# RESEARCH



# Comparison of clinical outcomes, complications and patient satisfaction following deep anterior lamellar keratoplasty and penetrating keratoplasty

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# Abstract

**Background** Keratoplasty is a surgical procedure in which a damaged or diseased cornea is replaced with healthy donor tissue, thereby restoring vision. Recent advancements have led to the replacement of penetrating keratoplasty (PKP) with the more selective deep anterior lamellar keratoplasty (DALK) procedure, especially for treating keratoplasty a shorter recovery time, less pain and a lower risk of rejection, PKP is still being performed for more severe corneal diseases. A comparative study of clinical profiles, treatment outcomes and patient-reported satisfaction will provide valuable insights into the cost-effectiveness, impact on quality of life and ability of each procedure to treat different pathologies of the cornea. Here, we aimed to compare the clinical and subjective outcomes of DALK with those of the PKP at a single center in the Kingdom of Saudi Arabia.

**Methods** This retrospective cohort study included eyes that underwent either PKP or DALK from January 2017 to January 2021. The demographic features, indications, best corrected visual acuity (BCVA) and complications of the patients were recorded for both groups, analyzed and compared. A subgroup of eyes with keratoconus was analyzed separately and compared to the larger group. A 6-item survey was conducted via telephone to assess patient satisfaction and expectation, and the results were compared between the two procedures. The chi-square test or Fisher's exact test for categorical variables or the t test or Kruskal–Wallis test for continuous variables were used as appropriate for all comparisons, and the level of significance was set at  $\alpha = 0.05$ .

**Results** A total of 97 patients were included. PKP and DALK were performed on 63 and 39 eyes, respectively. Patients who underwent DALK were younger (mean±standard deviation 31±10.82 years versus 43±26.89 years for patients who underwent PKP). The most frequent indication for PKP was keratoconus (35.5%); however, in 97.4% of the eyes undergoing DALK, the indication was keratoconus. In both groups, visual acuity and refractive error improved, but the postoperative corrected distance visual acuity in the DALK group (0.3 log MAR) was noticeably greater than that in the

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PKP group (0.6 log MAR). Compared with PKP, DALK may carry a lower risk of early graft edema and rejection. Overall, the reported postoperative patient satisfaction was similar for both procedures.

**Conclusion** The findings highlight the effectiveness of PKP and DALK in improving visual acuity and emphasize the importance of considering patient-reported outcomes in evaluating success. DALK has been demonstrated to be beneficial for protecting the corneal endothelium and lowering the risk of complications and graft rejection.

**Keywords** Corneal transplantation, Penetrating keratoplasty, Deep anterior lamellar keratoplasty

# Introduction

Corneal disease is the fifth leading cause of blindness globally, after cataracts, refractive error, glaucoma, and age-related macular degeneration [1]. Early access to ophthalmic care, along with timely diagnosis and intervention, can prevent a significant proportion of patients from progressing to corneal blindness. Corneal diseases, such as keratoconus, corneal dystrophies, and corneal ulcers, can severely impair vision. While various treatment options exist, including medications, contact lenses, and refractive surgeries, in advanced cases, corneal transplantation, also called keratoplasty (KP), remains the primary treatment modality. Importantly, if disease presentation, diagnosis, or treatment is delayed, the most viable solution for restoring vision in eyes affected by corneal disease is KP [2, 3]. The choice of KP depends largely on the type of corneal disease present, the geographical location, and the demographic characteristics and socioeconomic background of the patient [4–6]. For corneal stromal and endothelial diseases, penetrating keratoplasty (PKP) has been the primary surgical therapeutic option. An alternative surgical method to PKP for treating a variety of corneal stromal disorders with healthy endothelium is deep anterior lamellar keratoplasty (DALK). Because the corneal endothelium and Descemet's membrane remain in place after DALK surgery, the globe is more resilient to blunt trauma than following PKP; additionally, steroids can be administered for a shorter amount of time, and earlier suture removal can be performed because the wound heals sooner. In the Kingdom of Saudi Arabia (KSA), keratoconus is the most common surgical indication for KP, followed by corneal edema/decompensation, corneal scarring, and regrafting (in cases of previous failure) [7–9].

