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Clinical characteristics and risk factors for readmission after deep anterior lamellar keratoplasty: a nationwide, cross-sectional, multicenter study

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Abstract

Background To assess the incidence, cause and risk factors for unplanned readmission within 90 days after deep anterior lamellar keratoplasty (DALK).

Methods A multicentre cross-sectional study of 3603 eyes of 3588 patients after keratoplasty between January 1st, 2019, and September 30th, 2021 in 16 hospitals across China was performed. The demographic and clinical features between patients after DALK with 90-day unplanned readmission and those who did not have been compared. The risk factors of unplanned readmission were identified by a multivariable Cox regression model.

Results Among 873 patients (878 eyes) after DALK, and the primary indications for DALK were keratitis (391 eyes, 44.53%) and keratoconus (275 eyes, 31.32%). The rates of unplanned readmission within 30 days, 60 days, and 90 days were 1.95%, 4.01%, and 5.15%. The main reason of 90-day readmission was infectious keratitis (18 eyes, 40.00%), followed by corneal epithelial defects (11 eyes, 24.44%) and immune-related keratitis (10 eyes, 22.22%). Patients readmitted within 90 days exhibit a more advanced age ($p=0.013$). It is also more concentrated in patients with corneal ulcers or perforations ($p=0.029$) or blindness ($p=0.02$). Compared with patients with keratoconus, patients with keratitis (HR = 3.545, 95% CI 1.104–11.386, $p=0.034$) and corneal degeneration or malnutrition (HR = 6.470, 95% CI 1.942–21.560, $p=0.002$) are more likely to have an unplanned readmission risk within 90 days.

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Conclusion The main causes of unplanned readmission within 90 days after DALK were infectious keratitis, corneal epithelial defects, and immune-related keratitis. The indications for DALK were associated with 90-day readmissions.

Clinical trial number Not applicable.

Keywords Deep anterior lamellar keratoplasty, Unplanned readmission, Risk factors

Background

According to World Health Organization(WHO) data, corneal diseases were identified as the fifth leading cause of global blindness in 2015 [1], particularly in developing countries [2, 3]. As a refined therapeutic keratoplasty, deep anterior lamellar keratoplasty (DALK) preserves the healthy host endothelium while selectively replacing pathological corneal stroma, which is frequently employed in the treatment of infectious keratitis, keratoconus and corneal scars [4–6].

Compared with penetrating keratoplasty (PK), DALK establishes an anatomically continuous graft-host interface that significantly improves visual acuity outcomes, while improving the long-term graft survival rate through avoidance of endothelial rejection and host endothelial cell loss [7–10]. Furthermore, it effectively reduces the severe complications of open intraocular surgery, requires a shorter duration of postoperative corticosteroid use, exhibits greater resistance to globe rupture after blunt trauma, facilitates earlier suture removal. Lastly, DALK allows for one or multiple individuals to share a single donor cornea that optimizing the utilization of corneal tissue resources [11]. However, a meta-analysis in 2016 indicated that lamellar keratoplasty (LK) comprised only 29.7% of all keratoplasty procedures globally, with 31 countries (33%) reporting no implementation of LK [12]. In conclusion, due to its higher surgical skill requirements and longer learning curve for surgeons, the current implementation of this technique remains somewhat limited [13].

