

# Comparative graft survival and visual outcomes of penetrating keratoplasty versus lamellar keratoplasty: A retrospective cohort study

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## Research Article

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# Abstract

## BACKGROUND

Corneal transplantation remains a highly effective intervention for treating irreversible corneal disorders. While penetrating keratoplasty (PKP) has long been considered the standard technique, lamellar keratoplasty (LKP) has gained increasing attention due to its potential advantages in graft survival and visual outcomes. The study compared graft failure, visual outcomes, intraocular pressure, and postoperative complications following PKP and LKP.

## METHODS

A retrospective cohort study that included 255 eyes who underwent PKP or LKP between 2016 and 2023 at a tertiary care center. Descriptive and comparative analyses were performed between the groups. Graft failure was defined as irreversible graft opacity requiring re-transplantation or resulting in visual acuity worse than 20/100. Outcomes were compared overall, with multivariable logistic regression used for adjustment.

## RESULTS

Of the 255 eyes, 153 (60.0%) underwent PKP, and 102 (40.0%) underwent LKP. Graft failure was more frequent following PKP than LKP in the unadjusted analysis (20.3% vs. 2.9%;  $p < 0.001$ ). However, no difference was observed in the ectasia-restricted subgroup (1.8% vs. 2.1%;  $p = 1.000$ ). Surgical technique was not independently associated with graft failure after adjustment (adjusted odds ratio 1.48, 95% CI 0.38–5.79;  $p = 0.577$ ). On the last visit, BCVA better than 20/40 was more frequent following LKP than PKP (72.2% vs. 44.3%;  $p = 0.002$ ). Postoperative intraocular pressure increased more following LKP (+4.0 vs. +1.0 mmHg;  $p = 0.003$ ).

## CONCLUSION

Lamellar keratoplasty was associated with lower unadjusted graft failure and better outcomes compared with penetrating keratoplasty. However, the difference in graft failure was attenuated after accounting for surgical indication and case mix.

## Background

Corneal blindness is one of the significant causes of visual impairment worldwide accounting for a significant proportion of preventable and treatable vision loss [1]. When the pathology of the cornea leads to irreversible stromal or endothelial damage, keratoplasty becomes the definitive treatment to restore corneal transparency and vision [2]. Over the past few decades, the techniques of corneal

transplantation have evolved considerably, shifting from traditional full-thickness procedures towards more selective, layer-specific approaches that aim to improve outcomes and reduce complications [3].

Penetrating keratoplasty (PKP) is a full-thickness corneal transplant that has been considered the standard surgical approach for the management of a wide range of corneal disorders for a long time. These disorders include advanced corneal ectasia, scarring of the cornea, corneal dystrophies, and infectious pathologies of the cornea [4]. Though the surgical procedure is considered effective, it has several limitations including higher risks of graft rejection, astigmatism after the procedure, prolonged visual rehabilitation, and sight-threatening complications such as dehiscence of the wound and endophthalmitis [5]. It is these concerns that have driven the development and increasing adoption of lamellar keratoplasty techniques for corneal transplantation.

Lamellar keratoplasty (LKP) involves partial replacement of the corneal tissue with selective replacement of the diseased corneal layers along with preservation of healthy host tissue. Techniques like deep anterior lamellar keratoplasty and endothelial keratoplasty, such as Descemet's Stripping Automated Endothelial Keratoplasty (DSAEK) and Descemet's Membrane Endothelial Keratoplasty (DMEK), have gained popularity because of several advantages [6]. These advantages include reduced immunologic rejection, improved survival of the graft, faster recovery of vision, and better structural integrity of the globe [7]. However, lamellar procedures are technically more demanding and may be associated with unique intraoperative challenges with variable visual outcomes depending on surgical expertise and patient selection.

Numerous studies have reported outcomes of penetrating and lamellar keratoplasty individually but direct comparisons between the two techniques remain limited and sometimes conflicting [8]. The differences in the rate of graft survival, postoperative visual acuity, complication profiles, and long-term outcomes are still debatable, particularly across diverse populations of patients and their indications. Furthermore, most of the available data originates from heterogeneous clinical settings, which makes it very difficult to generalize findings to specific healthcare systems or institutional practices [9].

In Saudi Arabia, the services of corneal transplantations have expanded significantly with the establishment of dedicated eye banks and tertiary referral centers. However, the local data for the comparison of graft survival and visual outcomes between PKP and LKP remain scarce. Understanding of these outcomes can provide valuable insights into real-world surgical performance, inform clinical decision-making, and guide future practice patterns. Therefore, this study aimed to compare graft survival, visual outcomes, intraocular pressure, and postoperative complications between penetrating and lamellar keratoplasty.

## Methods

### Patients

This is a retrospective cohort study conducted at King Abdulaziz Medical City of Riyadh, Saudi Arabia, a tertiary care military hospital with a designated eye bank. All the medical records of patients who underwent corneal transplantation between January 2016 and March 2023 were reviewed. All the data was obtained from the National Guard Health Affairs BestCare electronic medical record system, hospital charts, and eye bank records. The study included all patients who underwent penetrating keratoplasty or lamellar keratoplasty during the period of study. All the patients were excluded if follow-up duration was less than three months, with incomplete or missing perioperative data, or if keratoplasty was performed for the tectonic support or eyes with poor preoperative visual potential. The study was approved by the Institutional Review Board of King Abdulaziz Medical City, Riyadh, KSA, and was performed in compliance with the principles of the Declaration of Helsinki.

### **Surgical techniques**

The surgical procedures included penetrating keratoplasty (PKP) and lamellar keratoplasty (LKP).

### **Data collection**

The patients' electronic medical records and eye- bank records were reviewed. The collected variables included age, sex, surgical indications, primary graft, regrant status, lens status, history of glaucoma, corneal vascularization, graft size, follow- up duration, Intraocular pressure (IOP), best-corrected visual acuity (BCVA), postoperative complications, and graft failure. BCVA was assessed preoperatively and at 1,3, and 12 months postoperatively and at the last follow-up visit.

Graft failure was defined as irreversible graft opacity requiring re-transplantation or resulting in BCVA worse than 20/100 despite optimal management. Visual outcomes were categorized as BCVA better than 20/40, between 20/40 and 20/100, or worse than 20/100.