In recent decades, PKP has been largely replaced by the more selective procedure DALK, as this technique allows the replacement of only the diseased cornea while keeping the Descemet membrane (DM) and endothelium intact, thus reducing the risk of endothelial graft rejection and postoperative complications over PKP [10]. Numerous studies have compared these two methods in patients with keratoconus; while some studies have reported comparable results for the two procedures, others have reported fewer postoperative problems with DALK [11, 12]. While DALK has become the preferred surgical option for many corneal conditions, PKP remains a valuable surgical tool when DALK may not be sufficient. In cases of severe corneal scarring and infectious keratitis, which involve the full thickness of the cornea, PKP may be necessary to remove the scarred tissue and restore vision. Additionally, if the corneal endothelium is severely damaged, PKP may be the only option for restoring vision. Most previous studies comparing these two procedures have concentrated on one pathology of the cornea, such as keratoconus or corneal dystrophy,. Additionally, there is a dearth of research on patientreported outcomes (PROs) following corneal transplantation or how transplants affect daily visual function and quality of life, despite the fact that metrics for assessing postoperative outcomes have traditionally concentrated on clinical and complication profiles. To date, no studies have compared the clinical profile and patient-reported satisfaction and expectations between these two keratoplasty techniques in the KSA.

This study aimed to compare all aspects of the two procedures, irrespective of the indication for the procedure, including subjective outcome measures via a patient satisfaction survey administered after each type of transplantation; a subgroup analysis among keratoconus patients was also conducted as it was the common indication for keratoplasty.

# Methods

### Patients

This was a retrospective, chart-review cohort study in which the pre- and postoperative data of eyes that underwent either PKP or DALK surgery at a tertiary care hospital in Riyadh, KSA, from January 2017 to January 2021 were collected. The study was approved by the Institutional Review Board of King Abdullah International Medical Research Center (KAIMRC), Riyadh, KSA, and was performed in compliance with the principles of the Declaration of Helsinki. The requirement for informed consent was waived because of the retrospective nature of the study.

The inclusion criteria were as follows: either sex, 18 years of age and a minimum follow-up of 14–18 months. All patients who met these criteria during the study period were included to exclude selection bias. However, patients who underwent combined procedures (e.g.,

intraocular surgeries such as cataract surgery or glaucoma surgery) as well as patients with other noncorneal ocular pathologies (retinal disease/cataract/glaucoma) were excluded.

#### Surgical techniques

Multiple corneal surgeons with an average of 13 years of experience at the Department of Ophthalmology at King Abdulaziz Medical City in Riyadh, KSA, performed the procedures with the patients under general anesthesia. For PKP, after a thorough examination of the donor corneas, vacuum trephination was used to treat the recipient corneas. Instead of being decentered over the cone apex, the trephination was centered on the cornea as measured at the time of surgery. In every instance, the donor tissue was trephined to be 0.25 mm larger than the recipient bed. The donor cornea was sutured to the recipient cornea with 16 10/0 nylon interrupted sutures following routine protocols. DALK was conducted via the big-bubble technique or hand dissection. Following trephination to the desired corneal thickness using a Hessburg-Barron suction trephine (Katena, Denville, USA), a 27-gauge needle was introduced into the stroma up to the center of the cornea. The needle was connected to a 5-cc syringe and bent at a 100° angle (bevel facing downward). A bubble that extended to the trephination border was created by carefully injecting air into the midstroma. A crescent blade was used to debulk the anterior two-thirds of the corneal stroma following the creation of the bubble. The Descemet membrane was protected from manipulation by the injection of a viscoelastic substance. If a sufficiently large bubble could not be achieved, a crescent knife was used to manually dissect the stroma down to the DM. After the endothelium was removed using cellulose sponges and vision blue staining, a 0.25 mm larger donor button was trephined using a punch. The suturing technique used for both PKP patients and DALK patients was determined by their risk of vascularization and rejection.

During the first year following PKP, a steroid taper was gradually implemented, whereas for DALK, steroid tapering was performed for the first three months postoperatively, after which drug treatment was terminated in most eyes. Most patients were assessed twice during the first week following surgery and again at 1, 3, 6, 12, 18, and 24 months. Best corrected visual acuity (BCVA), intraocular pressure measurement, and slit lamp examination were performed at all follow-up examinations and recording. The timing of suture removal was determined at the discretion of the treating ophthalmologist.

