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CLINICAL OUTCOMES AFTER DEEP ANTERIOR LAMELLAR KERATOPLASTY AND PENETRATING KERATOPLASTY FOR KERATOCONUS – A COMPARATIVE STUDY

Dr. Jyoti Meena	Senior Resident, Department of Ophthalmology, Rajkiya Bhagwan Das Khetan (BDK) District Hospital, Government Medical College, Jhunjhunu, Rajasthan-333001.
Dr. Sukriti Upadhyay	Assistant Professor, Department of Ophthalmology, Himalayan Institute of Medical Sciences, Swami Rama Himalayan University (SRHU), Jollygrant, Dehradun, Uttrakhand – 248016.
Dr. Udit Raj Sharma	Assistant Professor, Department of Ophthalmology, Himalayan Institute of Medical Sciences, Swami Rama Himalayan University (SRHU), Jollygrant, Dehradun, Uttarakhand – 248016.
Dr. Rajesh Goyal*	Professor, Department of Ophthalmology, SMS Medical College and Attached Group of Hospitals, Jaipur, Rajasthan-302001* Corresponding Author

ABSTRACT **Purpose:** To evaluate and compare the clinical outcomes of Deep Anterior Lamellar Keratoplasty (DALK) Penetrating Keratoplasty (PK) in keratoconus patients, providing insights into the efficacy, safety, and long-term benefits of each surgical technique. **Design:** Prospective observational comparative study **Methods:** This study was carried out over a period of one year involving 80 patients diagnosed with advanced keratoconus with 30 eyes in each group who underwent DALK and PK. Best corrected visual acuity (BCVA), refractive status (astigmatism), endothelial cell loss and central corneal thickness (CCT) were recorded in both the groups on the 1st postoperative day, weekly for the first month, biweekly for the second month, and then monthly until the 6th month. **Results:** From Day 1 to week 24th, the DALK group had lower mean BCVA (LogMAR) values ($p< 0.05$). With respect to CCT, there was no statistically significant difference between the two groups at any time point. Throughout the follow up period, PK group consistently showed significantly lower endothelial cell counts as compared to the DALK group ($p< 0.05$) and higher levels of astigmatism as compared to the DALK group. **Conclusion** DALK consistently offers superior visual acuity improvement as compared to PK over time in keratoconus. The DALK procedure also maintains more favorable corneal endothelial cell counts, indicating potentially less risk of endothelial cell loss.

KEYWORDS : Keratoconus, Deep Anterior Lamellar Keratoplasty, Penetrating Keratoplasty.

INTRODUCTION

Keratoconus is a progressive, non-inflammatory condition characterized by the thinning and conical deformation of the cornea. The condition typically presents during adolescence or early adulthood and progresses over a period of 10-20 years, potentially leading to severe visual disability if left untreated. Various therapeutic options have been explored to manage keratoconus, ranging from conservative treatments such as spectacles and contact lenses to surgical interventions like corneal collagen cross-linking (C3R), intracorneal ring segments, and corneal transplantation.[1]

Among the surgical options, corneal transplantation remains a cornerstone in the management of advanced keratoconus, where other treatments fail to provide adequate visual acuity. Two primary techniques for corneal transplantation in keratoconus are DALK (Deep Anterior Lamellar Keratoplasty) and PK (Penetrating Keratoplasty). DALK involves the selective replacement of the corneal stroma while preserving the recipient's Descemet's membrane (DM) and endothelium, thus reducing the risk of graft rejection and endothelial cell loss. On the other hand, PK involves the full-thickness replacement of the cornea, providing a more straightforward surgical procedure but with a higher risk of endothelial rejection and complications related to the entire corneal layer. [2]

The choice between DALK and PK depends on various factors, including the extent of corneal thinning, scarring, and the surgeon's expertise. The comparative clinical outcomes of these two procedures have been a subject of ongoing research, focusing on visual acuity, refractive outcomes, graft survival, and complication rates. Understanding these outcomes is crucial for optimizing the management of keratoconus and improving patients' quality of life. [3]

METHODS

This hospital based prospective observational comparative study was carried out over a period of one year in the Department of Ophthalmology, Sawai Man Singh (SMS) Medical College, Jaipur. This study was approved by the Institutional Ethics Committee and conducted in accordance with the tenets of the Declaration of Helsinki after taking written informed consent from each participant. The study included total 80 patients with 30 eyes in each group, i.e. DALK and PK group presenting to the out-patient department. The study population included all patients diagnosed with keratoconus with corneal thickness < 360 µm and keratometry reading (K) >48.2 D. Patients in whom other treatments like C3R were not possible or failed those with contact lens intolerance or inability to fit due to excessive ectasia and those with best corrected visual acuity BCVA < 1 LogMAR unit were also included.