However, DALK is also associated with the risk of graft failure attributable to postoperative complications such as infection, delayed corneal re-epithelialization, epithelial and stromal rejection, recurrence of primary diseases, and persistent double anterior chamber and graft-host interface problems (opacification, irregularity and/or neovascularization) [14, 15]. In severe cases, patients necessitate unplanned rehospitalization, including some requiring multiple keratoplasties [16]. Unplanned rehospitalization significantly impacts both individual patients and the healthcare system, negatively influencing resource utilization and increasing expenditure [17]. It also serves as a pivotal benchmark widely used internationally to assess healthcare quality and service levels [18–20]. A study conducted in the United States from 2007 to 2011 revealed that readmissions cost the U.S. government over $17 billion annually [21], with up to three-quarters of readmissions being preventable [22]. The majority of studies on hospital readmissions are unrelated to ophthalmology [23–26], however, a study on 30-day unplanned readmissions in pediatric ophthalmology in the Middle East in 2015 revealed that three of the top five reasons for readmission were related to complications following corneal suturing, typically in the context of keratoplasty [27]. This highlights that patients undergoing keratoplasty are at an elevated risk of readmission in ophthalmology, necessitating enhanced post-discharge follow-up and attention. Current research has affirmed that surgery-related complications are the primary cause of unplanned rehospitalization postoperatively [28, 29], effective strategies in this area can contribute to improving healthcare quality and alleviating economic burdens.

Currently, existing studies often focus on postoperative complications in DALK patients and the graft survival rate several years later [30–37]. However, unplanned readmissions within 90 days following deep anterior lamellar keratoplasty typically indicate severe postoperative complications, including but not limited to infections, graft rejection, or even necessitating repeat keratoplasty or enucleation. These high-risk events not only adversely affect visual prognosis but also exacerbate the strain on scarce corneal donor resources. Therefore, this study aims to evaluate the incidence of unplanned readmissions within 30 days, 60 days, and 90 days after DALK, describe the clinical characteristics and reasons for readmission, and identify the risk factors related to 90-day readmission.

Methods

Study design and participants

As a multicenter, retrospective, observational study conducted in 16 tertiary hospitals in 15 provinces across China. All patients who underwent keratoplasty between January 1^{st,} 2019, and September 30th, 2021 were consecutively included, the admission associated with the first keratoplasty procedure was considered the index admission, while those patients who missing crucial medical record data(admission records, discharge records and surgery record) were excluded. We selected patients after DALK for further analysis. DALK is defined as the keratoplasty that removes the complete stroma while leaving behind only bare Descemet's membrane and endothelium. We divided the patients into two groups: those who readmitted within 90 days after discharge due

to post-DALK complications, and those who did not. A comparison of demographic and clinical characteristics between the groups was performed, along with an analysis of associated risk factors. Rehospitalization medical records were collected from the same hospitals within 90 days after index admission to describe the cause for readmission. If patients were readmitted multiple times during this period, only the first readmission were included for retrospective analysis.

The study was approved by the ethics committee of Eye Hospital, Wenzhou Medical University, Zhejiang, China (approval no.2020-217-K-197-01). Otherwise, the study protocol was approved by the ethics committee at each participating centre, the study used data collected from inpatient medical records while maintaining patient anonymity, and the institutional review board approved waiver of patient informed consent.

Data collection, handling, and storage

Clinical data were collected by one or more trained physicians in each center from inpatient medical records (paper or electronic). Specific data collection items include demographics characteristics (age, gender, residence, ethnicity, healthcare insurance payment status and others), disease diagnoses (admission and discharge), clinical characteristics (vision acuity, corneal signs, course of disease, the length of hospitalization and others), past medical history (history of ocular diseases, ocular surgeries, ocular trauma, systemic diseases and others), test and examinations, treatment choices and medical costs. The corresponding medical records data were entered into an Electronic Data Capture (EDC) platform specifically created for this study (https://www.realdata.net.cn/). A standardized Case Report Form (CRF) specific to this study has been preloaded onto the platform. All center-specific medical records are numbered and entered following the prescribed steps mentioned above. The platform's backend system harmonizes the structured data forms and exports the data in a unified manner. All collected data align with the medical records stored in each center's archives, ensuring traceability.

Outcomes

The incidence and reasons for unplanned readmission within 90 days after DALK were the main outcomes of this study. The clinical features and risk factors associated with unplanned readmission within 90 days after DALK were secondary outcomes.