### **Statistical analysis**

Descriptive statistics included means with standard deviations for normally distributed continuous variables, medians with interquartile ranges for non-normally distributed variables, and frequencies with percentages for categorical variables. Normality was assessed using the Shapiro-Wilk test and visual inspection of histograms. Comparative analyses between PKP and LKP groups were performed using independent samples t-test or Mann-Whitney u test for continuous variables, as appropriate. Categorical variables were compared using chi-square or Fisher's exact tests.

Graft-failure proportions were compared in all cohort and in an ectasia-restricted subgroup, with risk ratios and 95% confidence intervals reported. Multivariable logistic regression was used to evaluate factors associated with graft failure, postoperative complications, and final BCVA better than 20/40. Adjusted odds ratio with 95% confidence intervals were reported. All tests were two-sided, and a p-value <0.05 was considered statistically significant. All analyses were performed using IBM SPSS Statistics (version 26; SPSS Inc, Chicago, IL).

# RESULTS

## Baseline characteristics

Our study included 255 eyes, with 153 (60.0%) undergoing PKP and 102 (40.0%) undergoing LKP. The median age was similar between the groups (34.0 [23.0–67.0] vs. 30.0 [24.0–37.0] years;  $p=0.062$ ). Adults were the majority in both groups, while pediatric patients were more common in the PKP group (13.7% vs. 3.9%;  $p=0.018$ ). Gender and laterality were comparable between groups ( $p=0.390$  and  $p=0.916$ , respectively). Surgical indications differed significantly ( $p<0.001$ ). Corneal ectasia was the most common indication for LKP (94 [92.2%]) compared with PKP (57 [37.3%]), whereas corneal scarring and edema were more frequent in PKP. Regrafting was also more common in PKP (21 [13.7%] vs. 1 [1.0%];  $p<0.001$ ). Lens status differed significantly between groups ( $p<0.001$ ), while glaucoma history was similar ( $p=0.270$ ) (Table 1).

*Table 1. Baseline characteristics of eyes undergoing penetrating keratoplasty versus lamellar keratoplasty*

|                                         |                              | <b>PKP<br/>(N=153)</b> | <b>LKP (N=102)</b>   | <b>Sig.<br/>Value</b> |
|-----------------------------------------|------------------------------|------------------------|----------------------|-----------------------|
| <b>Age (Years)</b>                      | Median (IQR)                 | 34.0 [23.0;<br>67.0]   | 30.0 [24.0;<br>37.0] | 0.062 <sup>c</sup>    |
| <b>Age Category<br/>(N=255)</b>         | Adult                        | 132 (86.3%)            | 98 (96.1%)           | 0.018 <sup>b</sup>    |
|                                         | Pediatric                    | 21 (13.7%)             | 4 (3.9%)             |                       |
| <b>Gender (N=255)</b>                   | Female                       | 58 (37.9%)             | 45 (44.1%)           | 0.390 <sup>a</sup>    |
|                                         | Male                         | 95 (62.1%)             | 57 (55.9%)           |                       |
| <b>Laterality (N=254)</b>               | Left                         | 78 (51.0%)             | 53 (52.0%)           | 0.916 <sup>a</sup>    |
|                                         | Right                        | 75 (49.0%)             | 48 (47.1%)           |                       |
| <b>Surgery indication<br/>(N=255)</b>   | Congenital opacity           | 14 (9.2%)              | 0 (0.0%)             | <0.001 <sup>b</sup>   |
|                                         | Corneal dystrophy            | 9 (5.9%)               | 1 (1.0%)             |                       |
|                                         | Corneal ectasia              | 57 (37.3%)             | 94 (92.2%)           |                       |
|                                         | Corneal edema/decompensation | 24 (15.7%)             | 0 (0.0%)             |                       |
|                                         | Corneal scarring             | 34 (22.2%)             | 6 (5.9%)             |                       |
|                                         | Infectious keratitis         | 1 (0.7%)               | 0 (0.0%)             |                       |
|                                         | Perforation/melting          | 5 (3.3%)               | 0 (0.0%)             |                       |
|                                         | Regrafting (failure)         | 9 (5.9%)               | 0 (0.0%)             |                       |
| <b>Primary vs. Re graft<br/>(N=253)</b> | Primary                      | 130 (85.0%)            | 101 (99.0%)          | <0.001 <sup>b</sup>   |
|                                         | Re graft                     | 21 (13.7%)             | 1 (1.0%)             |                       |
| <b>Glaucoma history<br/>(N=253)</b>     | No                           | 130 (85.0%)            | 81 (79.4%)           | 0.270 <sup>a</sup>    |
|                                         | Yes                          | 22 (14.4%)             | 21 (20.6%)           |                       |
| <b>Lens status (N=254)</b>              | Aphakic                      | 7 (4.6%)               | 2 (2.0%)             | <0.001 <sup>b</sup>   |
|                                         | Phakic                       | 101 (66.0%)            | 99 (97.1%)           |                       |
|                                         | Pseudophakic                 | 44 (28.8%)             | 1 (1.0%)             |                       |
| <b>Follow-up (Months)</b>               | Median (IQR)                 | 37.0 [26.0;<br>69.0]   | 33.0 [25.0;<br>51.0] | 0.049 <sup>c</sup>    |

Abbreviations: PKP, penetrating keratoplasty; LKP, lamellar keratoplasty; IQR, interquartile range; N, number of patients with available data Note: (a) Chi-Square Test, (b) Fisher's Exact Test, (c) Mann Whitney Test

## Graft characteristics and postoperative complications

Table 2 shows that graft and host trephine sizes were significantly larger in the LKP group than in the PKP group. The median graft size was 8.0 [7.8–8.2] mm in LKP compared with 7.8 [7.5–8.0] mm in PKP ( $p<0.001$ ), while the median host trephine size was 7.8 [7.5–8.0] mm versus 7.5 [7.0–7.8] mm, respectively ( $p<0.001$ ). Vascularization also differed significantly between groups ( $p<0.001$ ), with absent vascularization more common in LKP (90 [88.2%]) than PKP (100 [65.4%]). Overall complications were more frequent in PKP (32 [20.9%]) than LKP (13 [12.7%]), but the difference was not statistically significant ( $p=0.125$ ). Allograft rejection was the most common complication in PKP (16 [10.5%]), while microbial keratitis occurred in 4 (2.6%) PKP and 3 (2.9%) LKP cases.