Patients with glaucoma, amblyopia, any previous ocular surgery, severe dry eye, peripheral ulcerative keratitis, endothelial cell dysfunction, steroid-induced cataract, vernal keratoconjunctivitis or retinal pathologies were excluded from the study.

Preoperative evaluation included ocular history in addition to medical and family history. A thorough ocular examination including assessment of BCVA (LogMAR), refractive status by automated refractometer, corneal topography, specular microscopy was performed.

All the surgeries were performed by a single experienced surgeon. DALK was performed with the use of big bubble technique. During follow up, patients underwent comprehensive examination including visual acuity and specular microscopy on the 1st postoperative day, weekly for the first month, biweekly for the second month, and then monthly until the 6th month. All readings were recorded by a single observer to minimize bias both preoperatively and postoperatively. Parameters recorded were BCVA (LogMAR), refractive status (astigmatism), endothelial cell loss and central corneal thickness (CCT).

RESULTS

The mean age in the DALK and the PK group was 21.27 ±4.46 years and 22 ±4.10 years, respectively ($p=0.29$). 36.7% of participants in the DALK group were females as compared to 33.3% in the PK group, while 63.3% of participants in the DALK group were males as compared to 66.7% in the PK group($p=0.78$). 30.0% of participants in the DALK group were aged ≤20 years compared to 26.7% in the PK group, 46.7% of participants in the DALK group were aged 21-25 years compared to 53.3% in the PK group, and 23.3% of participants in the DALK group were aged >25 years compared to 20.0% in the PK group($p=0.874$).

BCVA (LogMAR) at different time intervals between the DALK and PK groups showed that there was no statistically significant difference pre- operatively. However, postoperatively from 1st day to week 24th, the DALK group consistently demonstrated significantly better visual outcomes as compared to PK group, as indicated by mean BCVA (LogMAR) values, with p-values less than 0.05 at each postoperative time point. **(Table 1)**

CCT at different time intervals between the DALK and PK groups showed no statistically significant differences at any time point, with all p-values being greater than 0.05 indicating that both procedures resulted in comparable corneal thickness over time. **(Table 2)**

Endothelial cell counts at different time intervals revealed no significant differences pre-operatively (p=0.758). However, postoperatively from 1st day to week 24th, the PK group consistently showed significantly lower endothelial cell counts as compared to the DALK group, with p-value less than 0.05 at each postoperative time point indicating that the PK procedure was associated with greater endothelial cell loss over time as compared to the DALK procedure. **(Table 3)**

The comparison of astigmatism between the two groups revealed no significant difference on postoperative day 1st. (p=0.075) However, postoperatively from 1st week to week 24th, the PK group consistently had significantly higher levels of astigmatism as compared to the DALK group, with p-values of 0.027, 0.016, 0.001, and 0.001, respectively. This suggested that the PK procedure resulted in higher degree of astigmatism over time as compared to the DALK procedure. **(Table 4)**

The complications in the DALK and PK groups showed that subepithelial opacification occurred in 2 patients(6.7%) of the DALK group as compared to none in the PK group (p=0.472). Endothelial graft rejection was observed in 3 patients (10.0%) of the PK group but none in the DALK group (p=0.236). Double anterior chamber occurred in 3 patients (10.0%) of the DALK group (p=0.236) while DM folds were seen in 8 patients (26.6%) in the PK group and 3 patients (10%) in the DALK group (p=0.182). IOP elevation was noted in only 2 patients (6.7%) in the DALK group as compared to 10 patients (33.3%) in the PK group (p=0.024). Conversion to PK was required in 2 patients (6.7%) in DALK group. (p=0.472). Cataract formation was seen in 1 patient (3.3%) in DALK group and 4 patients (13.3%) in the PK group (p=0.350). Overall, subepithelial opacification occurred more commonly in the DALK group, but endothelial graft rejection, IOP elevation, double anterior chamber, and DM folds were more common in the PK group. **(Table 5)**

DISCUSSION

30% of participants were 20 years or younger, 46.7% were between 21 and 25 years and 23.3% were older than 25 years in the DALK group. Similarly, in the PK group, 26.7% were 20 years or younger, 53.3% were between 21 and 25 years, and 20.0% were older than 25 years. Overall, majority of the patients were below 25 years. Compared to other studies conducted by Egrilmez S [4], Wagoner MD [5] and Mahmood MA [6] et al, our study population was younger, with a narrower age range, reflecting local patient demographics and early disease detection. The similarity in age trends across studies suggested that both DALK and PK are commonly performed in younger patients with keratoconus.