# Data collection

We conducted a thorough review of the patients' electronic medical records. BCVA, refractive error,

complications and patient satisfaction were included as the outcome measures. To assess patient satisfaction, we contacted the patients by telephone and asked them to respond to 6 items about their expectations and satisfaction; these items were derived from the Arabic-translated version of the 24-item questionnaire designed by Williams et al. at Flinders University of South Australia, Adelaide [13]. The questions were clearly and succinctly expressed in Arabic, and two researchers conducted independent telephone questionnaires for each surgical procedure to eliminate any potential for researcher bias.

#### Statistical analysis

The study participants were divided into PKP and DALK groups according to the type of surgery. Means and proportions were calculated to characterize the study participants overall and within the individual groups. Preoperative and postoperative characteristics, the incidence of postoperative complications, and postoperative patient satisfaction were compared between the two groups with the chi-square test or Fisher's exact test for categorical variables or the t test or Kruskal-Wallis test for continuous variables, as appropriate. Additionally, a subgroup analysis for patients who were indicated for the procedure due to keratoconus was performed to prevent identification discrepancies and draw relevant conclusions. For all comparisons, the level of significance was set at  $\alpha$ =0.05. Statistical analysis was conducted in SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

# Results

# Patient data

We included 102 eyes from 97 patients to compare the outcomes of PKP and DALK. PKP was performed on 63 eyes, whereas DALK was performed on 39 eyes. The demographic characteristics, preoperative data, graft size, time to suture removal and follow-up time of the patients in the PKP and DALK groups were compared. A total of 38/63 (60%) patients in the PKP group and 21/39 (53.8%) patients in the DALK group were males. The mean age (in years±SD) of the patients who underwent DALK was 31±10.82 years, whereas that of patients who underwent PKP was 43±26.89 years. The indications for PKP included keratoconus (35.5%), corneal scarring or ulcers (27.4%), and bullous keratopathy (16.1%); the vast majority of eyes treated with DALK had keratoconus (97.4%). For more than half of the patients in both the PKP (57.1%) and DALK groups (52.7%), the preoperative BCVA was worse than 20/100. The donor cornea was 0.25 mm larger than the recipient cornea in both procedures. The mean follow-up time was 36.4±14.96 months for PKP patients and 31.5±11.22 months for DALK patients (Table 1).

Preoperative Data	PKP (63)	DALK (39)	P value
Sex			
Male, n (%)	38 (60.3)	21 (53.8)	0.5201 ^
Female, n (%)	25 (39.7)	18 (46.2)	
Age, years, mean (SD)	43.0 (26.89)	31.0 (10.82)	0.1547^
<b>Eye</b> n (%)			
Right	30 (47.6)	19 (48.7)	0.914^^
Left	33 (52.4)	20 (51.3)	
Indication			
Bullous keratopathy	10 (15.87%)	0	< 0.0001 ^^
Corneal scarring	17 (26.98%)	1 (2.6)	
Congenital disease/dystrophy	7 (11.11%)	0	
• Keratoconus	22 (34.92%)	38 (97.4%)	
• Keratitis	7 (11.11%)	0	
Preoperative BCVA category, %			
• 20/100 or better	42.8	47.2	0.0021 ^
• Worse than 20/100	57.1	52.7	
Preoperative BCVA n, (%)			
• 20/40 or better	7 (12.3)	6 (15.8)	
• 20/50 – 20/200	15 (26.3)	19 (50.0)	
· 20/200 - 20/400	7(16.66)	5(13.89)	^0.0285
• 20/400-HM	10(23.81)	10(27.78)	
<ul> <li>Light perception</li> </ul>	7(16.67)	3(8.33)	
Donor cornea size, mm, mean (SD)	7.7 (0.51)	8.0 (0.27)	0.0008 ^
Recipient cornea size, mm, mean (SD)	7.4 (0.55)	7.8 (0.30)	0.0007 ^
Follow-up duration, months, mean (SD)	36.4 (14.69)	31.5 (11.22)	0.1385 ^
Time to suture removal, months,	38.7	32.6	0.0719

BCVA-best corrected visual acuity

^Fisher's exact test

^^Chi-square test

# Visual acuity and refractive results

BCVA improved in both the PKP and DALK groups. The postoperative BCVAs of 20/100 or better for the PKP and DALK groups obtained at 6 months were 81.20% and 74.19%, respectively; these proportions were maintained at 82.33% and 81.28%, respectively, by the end of the first postoperative year. (Table 2). This table shows BCVA in ranges according to Snellen's visual acuity.