Table 2. Graft and donor variables and postoperative complications

|                                  |                                | <b>PKP<br/>(N=153)</b> | <b>LKP<br/>(N=102)</b> | <b>Sig.<br/>Value</b> |
|----------------------------------|--------------------------------|------------------------|------------------------|-----------------------|
| <b>Graft size (mm)</b>           | median [IQR]                   | 7.8 [7.5; 8.0]         | 8.0 [7.8; 8.2]         | $<0.001^c$            |
| <b>Host trephine size (mm)</b>   | median [IQR]                   | 7.5 [7.0; 7.8]         | 7.8 [7.5; 8.0]         | $<0.001^c$            |
| <b>Vascularization (N=255)</b>   | Absent                         | 100 (65.4%)            | 90 (88.2%)             | $<0.001^b$            |
|                                  | Peripheral                     | 34 (22.2%)             | 12 (11.8%)             |                       |
|                                  | Central                        | 4 (2.6%)               | 0 (0.0%)               |                       |
|                                  | Not documented                 | 11 (7.2%)              | 0 (0.0%)               |                       |
| <b>Any complication (N=254)</b>  | No                             | 120 (78.4%)            | 89 (87.3%)             | 0.125 <sup>a</sup>    |
|                                  | Yes                            | 32 (20.9%)             | 13 (12.7%)             |                       |
| <b>Complication type (N=254)</b> | Allograft rejection            | 16 (10.5%)             | 3 (2.9%)               | 0.149 <sup>b</sup>    |
|                                  | Cataract                       | 2 (1.3%)               | 0 (0.0%)               |                       |
|                                  | Glaucoma/raised IOP            | 4 (2.6%)               | 1 (1.0%)               |                       |
|                                  | Lenticule detachment           | 0 (0.0%)               | 2 (2.0%)               |                       |
|                                  | Microbial keratitis            | 4 (2.6%)               | 3 (2.9%)               |                       |
|                                  | No complications               | 120 (78.4%)            | 89 (87.3%)             |                       |
|                                  | Other/unclassified (free text) | 1 (0.7%)               | 0 (0.0%)               |                       |
|                                  | Recurrence of primary disease  | 1 (0.7%)               | 0 (0.0%)               |                       |
|                                  | Wound dehiscence               | 4 (2.6%)               | 4 (3.9%)               |                       |

Abbreviations: PKP, penetrating keratoplasty; LKP, lamellar keratoplasty; IQR, interquartile range; IOP, intraocular pressure. *Note: (a) Chi-Square Test, (b) Fisher’s Exact Test, (c) Mann Whitney Test*

**Intraocular pressure and visual outcomes**

Table 3 shows IOP was lower pre-operatively in LKP than PKP (12.0 vs. 14.0 mmHg,  $p=0.018$ ) but rose more after surgery (median change +4.0 vs. +1.0 mmHg,  $p=0.003$ ), despite clinically significant glaucoma being uncommon in both groups (Figure 1). Visual outcomes favored LKP at nearly every timepoint: BCVA >20/40 was achieved by more LKP eyes than PKP eyes pre-operatively (25.0% vs. 8.5%,  $p=0.040$ ), at 1 month (23.1% vs. 14.3%,  $p=0.039$ ), and at 3 months (29.0% vs. 13.5%,  $p=0.046$ ), with no significant difference at 12 months (47.2% vs. 36.4%,  $p=0.548$ ). The gap was largest and most robust at last visit, where 72.2% of LKP eyes achieved BCVA >20/40 versus 44.3% of PKP eyes ( $p=0.002$ ), though available-case numbers were limited and differed by group at each timepoint (Figure 2).

*Table 3. Intraocular pressure and best-corrected visual acuity over time in PKP and LKP groups*

|                                   |              | PKP (N=153)       | LKP (N=102)       | Sig. Value         |
|-----------------------------------|--------------|-------------------|-------------------|--------------------|
| <b>IOP pre-operative (mmHg)</b>   | Median [IQR] | 14.0 [11.0; 17.0] | 12.0 [10.0; 15.0] | 0.018 <sup>c</sup> |
| <b>IOP post-operative (mmHg)</b>  | Median [IQR] | 15.0 [12.0; 16.2] | 15.0 [14.0; 18.0] | 0.018 <sup>c</sup> |
| <b>IOP change (mmHg)</b>          | Median [IQR] | 1.0 [-2.0; 4.0]   | 4.0 [0.0; 6.0]    | 0.003 <sup>c</sup> |
| <b>BCVA pre-operative (N=103)</b> | >20/40       | 4 (8.5%)          | 14 (25.0%)        | 0.040 <sup>a</sup> |
|                                   | 20/40–20/100 | 24 (51.1%)        | 29 (51.8%)        |                    |
|                                   | <20/100      | 19 (40.4%)        | 13 (23.2%)        |                    |
| <b>BCVA at 1 month (N=68)</b>     | >20/40       | 6 (14.3%)         | 6 (23.1%)         | 0.039 <sup>b</sup> |
|                                   | 20/40–20/100 | 24 (57.1%)        | 19 (73.1%)        |                    |
|                                   | <20/100      | 12 (28.6%)        | 1 (3.8%)          |                    |
| <b>BCVA at 3 months (N=83)</b>    | >20/40       | 7 (13.5%)         | 9 (29.0%)         | 0.046 <sup>b</sup> |
|                                   | 20/40–20/100 | 32 (61.5%)        | 20 (64.5%)        |                    |
|                                   | <20/100      | 13 (25.0%)        | 2 (6.5%)          |                    |
| <b>BCVA at 12 months (N=91)</b>   | >20/40       | 20 (36.4%)        | 17 (47.2%)        | 0.548 <sup>b</sup> |
|                                   | 20/40–20/100 | 26 (47.3%)        | 15 (41.7%)        |                    |
|                                   | <20/100      | 9 (16.4%)         | 4 (11.1%)         |                    |
| <b>BCVA at last visit (N=124)</b> | >20/40       | 31 (44.3%)        | 39 (72.2%)        | 0.002 <sup>b</sup> |
|                                   | 20/40–20/100 | 23 (32.9%)        | 13 (24.1%)        |                    |
|                                   | <20/100      | 16 (22.9%)        | 2 (3.7%)          |                    |

