ORIGINAL RESEARCH PAPER

Ophthalomology

EPIDEMIOLOGICAL PROFILE AND SURGICAL OUTCOMES OF DEEP ANTERIOR LAMELLAR KERATOPLASTY VERSUS PENETRATING KERATOPLASTY IN ADVANCED KERATOCONUS: A TERTIARY CARE STUDY

KEY WORDS: Keratoconus, Deep Anterior Lamellar Keratoplasty, Penetrating Keratoplasty, Visual Outcome

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ABSTRACT

Background: Keratoconus is a progressive, bilateral, non-inflammatory corneal ectatic disorder characterized by stromal thinning, irregular astigmatism, and progressive visual impairment. While corneal collagen cross-linking has reduced disease progression in many patients, advanced keratoconus still requires surgical intervention. Deep anterior lamellar keratoplasty (DALK) and penetrating keratoplasty (PK) remain the principal surgical options. Aim: To evaluate the epidemiological profile of keratoconus patients and assess the visual and surgical outcomes following DALK and PK in a tertiary care centre. **Methods:** A hospital-based observational study was conducted at the Regional Institute of Ophthalmology and Government Ophthalmic Hospital, Madras Medical College, Chennai. Eighty-four patients with keratoconus were enrolled, and fifteen with advanced disease underwent keratoplasty (seven DALK, eight PK). Best-corrected visual acuity (BCVA), postoperative astigmatism, graft clarity, intraocular pressure, graft rejection, graft failure, and complications were evaluated over one year. Results: Mean age was 21.79 ± 5.16 years, with a slight male predominance (51.2%). Allergic eye disease and chronic eye rubbing were present in 54.8% and 61.9% of patients, respectively. Mean BCVA improved from 0.98 ± 0.24 logMAR preoperatively to 0.16 ± 0.08 logMAR postoperatively. At one year, mean BCVA was 0.154 ± 0.053 logMAR after DALK and 0.19 ± 0.06 logMAR after PK. No graft rejection or graft failure was observed. Conclusion: Both DALK and PK provided excellent visual rehabilitation in advanced keratoconus. DALK demonstrated favorable visual outcomes while preserving the host endothelium, making it an effective alternative to PK in appropriately selected patients.

INTRODUCTION

Keratoconus is a progressive ectatic disorder of the cornea characterized by localized stromal thinning, conical protrusion, irregular astigmatism, and progressive visual impairment (Krachmer et al., 1984; Rabinowitz, 1998). The disease typically presents during the second and third decades of life (Godefrooij et al., 2017) and has a substantial impact on visual function, educational performance, occupational productivity, and quality of life. Recent advances in corneal imaging have shown that keratoconus is considerably more prevalent than previously believed, particularly in Asian populations, where environmental and genetic factors contribute significantly to disease development (Hashemi et al., 2020; Torres Netto et al., 2018).

The pathogenesis of keratoconus is multifactorial and involves a complex interaction between genetic predisposition, biomechanical instability, oxidative stress, inflammatory mediators, chronic eye rubbing, and allergic eye disease (Bawazeer et al., 2000; Galvis et al., 2015; McMonnies, 2009). Environmental factors, particularly ultraviolet exposure and persistent ocular allergy, have been implicated in accelerating disease progression (Bawazeer et al., 2000; McMonnies, 2009). Consequently, early recognition of modifiable risk factors is essential to delay progression and reduce the need for surgical intervention.

Although spectacles and contact lenses remain effective in early disease, progressive corneal ectasia eventually results in visual deterioration that cannot be adequately corrected with conventional optical methods. Corneal collagen cross-linking has transformed the management of progressive keratoconus by stabilizing the cornea (Wollensak et al., 2003); however, advanced disease associated with significant stromal scarring, marked corneal thinning, or contact lens intolerance frequently necessitates keratoplasty (Tan et al., 2012).

Penetrating keratoplasty has historically been regarded as the gold standard surgical treatment for advanced keratoconus because of its excellent long-term visual outcomes and graft survival (Tan et al., 2012). However, the introduction of deep anterior lamellar keratoplasty has shifted the surgical paradigm by preserving the host Descemet's membrane and endothelium, thereby minimizing the risk of endothelial rejection and improving long-term graft survival (Anwar & Teichmann, 2002; Reinhart et al., 2011). Nevertheless, both procedures have distinct indications, technical considerations, and postoperative outcomes that continue to be evaluated in contemporary clinical practice.