Statistical analysis

SPSS software version 25.0 was used for statistical analysis. Descriptive statistics were used to summarize the data. Continuous variables following a normal distribution were expressed as mean ± standard deviation, while non-normally distributed variables were presented as median. Categorical variables were reported as proportions. For normally distributed count data, t-tests were used for comparisons. The Mann-Whitney U test is utilized to examine non-normally distributed count data. Chi-square test were used for categorical count data. To identify the risk factors associated with unplanned readmission within 90 days after DALK, univariate Cox regression analysis were conducted to screen for independent variables firstly. Variables with a p-value < 0.05 were included in the multivariate Cox regression analysis. The Log-Rank test (Mantel-Cox test) was utilized to compare the non-readmission rates of the two groups. In all analyses, a p-value < 0.05 was considered to be statistically significant.

Results

Centres and the number of deep anterior lamellar keratoplasty

3588 patients (3603 eyes) after keratoplasty were included in this study. Among these clinical centers, 7 were specialized eye hospital, and 9 were general hospitals. Furthermore, based on the classification of Chinese three economic regions, 6 centers were located in the western region, 4 in the middle region, and 6 in the eastern region (Supplemental Fig. 1).

Among them, 878 cases were DALK, accounting for 24.37% of the total. The number and proportion of DALK varied greatly among different regions, the proportion of DALK in hospitals in the eastern region was 31.60%, 17.29% in the middle region, and 20.69% in the western region (Supplemental Table 1).

Baseline characteristics of deep anterior lamellar keratoplasty patients

Table 1 shows the demographic characteristics of the patients. In this study, the majority of DALK patients were male (574, 65.75%), and the median (interquartile range) age was 41 (22,57) years. The majority of patients were of the Han nationality (851, 97.48%), resided in rural areas (551, 63.12%), and were covered by medical insurance (446, 51.09%). Compared to those in the non-readmission group, the group of unplanned readmission within 90 days was significantly older ($p = 0.013$).

The indications for deep anterior lamellar keratoplasty

The study included a total of 873 DALK patients with 878 eyes, among which 39 eyes (4.44%) underwent repeat keratoplasty. As shown in Fig. 1, the main indications for DALK were keratitis (391 eyes, 44.53%), followed by keratoconus (275 eyes, 31.32%), corneal degeneration or dystrophy (88 eyes, 10.02%), corneal tumors (60 eyes, 6.83%), corneal injuries (45 eyes, 5.13%), and others (19

Table 1 Demographic characteristics of the deep anterior lamellar keratoplasty patients

Characteristic	DALK patients (*N* = 873)		Unplanned readmission within 90 days				*P*-Value[a]
			Yes(*N* = 45)		No(*N* = 828)		
Sex, *n*(%)							
Male	574	65.75	32	71.11	542	65.46	0.436
Female	299	34.25	13	28.89	286	34.54	
Age, y	41(22,57)		52(32,67)		39(22,57)		0.013*
Age, *n*(%)[b]							
Children	73	8.36	5	11.11	68	8.21	0.684
Adolescents	90	10.31	0	0.00	90	10.87	0.037*
Adults	306	35.05	9	20.00	297	35.87	0.03*
Middle-agers	280	32.07	19	42.22	261	31.52	0.134
Elderly	124	14.20	12	26.67	112	13.53	0.014*
Ethnicity, *n*(%)							
Han	851	97.48	45	100.00	806	97.34	0.536
Others	22	2.52	0	0.00	22	2.66	
Residence, *n*(%)[c]							
City	321	36.77	20	44.44	301	36.35	0.276
Rural	551	63.12	25	55.56	526	63.53	
Medical Insurance, *n*(%)[d]							
Yes	446	51.09	24	53.33	422	50.97	0.492
No	412	47.19	18	40.00	394	47.58	
Area, *n*(%)							
Eastern	451	51.66	17	37.78	434	52.42	0.056
Middle	125	14.32	8	17.78	117	14.13	0.496
Western	297	34.02	20	44.44	277	33.45	0.13

Abbreviations: DALK = deep anterior lamellar keratoplasty

[a] *p*-value of the comparison between patients with 90-day readmission and non-readmission