Abbreviations: BCVA, best-corrected visual acuity; IOP, intraocular pressure; IQR, interquartile range; PKP, penetrating keratoplasty; LKP, lamellar keratoplasty, (a) Chi-Square Test, (b) Fisher's Exact Test, (c) Mann Whitney Test. Note: BCVA was available for different numbers of patients at each assessment: pre-operative, PKP n=47 and LKP n=56; 1 month, PKP n=42 and LKP n=26; 3 months, PKP n=52 and LKP n=31; 12 months, PKP n=55 and LKP n=36; and last visit, PKP n=70 and LKP n=54. Percentages are calculated using the available observations at each time point.

## Graft failure

Table 4 shows graft failure differed sharply between PKP and LKP in the full, unadjusted cohort (20.3% vs. 2.9%; RR 6.89, 95% CI 2.16–21.94, p<0.001) (Figure 3). However, this comparison is confounded by indication: when restricted to the ectasia-restricted subgroup, no significant difference was observed in graft failure (1.8% vs. 2.1%; RR 0.82, 95% CI 0.08–8.89, p=1.000) (Figure 3). In non-ectasia indications

only, PKP showed a numerically higher failure rate than LKP (31.3% vs. 12.5%), but this was not statistically significant (RR 2.50, 95% CI 0.39–16.02,  $p=0.431$ ), likely reflecting the small LKP sample ( $n=8$ ) in this subgroup.

*Table 4. Comparative graft failure between PKP and LKP*

| Comparison                                              | PKP Fail/ N (%) | LKP Fail/N (%) | RR (PKP vs LKP) | 95% CI     | Sig. Value |
|---------------------------------------------------------|-----------------|----------------|-----------------|------------|------------|
| <b>Full cohort (All Indications, Unadjusted)</b>        | 31/153 (20.3%)  | 3/102 (2.9%)   | 6.89            | 2.16–21.94 | <0.001     |
| <b>Ectasia-Restricted Subgroup (Indication-Matched)</b> | 1/57 (1.8%)     | 2/94 (2.1%)    | 0.82            | 0.08–8.89  | 1.000      |
| <b>Non-Ectasia Indications Only</b>                     | 30/96 (31.3%)   | 1/8 (12.5%)    | 2.50            | 0.39–16.02 | 0.431      |

### Factors associated with graft failure and visual outcomes

Table 5 shows that on multivariable analysis, PKP versus LKP was not independently associated with graft failure (adjusted OR 1.48, 95% CI 0.38–5.79,  $p=0.577$ ) once indication and regrant status were accounted for, suggesting the unadjusted difference reflects case-mix rather than surgical technique. Ectasia was strongly protective against failure (OR 0.09,  $p<0.001$ ), while regrant status showed a borderline association with increased risk (OR 2.71,  $p=0.050$ ). For visual outcome, surgery type again showed no independent effect (OR 0.99,  $p=0.988$ ); ectasia (OR 5.49,  $p=0.008$ ) and phakic lens status (OR 9.48,  $p=0.049$ ) were independently associated with achieving BCVA >20/40, though the phakic estimate's wide CI reflects a small sample.

**Table 5. Multivariable regression analysis of graft failure and visual outcome**

| Outcome / Term                       | Adjusted OR | 95% CI     | p-value          |
|--------------------------------------|-------------|------------|------------------|
| <b>Graft failure</b>                 |             |            |                  |
| <b>PKP vs LKP</b>                    | 1.48        | 0.38–5.79  | 0.577            |
| <b>Ectasia indication (vs other)</b> | 0.09        | 0.02–0.31  | <b>&lt;0.001</b> |
| <b>Regrant (vs primary)</b>          | 2.71        | 1.00–7.34  | <b>0.050</b>     |
| <b>BCVA &gt;20/40 at last visit</b>  |             |            |                  |
| <b>PKP vs LKP</b>                    | 0.99        | 0.38–2.61  | 0.988            |
| <b>Ectasia indication (vs other)</b> | 5.49        | 1.56–19.25 | <b>0.008</b>     |
| <b>Regrant (vs primary)</b>          | 1.15        | 0.14–9.27  | 0.897            |
| <b>Phakic (vs not)</b>               | 9.48        | 1.01–88.87 | <b>0.049</b>     |

## Association of graft size with clinical outcomes

Table 6 shows that graft size was significantly associated with all three outcomes on univariate analysis. Smaller grafts were associated with graft failure (7.50 vs. 7.75 mm;  $p<0.001$ ) and complications (7.75 vs. 7.75 mm;  $p=0.033$ ). In contrast, larger grafts were associated with better visual outcomes, with higher graft size among eyes achieving BCVA  $>20/40$  (8.00 vs. 7.75 mm;  $p=0.025$ ). However, these differences were modest, and adjustment for indication and regrant status was necessary to assess independent associations.

Table 6. Univariate association between graft size and clinical outcomes

| Variable                    | Response                | Group 1                  | Group 2                  | P-Value          |
|-----------------------------|-------------------------|--------------------------|--------------------------|------------------|
| Graft failure               | Graft size (mm), median | No failure: n=214, 7.75  | Failure: n=33, 7.50      | <b>&lt;0.001</b> |
| Any complication            | Graft size (mm), median | None: n=203, 7.75        | Complication: n=43, 7.75 | <b>0.033</b>     |
| BCVA $>20/40$ at last visit | Graft size (mm), median | Not achieved: n=51, 7.75 | Achieved: n=68, 8.00     | <b>0.025</b>     |

**Abbreviation:** BCVA, best-corrected visual acuity.

Table 7 shows that after adjustment for surgical indication, regrant status, and surgery type, graft size was not independently associated with graft failure, complications, or achieving BCVA  $>20/40$ . For graft failure, graft size had an adjusted OR of 0.56 (95% CI: 0.24–1.31;  $p=0.181$ ). Similarly, no significant association was observed with complications (OR 0.67, 95% CI: 0.29–1.55;  $p=0.352$ ) or good visual outcome (OR 1.27, 95% CI: 0.29–5.50;  $p=0.747$ ). Ectasia was associated with lower odds of failure and complications, while ectasia was associated with higher odds of achieving BCVA  $>20/40$ . Regraft status was associated with higher odds of graft failure (OR 3.10;  $p=0.030$ ).

