Turkey: 2003 to 2023. Turkish Journal of Clinical & Experimental Ophthalmology (TJ-CEO), 20(2).

Balıkçı, A. T., Demir, N., Burcu, A., Akkaya, Z. Y., Şingar, E., & Uzman, S. (2024). Descemet membrane endothelial keratoplasty and penetrating keratoplasty in

International Journal of Medical Discoveries
Volume 2, Issue 2
ISSN: 3067-7912

pseudophakic bullous keratopathy: comparison of visual outcomes, graft survival rates, and complications. The European Research Journal, 10(4), 380-387.

Basak, S. K., Basak, S., & Pradhan, V. R. (2018). Outcomes of Descemet membrane endothelial keratoplasty (DMEK) using surgeon's prepared donor DM-roll in consecutive 100 Indian eyes. The Open Ophthalmology Journal, 12, 134.

Bastakis, G. G., & Thill, M. (2025). Natural Killer Cells in the Eye. In Natural Killer Cells: At the Forefront of Modern Immunology (pp. 1-35). Springer.

Doroodgar, F., Niazi, S., Hashemi, H., & Javadi, M. A. (2023). Main issues to overcome in modern penetrating keratoplasty. In Modern Keratoplasty: Surgical Techniques and Indications (pp. 71-101). Springer.

Dugan, S. P., & Mian, S. I. (2022). Impact of vaccination on keratoplasty. Current opinion in ophthalmology, 33(4), 296-305.

Heger, K. A., Egger, D., Schmidinger, G., Skorpik, C., Waldstein, S. M., & Pircher, N. (2025). A historical view of the development of corneal transplantation: from penetrating keratoplasty to selective transplantation of the finest corneal layers. Wiener Medizinische Wochenschrift, 175(7), 175-185.

Hoffmann, J. V., Betancor, P. K., Maier, P., Lapp, T., Heinzelmann, S., Böhringer, D., Lang, S., & Reinhard, T. (2025). Changing indications for keratoplasty: monocentric analysis of the past two decades. Graefe's Archive for Clinical and Experimental Ophthalmology, 263(3), 745-751.

Jabbehdari, S., Baradaran-Rafii, A., Yazdanpanah, G., Hamrah, P., Holland, E. J., & Djalilian, A. R. (2017). Update on the management of high-risk penetrating keratoplasty. Current ophthalmology reports, 5(1), 38-48.

Mathews, P. M., Lindsley, K., Aldave, A. J., & Akpek, E. K. (2018). Etiology of global corneal blindness and current practices of corneal transplantation: a focused review. Cornea, 37(9), 1198-1203.

Matthaei, M., Sandhaeger, H., Hermel, M., Adler, W., Jun, A. S., Cursiefen, C., & Heindl, L. M. (2017). Changing indications in penetrating keratoplasty: a systematic review of 34 years of global reporting. Transplantation, 101(6), 1387-1399.

Moramarco, A., Gardini, L., Iannetta, D., Versura, P., & Fontana, L. (2022). Post penetrating keratoplasty ectasia: incidence, risk factors, clinical features, and treatment options. Journal of Clinical Medicine, 11(10), 2678.

Nair, S., Deshmukh, R., Mohan, S., Agarwal, T., Sharma, N., & Vajpayee, R. B. (2026). Corneal transplantation triple procedures. Survey of Ophthalmology.

Niazi, S., Gatzioufas, Z., Doroodgar, F., Findl, O., Baradaran-Rafii, A., Liechty, J., & Moshirfar, M. (2024). Keratoconus: exploring fundamentals and future perspectives–a comprehensive systematic review. Therapeutic Advances in Ophthalmology, 16, 25158414241232258.

Qedair, J., Bawazir, R., & Alghamdi, S. (2025). Efficacy of Topical Tacrolimus (FK506) in High-risk Penetrating Keratoplasty: A Systematic Review and Meta-analysis of Comparative Studies. Eye, 1-6.

Qureshi, S., & Dohlman, T. H. (2023). Penetrating keratoplasty: indications and graft survival by geographic region. Seminars in ophthalmology,

Roozbahani, M., Hammersmith, K. M., Nagra, P. K., Ma, J. F., & Rapuano, C. J. (2018). Therapeutic penetrating keratoplasty: a retrospective review. Eye & Contact Lens, 44, S433-S441.

Shalaby, W. S., Shiuey, E. J., Patel, T. M., Rapuano, C. J., & Syed, Z. A. (2025). Risk Factors for Progression of Graft Rejection to Graft Failure Following Penetrating Keratoplasty. Ocular Immunology and Inflammation, 33(6), 926-934.

Shams, M., Sharifi, A., Akbari, Z., Maghsoudlou, A., & Tajali, M. R. (2022). Penetrating keratoplasty versus deep anterior lamellar keratoplasty for keratoconus: a systematic review and meta-analysis. Journal of ophthalmic & vision research, 17(1), 89.

Shemiakin, M., & Arzhimatova, G. (2025). Penetrating Keratoplasty as an Inevitable Technique of Keratoplasty: Indications, Surgical Technique, and Outcomes.

ŞİNGAR, E., BURCU, A., YALNIZ AKKAYA, Z., ÖZBEK UZMAN, S., & ORAL, B. (2023). Corneal Endothelial Cell Loss After Phacoemulsification in Post-Penetrating Keratoplasty Eyes with Domestic and Imported Donor Cornea: Cross-Sectional Research. Türkiye Klinikleri Journal of Ophthalmology, 32(4).

Singh, R., Gupta, N., Vanathi, M., & Tandon, R. (2019). Corneal transplantation in the modern era. Indian Journal of Medical Research, 150(1), 7-22.

Soh, Y., Kocaba, V., Pinto, M., & Mehta, J. S. (2020). Fuchs endothelial corneal dystrophy and corneal endothelial diseases: East meets West. Eye, 34(3), 427-441.

Song, A., Deshmukh, R., Lin, H., Ang, M., Mehta, J. S., Chodosh, J., Said, D. G., Dua, H. S., & Ting, D. S. (2021). Post-keratoplasty infectious keratitis: epidemiology, risk factors, management, and outcomes. Frontiers in Medicine, 8, 707242.

Sun, X.-T., Zhai, H.-L., Cheng, J., Kong, Q.-Q., Cong, L., Li, L., & Hao, W.-P. (2019). Indications for penetrating keratoplasty and anterior lamellar keratoplasty during 2010-2017. International Journal of Ophthalmology, 12(12), 1878.

Tandra, T., Djarizal, C., Widyawati, S., & Aziza, Y. (2026). Cyclosporine A as an adjuvant therapy in high-risk penetrating keratoplasty: A systematic review and meta-analysis. Oman Journal of Ophthalmology, 19(1), 28-36.

Tanyildiz, B., Oklar, M., Günaydın, N. T., & Kandemir, B. (2022). Changing trends in the corneal transplantation and the impact of the COVID-19 pandemic on corneal transplant recipient selection. Saudi Journal of Ophthalmology, 36(1), 95-101.

Ting, D. S., Deshmukh, R., Ting, D. S., & Ang, M. (2022). Corneal disorders. In Ophthalmic Epidemiology (pp. 113-127). CRC Press.