[b] Children are defined as individuals aged 12 and below, adolescents are aged between 13 and 18, adults are aged between 19 and 44, Middle-agers are aged between 45 and 64, and elderly are those aged 65 and above

[c] 1 data is missing for the residence distribution

[d] 15 data were missing for the medical insurance

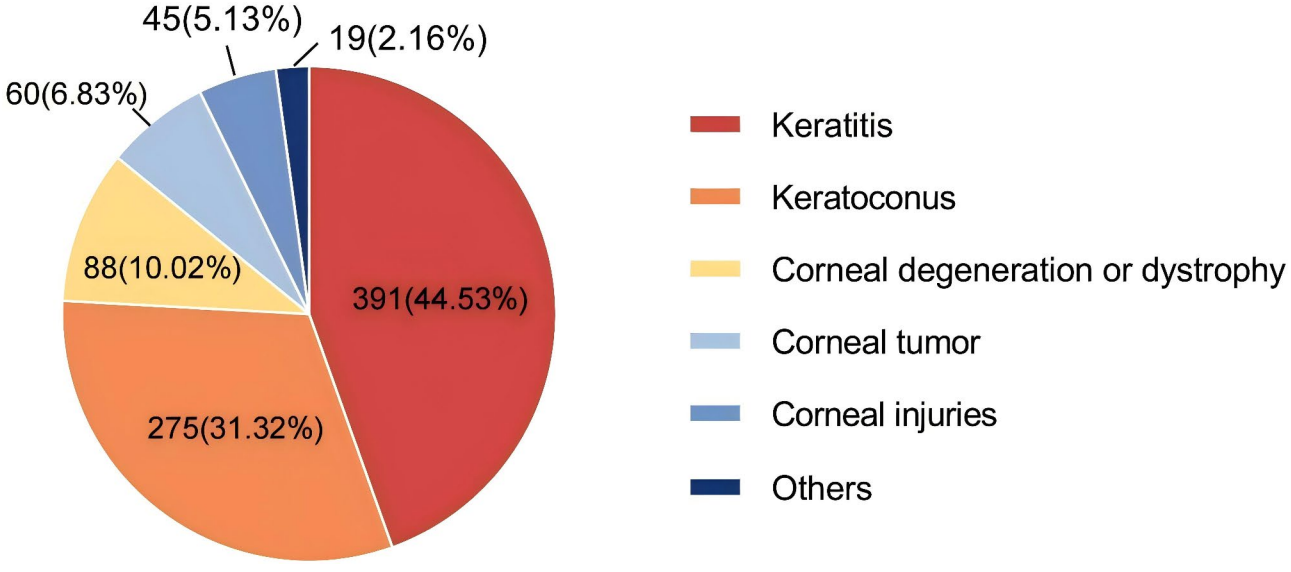

Fig. 1 Distribution of the indications for deep anterior lamellar keratoplasty (number of eyes, %)

eyes, 2.16%). The specific disease classification of indications are shown in Supplemental Table 2.

Unplanned readmission rates within 30 days, 60 days, and 90 days after deep anterior lamellar keratoplasty

The unplanned readmission rate within 30 days was 1.95%, within 60 days was 4.01%, and within 90 days was 5.15%. The number of unplanned readmissions reached half of the 90-day total on the 38th day, showing an overall increasing trend followed by a stable phase (Supplemental Fig. 2).

The unplanned readmission rates varied among different indications for DALK, as shown in Fig. 2. The unplanned readmission rates within 90 days, from highest to lowest, were corneal degeneration or dystrophy (9.41%), keratitis (7.16%), corneal injuries (6.67%), corneal tumor (3.33%), and keratoconus (1.47%).