#### Table 2 Postoperative BCVA after PKP and DALK

	РКР	DALK	P value
BCVA: 6 months postopera	tively		
• 20/100 or better	81.20%	74.19%	
• Worse than 20/100	18.70%	25.81%	
BCVA: 1 year postoperative	ly		
• 20/20-20/40	44.10%	28.14%	*0.7833
• 20/50 - 20/100	38.23%	53.14%	
· 20/200 - 20/400	5.88%	12.50%	
• 20/400-HM	8.82%	3.13%	
<ul> <li>Light perception only</li> </ul>	2.94%	3.13%	
*Fisher's exact test			

BCVA-Best corrected visual acuity

PKP-Penetrating keratoplasty

DALK- Deep anterior lamellar keratoplasty

We also compared postoperative logMAR visual acuity at six months and one year. Although both groups' visual acuity and refractive error improved following the procedure, the postoperative corrected distance visual acuity in the DALK group (0.3 logMAR) was noticeably greater than that in the PKP group (0.6 logMAR) (Table 3). The mean result for the final spherical equivalent power at 6 months in the PKP group was consistent with mild hyperopia; the DALK group showed a mean final spherical equivalent power consistent with mild myopia (mean+SD  $0.7 \pm 4.47$  versus  $-0.8 \pm 3.31$ ). The two groups presented mean spherical equivalents of myopia at the end of a year, although the PKP group was more myopic (mean+SD  $-2.2\pm4.09$  for the PKP group versus  $-1.5\pm3.30$  for the DALK group). The mean cylinder at the end of six months and one year in both groups was less than -5.0 D, although the DALK group had a slightly greater mean myopic cylinder, as shown in Table 3.

#### Complications

Early graft edema occurred in 50.8% of the PKP patients, significantly more often than in the DALK patients (30.8%, p=0.04). Endothelial rejection occurred in 18.8% of the eyes treated with PKP. Three cases of stromal rejection were reported in the PKP group, whereas none were reported in the DALK group. The incidences of glaucoma, cataract formation, scarring, keratitis, neovascularization and graft failure were nominally greater in the PKP group than in the DALK group, but none of the differences were significant (Fig. 1). The chi-square test was used when the expected count was at least five in each cell; otherwise, Fisher's exact test was used.

#### Patient satisfaction survey

Overall, patient satisfaction was similar for both procedures. A total of 84.6% of patients who underwent DALK surgery and 76% of patients who underwent PKP

Table 3 Comparison of preoperative and postoperative refractive error and visual acuity between PKP and DALK

	РКР	DALK	P value
Preoperative spherical equivalent: Mean (SD)	-2.5 (6.60)	-3.1 (9.03)	0.8542 *
Preop cylinder: Mean (SD)	-3.7 (4.28)	-4.9 (1.50)	0.3779 *
Preop corrected VA, logMAR, mean (SD)	1.1 (0.51)	0.8 (0.50)	0.0021^
Postop spherical equivalent at 6 months, diopter, mean (SD)	0.7 (4.47)	-0.8 (3.31)	0.4679 *
Postop cylinder at 6 months, diopter, mean (SD)	-3.5 (1.69)	-4.9 (1.16)	0.0910 *
Postop corrected VA at 6 months, logMAR, mean (SD)	0.6 (0.43)	0.5 (0.29)	0.4435^
Postop spherical equivalent at 12 months, diopter, mean (SD)	-2.2 (4.09)	-1.5 (3.30)	0.5266 *
Postop cylinder at 12 months, diopter, mean (SD)	-2.7 (2.42)	-4.0 (2.62)	0.1222 *
Postop corrected VA at 12 months, logMAR, mean (SD)	0.6 (0.47)	0.3 (0.22)	0.0065^

<sup>\*</sup> t test

^Kruskal–Wallis test

DALK- Deep anterior lamellar keratoplasty

SD – Standard deviation



Fig. 1 Comparison of complication incidences between PKP and DALK

reported that they would make the same decision to have the surgery (Fig. 2).