Despite numerous international studies comparing DALK and PK, published data from India remain relatively limited (Jonas et al., 2009). Furthermore, regional differences in environmental exposure, allergic eye disease, healthcare accessibility, and patient demographics may influence both disease characteristics and surgical outcomes. Therefore, the present study was undertaken to evaluate the epidemiological profile of keratoconus and compare the visual and surgical outcomes following DALK and PK in patients managed at a tertiary care referral centre.

Materials and Methods

Study Design and Setting

A hospital-based observational study was conducted at the Regional Institute of Ophthalmology and Government Ophthalmic Hospital (RIO-GOH), Madras Medical College, Chennai, over a period of one year (2025–2026). The study evaluated the epidemiological profile of patients with keratoconus and assessed the surgical outcomes following deep anterior lamellar keratoplasty (DALK) and penetrating keratoplasty (PK).

Study Population

A total of 84 patients diagnosed with keratoconus between 10 and 30 years of age were included. Patients were recruited consecutively after satisfying the eligibility criteria. Fifteen patients with advanced keratoconus underwent keratoplasty, comprising seven DALK and eight PK procedures.

Inclusion Criteria

- Clinically diagnosed keratoconus confirmed by corneal topography or Scheimpflug tomography.
- Advanced keratoconus requiring surgical intervention.

- Best-corrected visual acuity worse than 6/24.
- Central corneal thickness less than 500 μm.
- Endothelial cell density greater than 2000 cells/mm²
- Patients willing to participate and provide informed consent.

Exclusion Criteria

Patients with other ocular disorders affecting visual outcomes, including cataract, glaucoma, retinal pathology, amblyopia, non-compliance with follow-up, or unwillingness to participate, were excluded.

Clinical Evaluation

All participants underwent a comprehensive ophthalmic examination including uncorrected and best-corrected visual acuity assessment using Snellen's chart, slit-lamp biomicroscopy, intraocular pressure measurement, retinoscopy, dilated fundus examination, and corneal topography and Scheimpflug tomography. Demographic characteristics and potential risk factors including age, sex, socioeconomic status, allergic eye disease, family history of keratoconus, eye rubbing habits, spectacle use, and contact lens use were recorded using a standardized proforma.

Corneal Assessment

The following corneal parameters were documented preoperatively: maximum keratometry (Kmax), mean keratometry, central corneal thickness, thinnest pachymetry, anterior corneal curvature, posterior corneal elevation, and corneal astigmatism. Disease severity was graded according to the Amsler-Krumeich classification (Krumeich et al., 1998).

Surgical Technique

Patients with advanced keratoconus underwent either DALK or PK based on clinical indications. In the DALK group, partial-thickness trephination followed by stromal dissection was performed. Whenever feasible, the Anwar and Teichmann big-bubble technique was employed to expose Descemet's membrane before placement of the donor button (Anwar & Teichmann, 2002). Patients undergoing PK received full-thickness corneal transplantation with donor graft fixation using interrupted 10-0 nylon sutures.

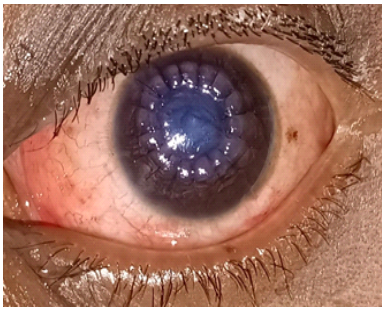


Figure 1: post operative – Left eye Penetrating keratoplasty (PK)

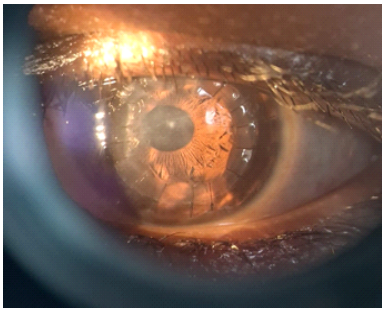


Figure 2 : post operative – Left eye Deep anterior lamellar keratoplasty (DALK)

Postoperative Management

All patients received standard postoperative topical antibiotic-steroid therapy and lubricants. Follow-up examinations were scheduled on postoperative day one, one week, one month, three months, six months, and one year. At every visit, best-corrected visual acuity, graft clarity, intraocular pressure, postoperative astigmatism, graft rejection, graft failure, and other postoperative complications were assessed.

Outcome Measures

The primary outcome measure was postoperative best-corrected visual acuity. Secondary outcome measures included postoperative astigmatism, intraocular pressure, graft clarity, graft rejection, graft failure, recurrence of keratoconus, and postoperative complications.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 25. Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were expressed as frequencies and percentages. Appropriate statistical tests, including the Student's t-test, Chi-square test, and analysis of variance, were used where applicable. A P value < 0.05 was considered statistically significant.