Causes of unplanned readmission within 90 days after deep anterior lamellar keratoplasty

There were 45 patients with 45 eyes who had unplanned readmissions within 90 days in this study. As shown in Fig. 3, infectious keratitis was the most common cause of readmission (18 eyes, 40.00%), followed by corneal epithelial defects (11 eyes, 24.44%) and immune-related keratitis (10 eyes, 22.22%). Additionally, other causes of readmission were the presence of a Descemet membrane or endothelium detachment (2 eyes, 4.44%), loose sutures or removal of sutures (2 eyes, 4.44%), trauma (1 eye, 2.22%), and unknown graft opacity (1 eye, 2.22%). The anterior segment photographed images of patients at readmission were shown in Supplemental Fig. 3. The causes of readmission among patients with different indications for corneal transplantation are showed in the Supplementary Fig. 4.

Among the 18 patients who were readmitted due to infectious keratitis, the diagnosis or culture results confirmed the pathogen in 15 eyes. The most common identified pathogens included bacterium (5 eyes, 11.11%) and fungus (5 eyes, 11.11%).

Clinical characteristics of deep anterior lamellar keratoplasty patients at index admission

The clinical characteristics of DALK patients during their index admission were shown in Table 2. In terms of the distribution of indications, keratitis is more common in the readmission group ($p = 0.014$), while the proportion of patients with keratoconus was lower ($p = 0.001$). Regarding disease features, patients in the readmission group had a relatively shorter disease course ($p = 0.001$ and $p < 0.001$). Furthermore, more patients presenting with corneal ulcers or perforation on admission ($p = 0.029$) and blindness ($p = 0.02$). The hospitalization time of the readmission group is also longer ($p = 0.048$).

Risk factors for unplanned readmission within 90 days after deep anterior lamellar keratoplasty

An analysis of risk factors for unplanned readmission within 90 days after DALK revealed the following results using a multivariable Cox regression model (Table 3): compared to patients with keratoconus, those with keratitis (HR = 3.545, 95% CI 1.104–11.386, $P = 0.034$) and corneal degeneration or dystrophy (HR = 6.470, 95% CI