# Subgroup analysis in eyes with keratoconus

We also compared the baseline characteristics, visual outcomes and satisfaction scores of the keratoconus patients, as shown in Table 4. While visual acuity (preoperative: 0.9 versus 0.8 logMAR units) improved in both groups at 6 months (0.4 versus 0.5 logMAR units), the percentages of PKP and DALK patients for whom the postoperative BCVA was better than 20/100 at 6 months were 36.4% and 50%, respectively. Additionally, for patients who underwent PKP, the postoperative BCVA was consistent at 1 year (0.4 logMAR units), whereas patients who underwent DALK demonstrated an improvement in the BCVA at 1 year (0.3 logMAR units), although the difference was not statistically significant. In this subgroup, 4 PKP patients experienced endothelial rejection, and one experienced failure, whereas none of the patients in the DALK group experienced rejection. Satisfaction survey responses were similar in both groups. In total, 77.8% of the patients in the PKP group and 70% of those in the DALK group were happy with their outcome, whereas 18.5% of those in the PKP group and 11% of those in the DALK group had more complications than expected. From the results of this subgroup analysis, we concluded that the BCVA of keratoconus patients who underwent

PKP-Penetrating keratoplasty



Fig. 2 Postoperative patient satisfaction survey response percentages in the PKP and DALK groups

DALK was consistent at 1 year, and fewer complications were reported.

# Discussion

This retrospective comparative study demonstrated comparable visual and refractive outcomes for both DALK and PKP procedures. Additionally, findings suggest that DALK may offer a less invasive alternative to PKP with similar functional outcomes and a reduced risk of severe complications. However, further prospective studies with larger sample sizes are needed to confirm these results and to evaluate long-term outcomes. Similar studies have demonstrated the advantages of DALK over PKP [11-15]. According to a meta-analysis, men undergo keratoplasty procedures more often than women do, which is consistent with our findings [16]. Keratoconus was the most common indication for both PKP and DALK in this study. Previous studies have indicated that the most common indications in high-income countries are bullous keratopathy and Fuchs' endothelial dystrophies, whereas the most common indication in developing nations is microbial keratitis [17]. We believe that the comparatively high prevalence of keratoconus in the KSA, which is reflected in the relatively young mean age of patients receiving both types of procedures, is the cause of the differences in the indications for keratoplasty in the current study relative to other studies. Prior studies have also shown that the number of keratoconus surgeries is increasing in Saudi Arabia, primarily because of improvements in health care availability, increased graft availability, and recent population explosions [15].

In the present study, the postoperative BCVAs of the PKP and DALK patients were comparable, with no statistically significant differences detected between the total cohort and the subgroup of keratoconus patients. This finding is consistent with previous studies that reported similar visual outcomes for both PKP and DALK [16, 18]. Additionally, in a case series of macular corneal dystrophy in KSA, Al Araj et al. reported a lack of significant differences in postoperative visual outcome in terms of BCVA between PKP and DALK and that both groups of patients demonstrated improvements in BCVA after the operation [19]. However, our study findings contradict those of the systematic review by Henien et al., who reported a statistically significant difference in postoperative BCVA between the PKP group and the DALK group [20]. This difference in findings may have been due to the low to moderate quality of evidence caused by heterogeneity in the study design, outcome measures and follow-up periods. Additionally, our study revealed slightly greater myopic refraction in the DALK group postoperatively, which can be attributed to the size of the donor cornea as well as the high degree of preoperative ametropia in keratoconus patients.

Generally, PKP is considered an efficient and harmless procedure; however, graft failure is a major concern [21]. This concern was also validated in the present study, as three patients in the PKP group experienced graft failure but none in the DALK group did. In the majority of PKP cases, graft failure is attributed to immunological allograft rejection, which leads to the loss of endothelial cells [21, 22]. In DALK patients, however, corneal surface