Table 7. Multivariable regression analysis incorporating graft size

|                                     |                               | <b>E</b>    | <b>95% CI</b> | <b>p-value</b> |
|-------------------------------------|-------------------------------|-------------|---------------|----------------|
| <b>Graft failure</b>                | PKP vs LKP                    | 1.33        | 0.34–5.26     | 0.683          |
|                                     | Ectasia indication (vs other) | 0.11        | 0.03–0.41     | <b>0.001</b>   |
|                                     | Regraft (vs primary)          | 3.10        | 1.12–8.63     | <b>0.030</b>   |
|                                     | <b>Graft size (per mm)</b>    | <b>0.56</b> | 0.24–1.31     | 0.181          |
| <b>Any complication</b>             | PKP vs LKP                    | 0.92        | 0.38–2.23     | 0.857          |
|                                     | Ectasia indication (vs other) | 0.38        | 0.16–0.92     | <b>0.032</b>   |
|                                     | Regraft (vs primary)          | 0.45        | 0.12–1.67     | 0.231          |
|                                     | <b>Graft size (per mm)</b>    | <b>0.67</b> | 0.29–1.55     | 0.352          |
| <b>BCVA &gt;20/40 at last visit</b> | PKP vs LKP                    | 0.98        | 0.36–2.62     | 0.962          |
|                                     | Ectasia indication (vs other) | 5.43        | 1.55–19.08    | <b>0.008</b>   |
|                                     | Regraft (vs primary)          | 1.08        | 0.13–8.79     | 0.943          |
|                                     | Phakic (vs not)               | 7.92        | 0.81–77.37    | 0.075          |
|                                     | <b>Graft size (per mm)</b>    | <b>1.27</b> | 0.29–5.50     | 0.747          |

**Abbreviations:** PKP, penetrating keratoplasty; LKP, lamellar keratoplasty; BCVA, best-corrected visual acuity; OR, odds ratio; CI, confidence interval.

### indications and graft failure by technique

Figure 4 shows corneal ectasia was the most common indication overall (N=151), accounting for the large majority of LKP cases (94, 62%) versus a smaller share of PKP (57, 38%). Corneal scarring (N=40) was predominantly managed with PKP (34, 85%), while PKP was the sole technique used for corneal edema/decompensation (24), congenital opacity (14), regrafting for prior failure (9), perforation/melting (5), and infectious keratitis (1). LKP contributed only one additional case, in corneal dystrophy (1/10, 10%).

Table 8 shows that graft failure rates varied across keratoplasty techniques. PKP had a crude failure rate of 20.3% (31/153), while LKP had a substantially lower rate of 2.9% (3/102).

Table 8. Crude graft failure outcomes by keratoplasty technique

| <b>Technique</b> | <b>N records (raw)</b> | <b>N with known outcome</b> | <b>N failures</b> | <b>Crude failure rate</b> |
|------------------|------------------------|-----------------------------|-------------------|---------------------------|
| <b>PKP</b>       | 157                    | 153                         | 31                | 20.3%                     |
| <b>LKP</b>       | 103                    | 102                         | 3                 | 2.9%                      |

## DISCUSSION

Keratoplasty is an established treatment for advanced corneal disease. Penetrating keratoplasty (PKP) and lamellar keratoplasty (LKP) are commonly selected according to the underlying pathology [10]. PKP replaces full thickness of the cornea, whereas LKP selectively replaces diseased corneal layers and may preserve healthy tissue [11]. Although LKP may offer advantages in selected conditions, differences in graft survival and visual recovery between PKP and LKP remain clinically relevant. Surgical indication, graft characteristics, and patient factors may influence outcomes and complicate direct comparisons. Therefore, evaluation of the graft survival and visual outcomes between PKP and LKP may clarify their relative effectiveness in clinical practice.

Our study compared graft failure, visual outcome, and intraocular pressure (IOP) between PKP and LKP in a retrospective cohort of 255 eyes. In the unadjusted analysis, PKP failed considerably more often than LKP (20.3% vs. 2.9%), but this difference was almost entirely attributable to indication rather than surgical technique. However, once restricted to corneal ectasia, the indication accounting for most LKP cases, failure rates converged (1.8% vs. 2.1%) and were no longer statistically significant. This pattern is consistent with recent comparative series. Similarly, a study by Feizi et al. (2023) found comparable long-term graft survival between PKP and deep anterior lamellar keratoplasty (DALK) in advanced keratoconus, despite PKP achieving marginally better early visual acuity [12]. Tüfekçi Balıkcı et al. also reported similar survival rates following PKP and DALK in macular corneal dystrophy (87.5% vs. 88.2%) [13]. Furthermore, there is a study by Borderie et al., (2023) evaluated 502 eyes undergoing DALK or PKP for keratoconus and reported excellent long-term graft survival, with 96.7% at 10 years and 95.6% at 20 years, with no significant difference in visual acuity between the techniques, emphasizing that outcomes should be interpreted in the context of the underlying indication and patient selection rather than surgical technique alone [14]. Arundhati et al. reported that DALK had superior long-term graft survival compared with PKP. The survival benefit was largely attributable to substantially lower rates of allograft rejection and endothelial failure, reflecting preservation of the recipient endothelium with DALK [15]. Our findings support interpreting the crude difference in graft failure between PKP and LKP as being influenced by case-mix differences and surgical indications rather than technique alone. This interpretation is further supported by the multivariable analysis, in which surgical technique was no longer independently associated with graft failure after adjustment for indication and regrant status.