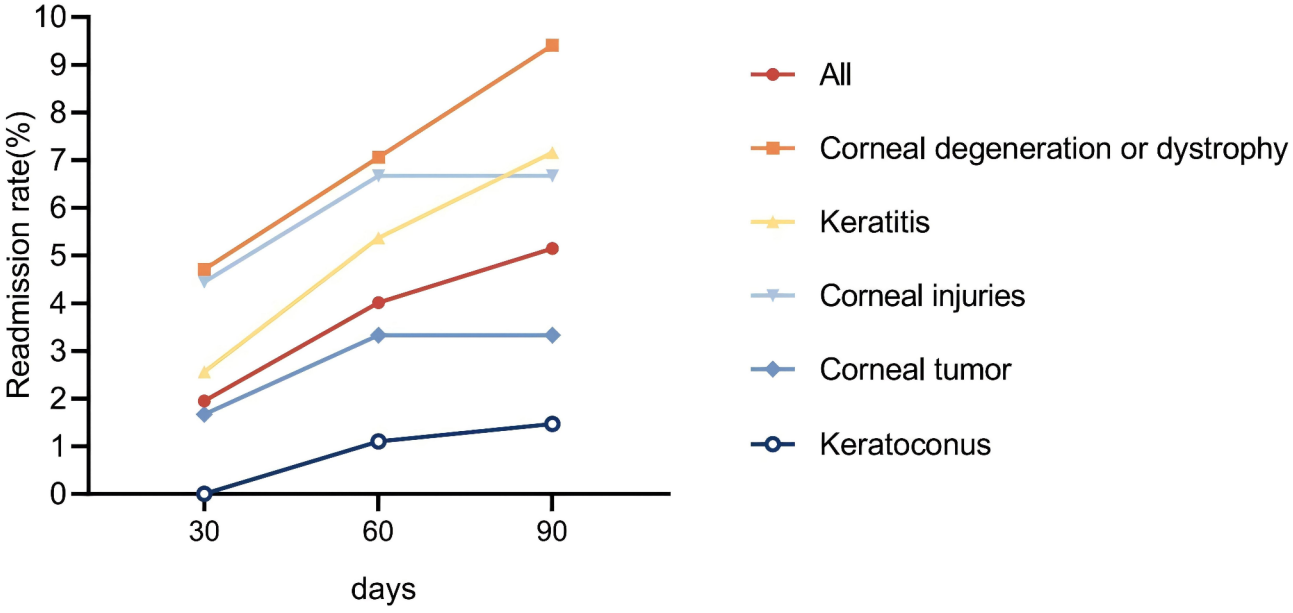

Fig. 2 Readmission rate of deep anterior lamellar keratoplasty patients (%). *Readmission rate is defined as the number of unplanned readmissions of patients with a certain type of disease within 90 days /the total number of first-time admissions of patients with this type of disease

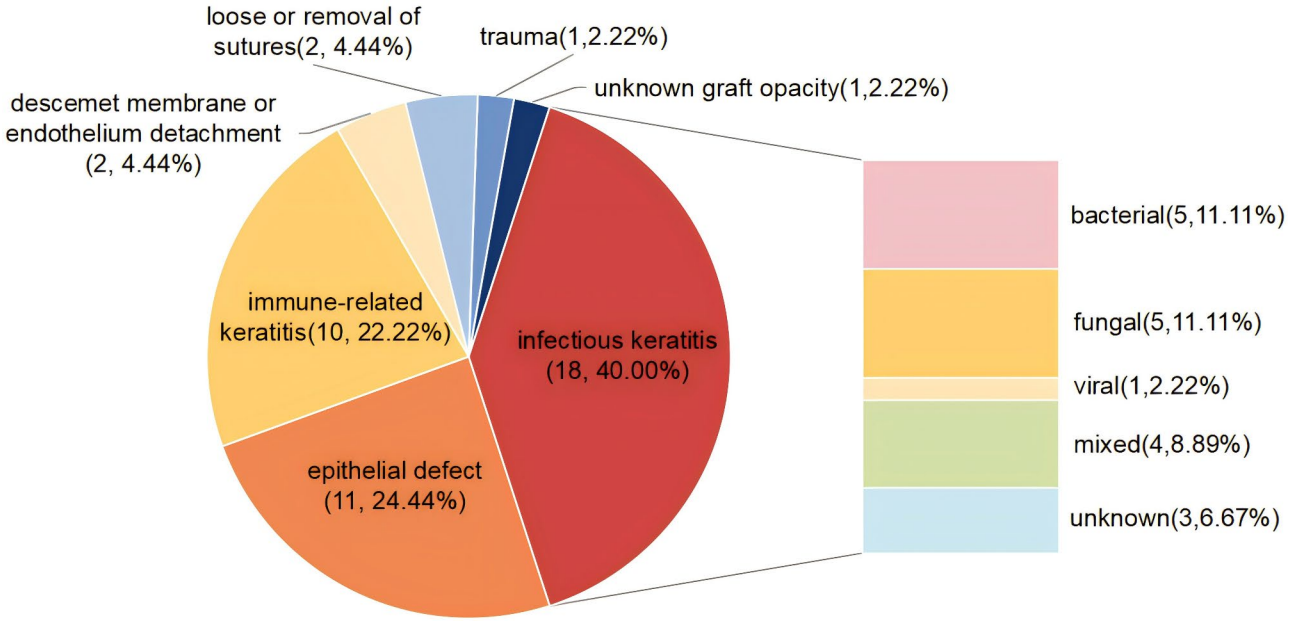

Fig. 3 Cause of 90-days unplanned readmission after deep anterior lamellar keratoplasty (number of eyes, %)

Table 2 Clinical characteristics of the deep anterior lamellar keratoplasty patients at index admission