# Table 4 Baseline characteristics, visual outcomes, and complications of patients with keratoconus

	РКР <i>N</i> =22	DALK N=38	P-value
Preoperative Data			
Sex, n(%)			
Male	17 (77.3)	20 (52.6)	0.0585 **
Female	5 (22.7)	18 (47.4)	0.0585 **
Preoperative BCVA category, %			
• 20/100 or Better	12(57.2)	25(67.6)	0.7282 **
Worse Than 20/100	9(42.9)	21(36.2)	0.7282 **
Donor cornea size, mm, mean (SD)	7.9 (0.29)	8.0 (0.24)	0.0968 ^
Recipient cornea size, mm, mean (SD)	7.7 (0.40)	7.8 (0.28)	0.2139 ^
Preoperative VA, logMAR, mean (SD)	0.9 (0.46)	0.8 (0.40)	0.3669 ^
Preoperative spherical equivalent, diopter, mean (SD)	-3.5 (6.99)	-3.1 (9.03)	0.8938 *
Preoperative cylinder, diopter, mean (SD)	-4.0 (4.88)	-4.9 (1.50)	0.6230 *
6-Month postoperative BCVA			
• 20/100 or better	8 (36.4)	19 (50.0)	0.3062 **
Worse than 20/100	14 (63.6)	19 (50.0)	0.3062 **
Postoperative VA at 6 Months, logMAR, mean (SD)	0.4 (0.30)	0.5 (0.29)	0.0822 ^
Postoperative VA at 12 months, logMAR, mean (SD)	0.4 (0.32)	0.3 (0.22)	0.4618 ^
Postoperative spherical equivalent at 6 months, diopter, mean (SD)	1.1 (3.69)	-0.8 (3.31)	0.3404 *
Postoperative cylinder at 6 months, diopter, mean (SD)	-3.2 (1.73)	-4.9 (1.16)	0.0619 *
Complications			
• Early graft edema	11 (50.0)	11 (28.9)	0.1029 **
• Glaucoma	1 (5.0)	1 (2.9)	1.0000 ^^
Descemet membrane detachment	0	1 (3.1)	1.0000 ^^
Stromal rejection	4 (10.5)	2 (3.6)	0.2174 ^^
Endothelial rejection	4 (10.5)	0	0.2174 ^^
• Keratitis	1 (4.5)	1 (2.6)	1.0000 ^^
Neovascularization	4 (20.0)	8 (26.7)	0.7400 ^^
Scarring	0	2 (6.3)	0.5173 ^^
• Cataract	0	2 (6.3)	0.5173 ^^
• Dry eye	1 (4.5)	11 (31.4)	0.0193 ^^
Graft failure	1 (20.0)	0	0.3333 ^ ^
Satisfaction survey (yes)			
Happy with the graft outcome	21 (77.8)	19 (70.4)	0.8265 ^^
Outcome meets expectations	17 (63.0)	13 (48.1)	0.4399 ^ ^
Would make the same decision to undergo the procedure again	19 (70.4)	21 (77.8)	0.3262 ^^
<ul> <li>Undergoing the procedure was worth it</li> </ul>	20 (74.1)	19 (70.4)	0.4591 ^^
<ul> <li>Had more complications than expected</li> </ul>	5 (18.5)	3 (11.1)	0.7040 ^^
Overall happiness with the graft outcome	23 (85.2)	20 (74.1)	0.6217 ^^

DALK - deep anterior lamellar keratoplasty, PKP - penetrating keratoplasty

\*\* Chi-square test, ^^ Fischer exact test, \* t test, and the ^Kruskal–Wallis test were used to calculate the p value

diseases such as infectious keratitis, limbal stem cell deficiency, and persistent epithelial defects have been shown to be the primary causes of graft failure [23]. Our findings are not consistent with those of Liu et al. [24], who reported similar rates of graft failure in both the PKP and DALK groups. In another study, the rate of endothelial rejection was 18.8% among PKP patients [25, 26]; PKP patients also experience a greater reduction in the number of endothelial cells [27]. This decrease in the endothelial cell count is not usually found in DALK patients because the innate endothelium is preserved during the procedure. In a long-term (5-year) study, the overall rejection rate following DALK varied from 1.7 to 13%, which is much lower than that following PKP [28]. In our investigation, 2 patients in the PKP group with endothelial rejection underwent regrafting, and all graft rejections were reversed with topical steroids. One patient who underwent DALK had to undergo regrafting due to optical failure.