The predominance of ectasia cases in the LKP group (92.2%) is consistent with established clinical practice. Because ectasia typically spares the corneal endothelium, DALK is generally preferred over PKP to avoid the risks of endothelial rejection. This approach is widely supported in contemporary reviews of keratoconus management [16]. Janiszewska-Bil et al. (2021) likewise reported that DALK was associated with fewer adverse events and lower endothelial cell loss than PKP in a prospective keratoconus cohort, while visual outcomes were comparable between groups at 6 and 12 months [17]. Our finding that LKP achieved better visual acuity at last visit (72.2% vs. 44.3% achieving BCVA>20/40) is therefore somewhat more favorable to LKP than several comparable series and should be interpreted cautiously given the substantial and differential missing data affecting BCVA follow-up timepoints (45–

75% missing). Aldebasi et al. (2024) similarly found generally comparable visual and patient-satisfaction outcomes between DALK and PKP, with differences emerging mainly in the complication profile [18]. These findings suggest that the more pronounced difference in visual outcomes observed in our study may partly reflect the available-case nature of the analysis, including differences in follow-up and BCVA availability, rather than representing a true difference in treatment effect.

The IOP findings were less consistent with previous literature. In our study, LKP was associated with a greater postoperative increase in IOP than PKP (median change, +4.0 vs. +1.0 mmHg), despite lower preoperative IOP in the LKP group. This contrasts with the general pattern reported in previous studies, where LKP, particularly DALK, is often associated with a lower risk of postoperative ocular hypertension than PKP. The unexpected finding in our cohort may reflect differences in patient characteristics, surgical indications, postoperative steroid use, follow-up duration, or other unmeasured factors. Therefore, the observed IOP difference should be interpreted cautiously and should not be considered evidence of an inherent tendency for LKP to increase IOP more than PKP. Janiszewska-Bil et al. (2021) reported elevated IOP in only 8% of DALK eyes compared with 52.5% of PKP eyes, suggesting a substantially lower risk of postoperative ocular hypertension following DALK [17]. Similarly, Gümüş et al. (2022) found that lamellar techniques, including DALK and DMEK, were associated with smaller early postoperative IOP changes than PKP. This has been attributed to less disruption of the anterior chamber angle and preservation of the recipient corneal anatomy. Therefore, the greater IOP increase observed in our LKP group appears inconsistent with the established literature and may reflect differences in case mix, postoperative management, or the heterogeneous nature of the LKP group. [19]. Günaydın et al. (2023) similarly found significantly lower IOP in DALK than PKP at 6 months in a contralateral-eye comparison [20], and reviews of post-keratoplasty glaucoma consistently identify corticosteroid response and angle trauma as the principal mechanisms, both traditionally more prominent after full-thickness grafting (Anders et al. 2021) [21]. This divergence may be related to differences in postoperative steroid tapering protocols, the timing of postoperative IOP assessment, or other cohort-specific factors. The shorter observation period in our study compared with previous studies may also have influenced the findings. Therefore, the observed increase in IOP among LKP eyes should be interpreted cautiously and requires confirmation in prospective studies with standardized postoperative management and predefined IOP assessment time points.

## **Limitations**

There are several limitations of this study that should be acknowledged. Most importantly, the absence of a graft-failure date field precluded a valid Kaplan–Meier or Cox survival analysis, which forced reliance on cross-sectional failure proportions. This is a recognized limitation in retrospective corneal transplant studies. Dutta et al., (2023) in a comparable retrospective series from Eastern India, documented follow-up completion falling to just 35.2% by 36 months, illustrating how commonly incomplete longitudinal data compromise time-to-event analysis in this literature [22]. The extensive, differential missingness in our BCVA data is consistent with this broader pattern and limits confidence in the visual-outcome estimates, which should be read as available case findings. Suture-related astigmatic management,

known to meaningfully influence post-keratoplasty refractive outcomes [23], could not be evaluated because suture removal timing was not recorded in the source data. Additionally, the lack of patient identifiers prevented assessment of clustering among bilateral cases. Although graft size was associated with all outcomes in univariate analysis, these associations disappeared after adjustment, suggesting that graft size primarily reflected underlying case selection rather than an independent determinant of outcomes.

## Conclusion

Our study shows that the apparent graft survival advantage of lamellar over penetrating keratoplasty was largely explained by differences in the surgical indications rather than technique itself. The advantage was no longer observed in the ectasia-restricted subgroup or after adjustment for surgical indication and regraft status. Visual outcomes favored lamellar keratoplasty, although substantial missing follow-up data limit the strength of this finding. The unexpectedly greater increase in postoperative IOP in the lamellar group also warrants further investigation. Overall, keratoplasty technique should be selected primarily according to the underlying clinical indication rather than assumed superiority of one approach. Future prospective studies with standardized follow-up and complete outcome assessment are needed in order to establish the true comparative effectiveness of these techniques.

## Abbreviations

PKP: Penetrating keratoplasty

LKP: Lamellar keratoplasty

DALK: Deep anterior lamellar keratoplasty

BCVA: Best-corrected visual acuity

IOP: Intraocular pressure

OR: Odds ratio

RR: Risk ratio

CI: Confidence interval

## Declarations

## Acknowledgements

Not applicable.

### **Author contributions**

All authors contributed to the study conception, data collection, analysis, drafting, and final approval of the manuscript.

### **Data availability**

The datasets generated and analysed during this study are available from the corresponding author on reasonable request.

### **Ethics statement**

Ethical approval to conduct this study was obtained from the Institutional Review Board of King Abdulaziz Medical City, Riyadh (approval number IRB/2635/23). Informed consent was waived because of the retrospective nature of the study. The study was conducted in accordance with the Declaration of Helsinki.

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### **Consent for publication**

Not applicable.

### **Conflicts of interest**

There are no conflicts of interest.