Characteristic	DALK patients (*N* = 878)		Unplanned readmission within 90 days				*P*-Value[a]
			Yes(*N* = 45)		No(*N* = 833)		
Indication, *n* (%)							
Keratitis	391	44.53	28	62.22	363	43.58	0.014*
Keratoconus	275	31.32	4	8.89	271	32.53	0.001**
Corneal degeneration or dystrophy	88	10.02	8	17.78	80	9.60	0.128
Corneal tumor	60	6.83	2	4.44	58	6.96	0.727
Corneal injuries	45	5.13	3	6.67	42	5.04	0.893
Others	19	2.16	0	0.00	19	2.28	0.618
Course of disease, *n* (%)[b]							
≤ 1month	175	19.93	11	24.44	164	19.69	0.439
>1month and ≤ 3months	81	9.23	11	24.44	70	8.40	0.001**
>3months	621	70.73	23	51.11	598	71.79	< 0.001***
Corneal signs on admission, *n* (%)[c]							
Opacity	450	51.25	20	44.44	430	51.62	0.34
Neovascularization	175	19.93	13	28.89	162	19.45	0.125
Ulcer or perforation	210	23.92	19	42.22	226	27.13	0.029*
Vision Acuity on admission, *n* (%)[d]							
Blindness	316	35.99	22	48.89	294	35.29	0.02*
Non-blindness	523	59.57	18	40.00	505	60.62	
Repeat keratoplasty, *n* (%)	39	4.44	2	4.44	37	4.44	1.000
Ocular comorbidity, *n* (%)							
Glaucoma	7	0.80	0	0.00	7	0.84	1.000
Cataract	198	22.55	14	31.11	184	22.09	0.158
Retinal diseases	20	2.28	2	4.44	18	2.16	0.626
Length of hospitalization, d	7(5,9)		8(6,11)		7(5,9)		0.048*

Abbreviations: DALK = deep anterior lamellar keratoplasty

[a] *P*-value of the comparison between patients with 90-day readmission and non-readmission

[b] 1 course of disease is missing

[c] 2 corneal signs on admission are missing

[d] Visual acuity measurements were based on the presenting VA. According to the WHO definition, blindness was defined as VA worse than 3/60 (logMAR equivalent, 1.30). 39 visual acuity on admission records are missing

Table 3 Risk factors for unplanned 90-days readmission of the deep anterior lamellar keratoplasty patients

Characteristic	Readmission (*N* = 45)		Non-readmission (*N* = 833)		Multivariate Cox regression			
	n	%	*n*	%	β	HR	95%CI	*P*-Value
Indication [a]								
Keratitis	28	62.22	363	43.58	1.265	3.545	1.104–11.386	0.034*
Keratoconus	4	8.89	271	32.53	1(reference)			
Corneal degeneration or dystrophy	8	17.78	80	9.60	1.867	6.470	1.942–21.560	0.002**
Corneal tumor	2	4.44	58	6.96	-14.550	0.000	0.000-null	0.995
Corneal injuries	3	6.67	42	5.04	0.946	2.574	0.460-14.416	0.282
Corneal ulcer or perforation on admission[b]	19	42.22	226	27.13	0.174	1.190	0.570–2.484	0.643
Admission vision acuity [c]								
Blindness	22	48.89	294	35.29	0.473	1.605	0.807–3.191	0.177
Non-blindness	18	40.00	505	60.62	1(reference)			

Abbreviations: β value = regression coefficient, HR = hazard ratio, CI = confidence interval

[a] The indication group excludes others groups (19 eyes)

[b] There is 2 missing corneal signs on admission

[c] Visual acuity measurements were based on the presenting VA. According to the WHO definition, blindness was defined as VA worse than 3/60 (logMAR equivalent, 1.30). There is 39 missing visual acuity on admission

1.942–21.560, $P = 0.002$) had a higher risk of unplanned readmission within 90 days.

Discussion

The aim of this study was to investigate the rate, clinical characteristics and risk factors associated with unplanned readmission within 90 days after DALK. The findings revealed that the main indications for DALK were keratitis, followed by keratoconus. The unplanned readmission rates within 30, 60, and 90 days were 1.95%, 4.01%, and 5.15%, respectively. Infectious keratitis were the most common cause of unplanned readmission within 90 days, followed by corneal epithelial defects and immune-related keratitis. The indications for DALK were associated with a greater risk of unplanned readmission within 90 days.