RESULTS

A total of 84 patients diagnosed with keratoconus were included in the study. The mean age of the study population was 21.79 ± 5.16 years (range: 12–30 years). The majority of patients belonged to the 21–25-year age group (35.7%). There was a slight male predominance, with 43 (51.2%) males and 41 (48.8%) females. Fifteen patients with advanced keratoconus underwent keratoplasty, including 7 DALK and 8 PK procedures (Table 1).

Table 1 Baseline Demographic and Epidemiological Characteristics

Characteristic	Value
Total patients	84
Mean age (years)	21.79 ± 5.16
Male	43 (51.2%)
Female	41 (48.8%)
Middle socioeconomic status	39 (46.4%)
Allergic eye disease	46 (54.8%)
History of eye rubbing	52 (61.9%)
Positive family history	18 (21.4%)
Bilateral disease	62 (73.8%)

More than half of the patients had associated allergic eye disease, while nearly two-thirds reported chronic eye rubbing, reinforcing their importance as modifiable risk factors. Bilateral involvement was observed in approximately three-fourths of patients.

Preoperative Clinical Characteristics

The mean maximum keratometry (Kmax) was 58.33 ± 6.12 D, and the mean central corneal thickness was 439.55 ± 59.23 m. The mean preoperative BCVA was 0.98 ± 0.24 logMAR (Table 2).

Table 2 *Preoperative Clinical Characteristics*

Parameter	Mean ± SD
Age (years)	21.79 ± 5.16
Maximum keratometry (D)	58.33 ± 6.12
Mean keratometry (D)	54.50 ± 5.20
Central corneal thickness (μm)	439.55 ± 59.23
Preoperative BCVA (logMAR)	0.98 ± 0.24
Intraocular pressure (mmHg)	14.20 ± 2.80

Surgical Outcomes

Among the fifteen eyes undergoing keratoplasty, eight underwent PK and seven underwent DALK. Both procedures resulted in substantial improvement in postoperative visual acuity. Overall mean postoperative BCVA improved to 0.16 ±

0.08 logMAR. Mean postoperative astigmatism was 1.80 ± 0.72 D, while postoperative intraocular pressure remained within the normal range (15.10 ± 2.10 mmHg). Comparison of preoperative and postoperative BCVA demonstrated a marked improvement following surgery, indicating successful visual rehabilitation in the majority of patients (Table 3).

Table 3 ***Comparison of Postoperative Outcomes Between DALK and PK***

Parameter	DALK (n = 7)	PK (n = 8)
BCVA (logMAR)	0.154 ± 0.053	0.19 ± 0.06
Astigmatism (D)	1.84 ± 0.72	1.90 ± 0.54
IOP (mmHg)	14.8 ± 2.0	15.5 ± 2.3
Graft rejection	0	0
Graft failure	0	0
Recurrence	0	0

Visual outcomes were comparable between the two surgical techniques. Although DALK demonstrated slightly better mean postoperative BCVA, both procedures achieved excellent visual rehabilitation. No graft rejection, graft failure, or recurrence of keratoconus was observed during the study period.

Visual Outcomes During Follow-up

Visual acuity improved progressively in both groups throughout follow-up. Improvement was particularly evident between the third and sixth postoperative months, with stabilization by one year (Table 4).

Table 4 ***Visual Acuity (logMAR) During Follow-up***

Follow-up	DALK	PK
3 months	0.336 ± 0.080	0.339 ± 0.078
6 months	0.191 ± 0.104	0.311 ± 0.058
1 year	0.154 ± 0.053	0.178 ± 0.050

Both DALK and PK demonstrated progressive improvement in BCVA over the one-year follow-up period. DALK showed marginally better visual outcomes at six months and one year; however, both procedures resulted in satisfactory postoperative vision.

Postoperative Complications

Postoperative complications were minimal (Table 5). No cases of graft rejection or graft failure were encountered during the follow-up period. Loose sutures represented the most frequent postoperative complication in both groups. One patient in the DALK group developed interface haze, while one patient in the PK group developed an epithelial defect, both of which were managed conservatively.

Table 5 ***Postoperative Complications***

Complication	DALK	PK
Loose sutures	2	2
Epithelial defect	0	1
Interface haze	1	0
Graft rejection	0	0
Graft failure	0	0

DISCUSSION

The present hospital-based observational study evaluated the epidemiological characteristics of keratoconus and compared the surgical outcomes following deep anterior lamellar keratoplasty (DALK) and penetrating keratoplasty (PK). The findings demonstrated that keratoconus predominantly affected young adults and that both surgical procedures resulted in significant improvement in visual acuity with excellent graft survival over one year.