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## Figures

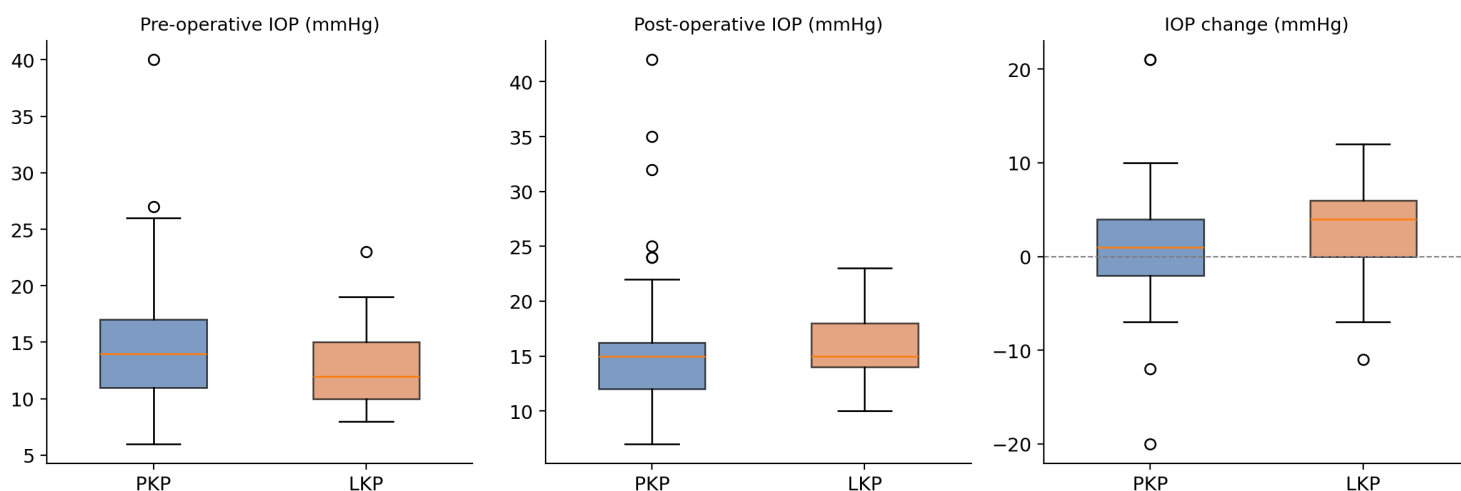


**Figure 1**

*Intraocular pressure by surgery type.*

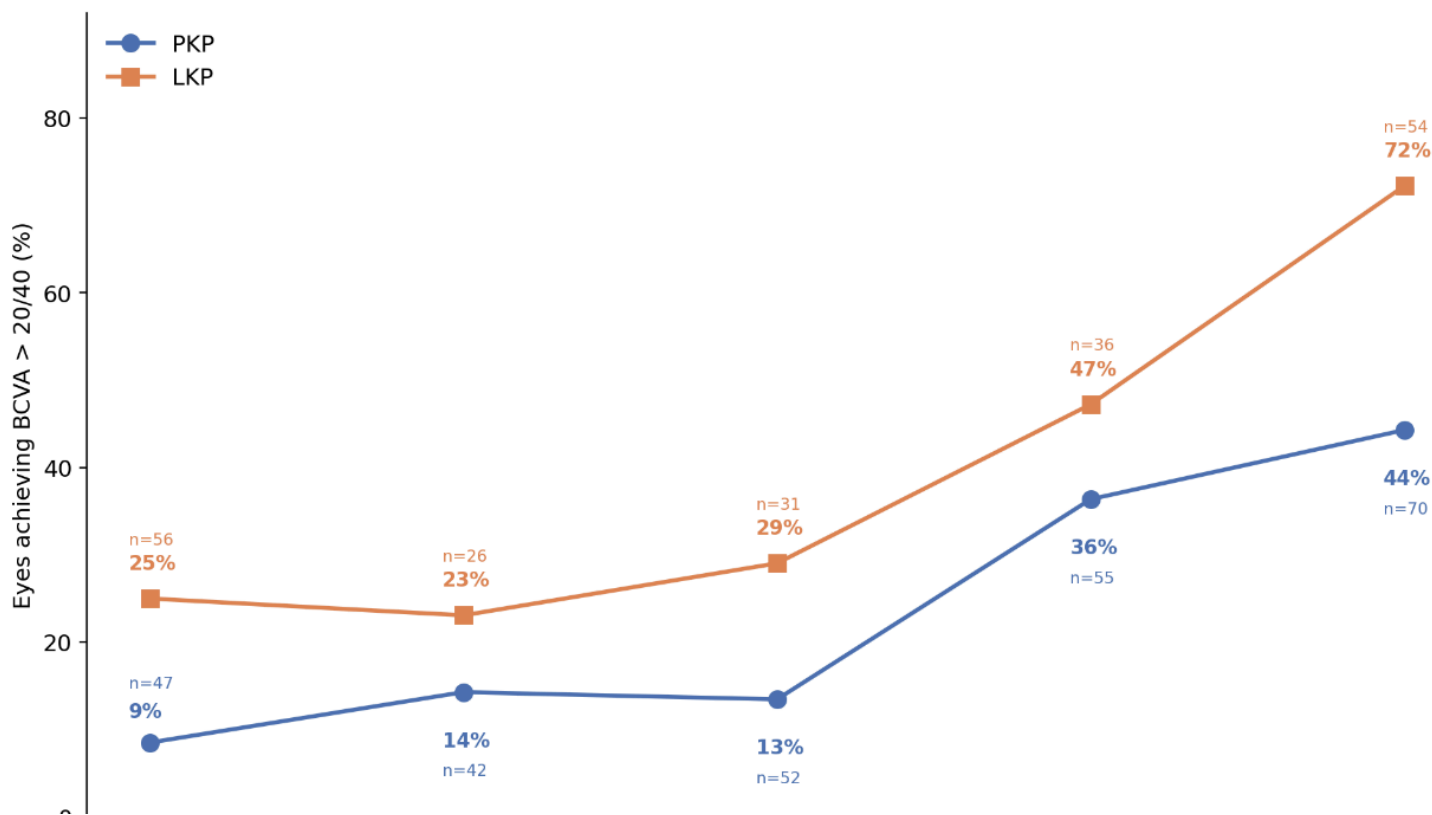


**Figure 2**

*BCVA >20/40 over time by surgery type, with the available-case N shown at each point.*