The patients who underwent DALK had significantly better visual outcomes than who underwent PK at various postoperative intervals, with better mean BCVA values ($p<0.05$), indicating superior improvements. Dhakad et al [7] observed significant improvements in DALK, with preoperative BCVA of -1.106 ± 0.160 improving to 0.495 ± 0.127 by 12 months ($p\leq0.001$). Funnell et al [8] reported that at 6 months, both DALK and PK groups achieved a median BCVA of 6/9, but at 12 months, PK improved to a median BCVA of 6/6 (range: 6/5–6/60), while DALK remained at 6/9 (range: 6/5–6/24).

No significant differences were found in CCT between the DALK and PK groups at various time intervals, with all p- values exceeding 0.05. This indicated that both the surgical procedures yield similar outcomes with respect to corneal thickness. Shimazaki et al. reported that while there were no significant differences in corneal topography between DALK and PKP patients postoperatively. [9] Dhakad et al demonstrated a notable improvement in CCT among keratoconus patients undergoing DALK, with preoperative values of 370.625 ± 24.205 µm increasing to postoperative values of 502.500 ± 9.993 µm at 3 months and gradually stabilizing at 492.843 ± 14.438 µm by 12 months. [7]

The PK group consistently showed significantly lower mean endothelial cell counts as compared to the DALK group at each postoperative visit. ($p<0.05$) Panda et al reported mean endothelial cell counts of 2,233.3 ± 64.453 cells/mm² at 6 months and 2,219.6 ± 102.48 cells/mm² at 1 year after DALK, showing no significant differences. [10] Reinhart et al highlighted that endothelial cell density stabilized within 6 months after DALK and consistently remained higher than in PK groups, with significant differences observed at all time points beyond 6 months. [11] These findings collectively reinforce the notion that DALK may offer better preservation of endothelial cells compared to PK.

No significant difference in the mean astigmatism was observed on Day 1 ($p= 0.075$) between the two procedures, the PK group demonstrated significantly higher levels of astigmatism on all subsequent postoperative visits. ($p<0.05$) Funnell et al found higher degree of mean astigmatism in the PK group (5.0 D) compared to the DALK group (3.1 D) at 12 months ($p = 0.022$). [8] Similarly, Panda et al observed that 83% of DALK eyes had astigmatism under 3D, compared to 33% of PK eyes. At 1-year, 20 DALK eyes had astigmatism <3D, whereas more PK eyes (5D or more) were reported ($p < 0.001$). [10] Dhakad et al. recorded a progressive decline in astigmatism from 3.968 ± 1.046 D preoperatively to 2.015 ± 0.677 D by 12 months after DALK, showing significant improvement. [7] This reflected that DALK results in better astigmatism outcomes as compared to PK, likely due to the residual stroma and Descemet's membrane providing greater graft stability and alignment.

As far as the postoperative complications were concerned, subepithelial opacification occurred more commonly in the DALK group, but endothelial graft rejection, IOP elevation, double anterior chamber, and DM folds were predominantly seen in the PK group. Conversion to PK was required in 2 patients (6.7%) in DALK group. Fontana et al reported comparable visual outcomes between DALK (using the big- bubble technique) and PK groups but found that 11.3% of DALK cases had stromal or epithelial rejection, and 1.8% required regrafting. [12] Romano et al highlighted that eyes achieving successful big-bubble dissection in DALK showed better BCVA, with only 1 case of mild stromal rejection, whereas 18 out of 159 DALK eyes (11.3%) had some rejection episode. [13] Funnell et al observed small DM perforations in 3 DALK cases but reported no graft failures, whereas the PK group had 3 graft rejections (13.6%) and 1 graft failure due to infective keratitis. [8] Shimazaki et al found that IOP was significantly elevated in the PK group at 12 months ($p = 0.004$), while DALK maintained stable pressures ($p = 0.41$). Additionally, endothelial density in PK patients decreased progressively, with a significant difference at 24 months ($p = 0.04$), supporting better endothelial preservation in DALK. [9] Studies on PK by Egrilmez S [4], Wagoner MD [5]and Mahmood MA et al [6] reported graft rejection rates of 4.3%, 13.3%, and 12.5%, respectively, with complications like glaucoma (8.7%) and cataract (17.4%) being more common in PK patients. These observations reinforce DALK's safety profile, with fewer IOP elevations, better endothelial preservation, and a lower risk of rejection compared to PK.