Previous studies have reported a significantly greater incidence of elevated intraocular pressure (IOP) in patients undergoing PKP than in those treated with DALK [29]. In the present study, 13 patients (24.7%) who underwent PKP developed glaucoma; this percentage was much greater than the corresponding proportion in the DALK group (8%). This can be explained by the less invasive nature of DALK and the avoidance of postoperative steroid use in these patients. Other common complications reported in the current study included dry eye, loose suturing, cataracts, neovascularization, early graft edema, and keratitis in both the PKP and DALK groups. These findings are not consistent with those reported by Khattak et al., who described a greater risk of loose sutures in DALK than in PKP. However, the risk of cataracts observed in their study was similar to that reported in the present study [29]. DALK entails a more interesting and challenging technical process, but it also poses a greater risk of intraoperative complications, including the formation of a dual anterior chamber, which might be the main cause of procedure failure [30]. In the present study, DALK was associated with fewer postoperative complications, likely because DALK does not interrupt intraocular eye structures, reducing the risk of postoperative glaucoma, retinal detachment, cataract formation, and expulsive choroidal hemorrhage [19, 31]. Additionally, when the two procedures were compared for patients with keratoconus only, the DALK group had a lower incidence of complications overall.

Here, we evaluated patient satisfaction with the two procedures. 63% of the keratoconus patients in the PKP group and 48% of those in the DALK group reported that the surgical outcome met their expectations. The reports of satisfaction in our study are in line with those of a previous study, which reported similar satisfaction outcomes regarding the safety of these procedures [24]. However, our results differed from those of an earlier study conducted by Yeung et al. [32], who compared the perspectives of patients with a heterogeneous set of corneal diseases (including keratoconus, granular dystrophy, bilateral postinfectious scarring, and old interstitial keratitis) who underwent PKP in one eye and DALK in the contralateral eye. In their study, 8 out of 10 patients favored PKP in terms of vision, with a significantly different overall contentment rate than for the DALK eye (p=0.02). Notably, there were comparable rates of preoperative and intraoperative complications between the two groups of eyes.

#### Limitations

Owing to the retrospective nature of the study and the relative lack of documentation, it was difficult to collect topographic variables and visual quality metrics such as contrast sensitivity and endothelial cell count. While this limitation may affect the depth of analysis, it does not undermine the primary conclusion that DALK offers visual and refractive outcomes comparable to those of PKP, with a lower risk of severe complications. To provide further evidence, future studies with a prospective design and rigorous data collection protocols, including detailed topographic and visual quality assessments are essential. This will allow for a more comprehensive evaluation of long-term outcomes and potential differences between the two procedures. Additionally, differences in surgical technique among surgeons can impact outcomes, potentially confounding the results. A longer follow-up period would provide more insights into longterm outcomes and complications.

# Conclusion

In conclusion, this study offers a comprehensive comparison of PKP and DALK. Our findings suggest that both procedures can be effective in improving visual acuity. However, further research is needed to definitively establish their efficacy. Additionally, patient-reported outcomes, such as quality of life and satisfaction, may provide valuable insights into the overall success of these treatments. Furthermore, fewer postoperative complications were observed with DALK, suggesting the distinct advantages of this procedures in terms of its lower risk of endothelial rejection and graft failure compared to PKP. However, our findings do not lead us to conclude that DALK is ultimately superior to PKP for treating keratoconus. Future studies can build upon these findings to refine surgical approaches and optimize outcomes for patients undergoing corneal transplantation.

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#### Author contributions

Tariq Aldebasi: Data curation, Methodology, Supervision, Writing – original draft, Writing – review & editing, Funding acquisition.Shiji Gangadharan: Data curation, Methodology, Supervision, Writing – original draft, Writing – review & editing, Funding acquisition. Yara Sultan Alshammari: Conceptualization, Data curation, Formal analysis, Investigation, MethodologySahar Salem Alruhaimi: Conceptualization, Data curation, Formal analysis, Investigation, Methodology Sarah Omar Alrashid: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft.Jamila Al Shahrani: Data curation, Methodology, Writing – original draft.Jamila Al Shahrani: Data curation, Methodology, Visualization, Motasim Badri: Formal analysis, Methodology, Writing – original draft.Fahad AlFardan: Data curation, Methodology, Visualization, Alfardan: Data curation, Methodology, Visualization, Methodology, Vi

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#### Data availability

No datasets were generated or analysed during the current study.

#### Declarations

#### Ethics approval and consent to participate

The study was approved by the Institutional Review Board (IRB)/Ethics Committee at the King Abdullah International Medical Research Center, Riyadh, Saudi Arabia. Informed consent was waived because of the retrospective nature of the study.

#### **Consent for publication**

Not applicable.

#### Competing interests

The authors declare no competing interests.

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