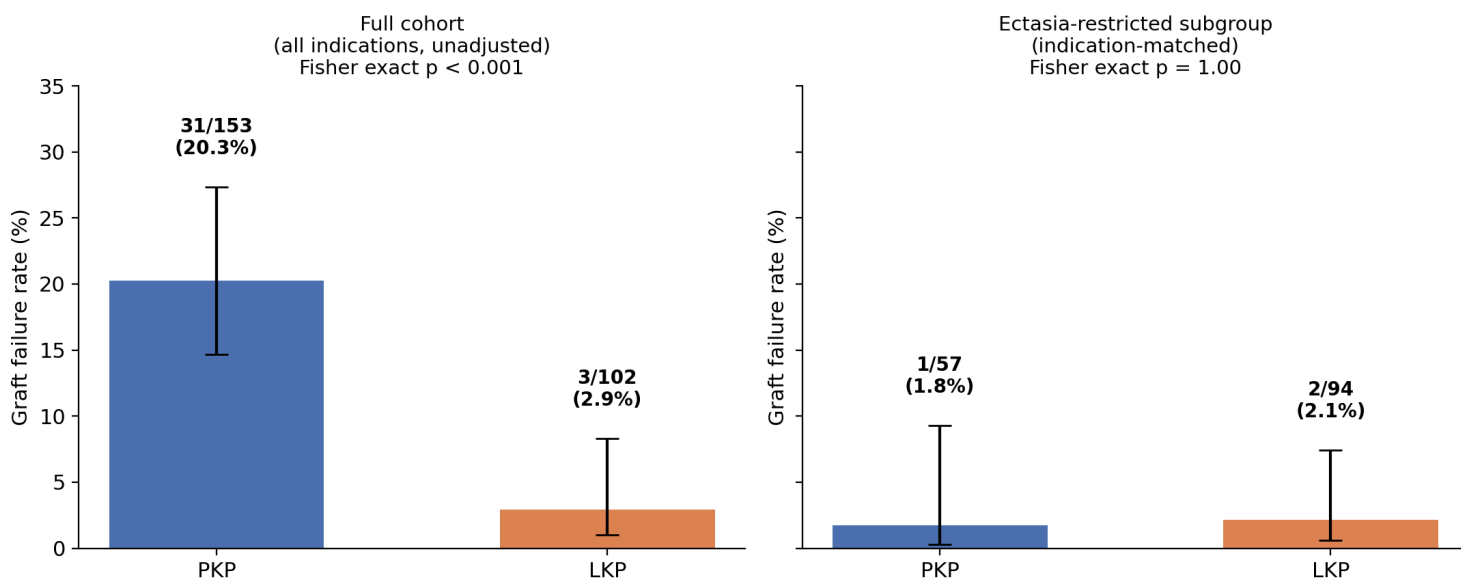


**Figure 3**

*Graft failure rate by surgery type, with 95% CI. Left: full cohort (unadjusted). Right: ectasia-restricted subgroup (indication-matched).*

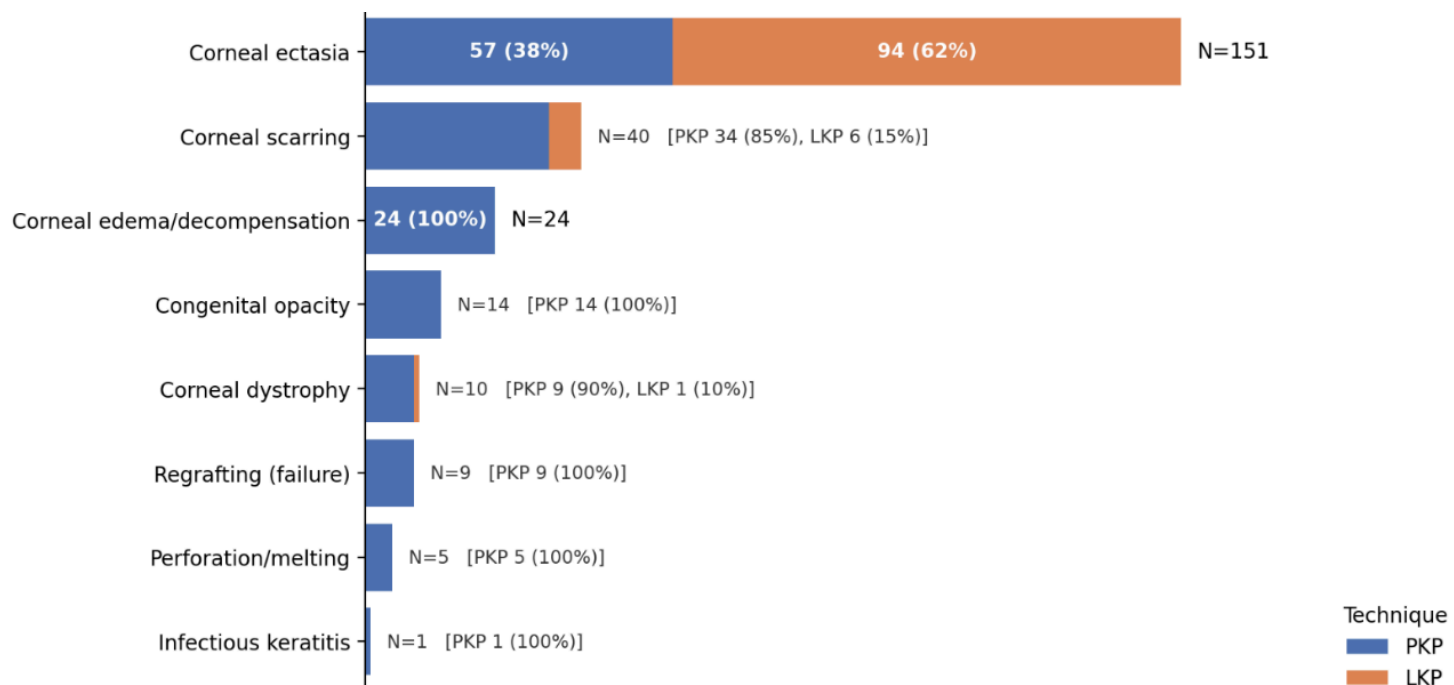


**Figure 4**

*Surgical indications across keratoplasty techniques.*