The study had some limitations. A small sample size and single-centre data do not allow for generalisability. The short follow-up duration may not capture long-term complications or outcomes such as graft rejection, late astigmatism, or changes in visual acuity over time. The study focused on clinical outcomes such as visual acuity and endothelial cell loss but does not assess patients' quality of life or functional vision, which are important in evaluating the overall impact of surgery.

CONCLUSION

Both DALK and PK demonstrate effective outcomes in treating keratoconus, DALK consistently offers superior visual acuity improvement as compared to PK over time. The DALK procedure also maintains more favourable corneal endothelial cell counts, indicating potentially less risk of endothelial cell loss. PK, on the other hand, is associated with higher levels of astigmatism as time progresses and presents more challenges with higher endothelial graft disease and certain corneal complications.

Tables

Table 1: Comparison of BCVA (LogMAR) at different time interval between both groups

Group	DALK		PK		p-value
	Mean	SD	Mean	SD	
Preoperative	1.29	0.13	1.29	0.23	0.108
Day 1	1.07	0.07	1.07	0.09	0.001
Week 1	1.07	0.07	1.04	0.16	0.002
Week 4	0.78	0.12	0.96	0.13	0.014
Week 12	0.65	0.10	0.87	0.14	0.025
Week 24	0.56	0.11	0.83	0.13	0.001

Table 2: Comparison of CCT (µ) at different time interval between both groups

Group	DALK		PK		p-value
	Mean	SD	Mean	SD	
Preoperative	348.87	8.22	349.80	9.19	0.437
Day 1	545.87	4.72	545.83	4.94	0.826
Week 1	544	4.18	544.93	4.43	0.178
Week 4	541.37	4.80	543.63	4.66	0.171
Week 12	540.50	5.11	542.23	4.52	0.078
Week 24	539.07	5.08	540.93	4.46	0.358

Table 3: Comparison of endothelial cell count (cells/mm^2) at different time interval between both groups

Group	DALK		PK		p-value
	Mean	SD	Mean	SD	
Preoperative	2190.667	113.65	2132.1	126.45	0.758
Day 1	2151.83	70.84	2061.93	127.35	0.001
Week 1	2119.9	62.55	2010	122.35	0.001
Week 4	2100.1	63.90	1971.16	115.81	0.001
Week 12	2071.133	64.85	1951.86	118.13	0.001
Week 24	2046.767	60.08	1888.43	118.75	0.001

Table 4: Comparison of postoperative astigmatism (dioptres) at different time interval between both groups

Group	DALK		PK		p-value
	Mean	SD	Mean	SD	
Day 1	4.62	0.64	5.68	0.49	0.075
Week 1	4.2	0.57	5.50	0.45	0.027
Week 4	4.05	0.56	5.38	0.48	0.016
Week 12	3.77	0.60	5.30	0.44	0.001
Week 24	3.40	0.53	5.18	0.44	0.001

Table 5: Comparison of postoperative complications between both groups

Complication	DALK		PK		p-value
	Count	Percent	Count	Percent	
Subepithelial opacification	2	6.7	0	0	0.472
Endothelial graft rejection	0	0	3	10	0.236
Double anterior chamber	3	10	0	0	0.236
DM folds	3	10	8	26.6	0.182
IOP elevation	2	6.7	10	33.3	0.024*
Need for conversion to PK	2	6.7	0	0	0.472
Cataract formation	1	3.3	4	13.3	0.350

(* Indicate significance at $p<0.05$)

(Due to the presence of cells with expected frequencies less than 5, Yates' continuity correction was applied to the chi-squared test to ensure the accuracy and reliability of the results.)

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