The mean age of the study population was 21.79 ± 5.16 years, with the highest proportion of patients belonging to the 21–25-year age group. This finding is consistent with the established natural history of keratoconus, which typically manifests during adolescence and progresses through the second and third decades of life. Chung et al. (2024) reported the highest incidence among individuals aged 20–29 years, while Godefrooij et al. (2017) similarly observed that disease progression is greatest during adolescence and early adulthood. The relatively young age profile in the present study highlights the importance of early detection and timely intervention to prevent irreversible visual impairment.

A slight male predominance (51.2%) was observed, although the gender distribution was nearly equal. Comparable findings have been reported by Pearson et al. (2000), whereas Gordon-Shaag et al. (2012) concluded that sex distribution varies across different geographical populations. These differences may reflect variations in environmental exposure, healthcare-seeking behavior, and referral patterns rather than a true biological predisposition.

More than half of the patients had allergic eye disease (54.8%), and 61.9% reported chronic eye rubbing. These findings support previous studies identifying allergy and habitual eye rubbing as major modifiable risk factors for disease progression. Bawazeer et al. (2000) demonstrated a strong association between atopy and keratoconus, while McMonnies (2009) suggested that repetitive mechanical trauma causes stromal microdamage, keratocyte apoptosis, and progressive biomechanical weakening. The high prevalence of these risk factors in our study emphasizes the need for early treatment of ocular allergy and patient education regarding avoidance of eye rubbing.

The mean preoperative Kmax of 58.33 D and central corneal thickness of 439.55 m indicated advanced disease in the surgical cohort. These findings are comparable with previous reports describing keratoplasty candidates as having marked corneal steepening and stromal thinning before surgery. Such parameters continue to play an important role in surgical decision-making and prognosis.

One of the principal findings of this study was the significant improvement in postoperative visual acuity. Mean BCVA improved from 0.98 ± 0.24 logMAR preoperatively to 0.16 ± 0.08 logMAR following keratoplasty, confirming that both DALK and PK provide effective visual rehabilitation in advanced keratoconus. Progressive improvement throughout the follow-up period reflects gradual wound healing, reduction in postoperative astigmatism, and stabilization of the graft-host interface.

When both surgical procedures were compared, DALK demonstrated slightly better mean BCVA at one year (0.154 logMAR) than PK (0.19 logMAR), although both procedures achieved excellent visual outcomes. This observation is consistent with the systematic review by Reinhart et al. (2011), who concluded that DALK provides visual outcomes comparable to PK while preserving the host endothelium. Similarly, Kubaloglu et al. (2012) and Javadi et al. (2010) reported that DALK offers equivalent postoperative vision with substantially lower endothelial complications.

No cases of graft rejection or graft failure were observed in either group during the one-year follow-up. Although the follow-up duration was relatively short, this finding reflects meticulous surgical technique, careful patient selection, and close postoperative monitoring. The preservation of the host endothelium in DALK theoretically eliminates endothelial rejection, one of its major advantages over PK. Our findings are in agreement with Borderie et al. (2012), who demonstrated superior long-term endothelial survival following DALK.

Postoperative complications were infrequent and generally minor. Loose sutures were the most common complication in both groups, while one patient developed interface haze

following DALK and another developed an epithelial defect after PK. Both complications resolved with appropriate management and did not adversely affect the final visual outcome. Importantly, no recurrence of keratoconus was observed during the follow-up period.

The strengths of the present study include prospective data collection, standardized clinical evaluation, and direct comparison of the two commonly performed keratoplasty techniques in a tertiary referral centre. However, several limitations should be acknowledged. The number of patients undergoing keratoplasty was relatively small, particularly within each surgical subgroup, thereby limiting statistical power. In addition, endothelial cell density and corneal topographic outcomes were not evaluated during follow-up, and the follow-up period was limited to one year. Future studies with larger sample sizes, longer follow-up, and incorporation of endothelial cell counts and tomographic parameters would provide more comprehensive evidence regarding long-term graft survival and visual outcomes.

CONCLUSION

Both DALK and PK provided excellent visual rehabilitation in advanced keratoconus. DALK demonstrated favorable visual outcomes while preserving the host endothelium, making it an effective alternative to PK in appropriately selected patients. Early diagnosis and timely surgical intervention remain essential for achieving optimal visual outcomes. While both procedures produced excellent visual rehabilitation, DALK offers the additional advantage of preserving the host endothelium, making it an attractive option in eyes with healthy Descemet's membrane and endothelium.

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