In our study, the most common indications for DALK were keratitis, followed by keratoconus and corneal degeneration or dystrophy, which differs from the distribution of indications for corneal transplantation in other countries [12, 13, 38, 39], mainly due to the fact that infectious keratitis is the main cause of corneal blindness in China [40, 41]. Our research found that that compared to patients with keratoconus, patients with keratitis and degeneration with malnutrition were more prone to unplanned readmission within 90 days. These findings collectively suggest a close association between keratoplasty indications and readmission. Indications are the major prognostic factors for graft survival after keratoplasty and are among the most important associated risk factors [42, 43]. According to a 2018 Australian corneal transplant registry report study, patients with keratoconus as the indication for keratoplasty demonstrated significantly higher graft survival rates (91% of patients had graft survival at 8 years). Conversely, patients with corneal ulcer or perforation, a history of previous failed keratoplasty, and bullous keratopathy had the lowest graft survival rates (51%, 63%, and 63% graft survival at 8 years, respectively) [44]. Additionally, keratoplasty indications with poor outcomes often have high-risk factors associated with failure, including active ocular inflammation, corneal neovascularization, and ocular comorbidity (e.g. glaucoma) [45–47]. Our research indicated that patients with corneal degeneration or dystrophy and keratitis had higher readmission rates within 90 days, whereas patients with keratoconus had the lowest readmission rate.

In this study, unplanned readmission within 90 days after DALK was mainly caused by infectious keratitis (18 eyes, 40.00%) and corneal epithelial defects (11 eyes, 24.44%). Previous studies have shown that most patients undergoing LK experience varying degrees of corneal superficial abnormalities in the first month after surgery [48, 49]. The mechanisms include corneal nerve damage, long-term use of topical corticosteroids, frequent exposure to toxic topical remedy, poor corneal surface wetting, and anatomical changes in the cornea and graft interface after keratoplasty. These factors contribute to difficulties in epithelialization, resulting in impaired epithelial barrier function and susceptibility to complications that can severely damage vision. Additionally, exposed or loose sutures can disrupt the corneal epithelial surface barrier, thereby aiding microorganisms in entering the corneal stroma [48, 50, 51]. Furthermore, DALK has relatively lenient requirements for the quality of corneal donor tissue. Studies have shown that the use of low-quality corneal donor tissue also increases the incidence of epithelial defects after surgery [52]. Global research shows that there are regional differences in the incidence rate of infectious keratitis after corneal transplantation. The incidence rate in developing countries

(9.2–11.9%) is higher than that of developed countries (0.02–7.9%). Bacterial and fungal pathogens are the most common pathogens [53]. Additionally, the increasing number of LK has led to an increase in complications including infectious interface keratitis, resulting in severe visual impairment or blindness [54]. In this study, among the 18 patients readmitted for infectious keratitis after DALK, one eye had concomitant endophthalmitis, whole 6 had severe enough infection to require repeat keratoplasty during readmission period. Relevant literature signifies that common risk factors for postoperative infectious keratitis after keratoplasty encompass the usage of local corticosteroids, suture-related issues, persistent epithelial defects, and prior corneal infections [53, 55, 56]. These findings emphasize the importance of closely monitoring patients with these aforementioned risk factors for postoperative infectious keratitis in future clinical practice. Strengthening postoperative follow-up care is crucial in order to prevent or promptly identify postoperative infections, potentially enhancing graft survival rates and improving prognosis in long term.

A survey study on corneal transplantation in China revealed that the proportion of PK decreased from 57.97% in 2014 to 52.88% in 2018, while the proportion of anterior lamellar keratoplasty increased from 36.04% in 2014 to 37.92% in 2018 [40]. Furthermore, the study suggests that the geographical distribution of corneal transplantation may be related to regional economies, surgical centers in the eastern region have a competitive edge over those in the central and western regions [40]. In our study, DALK accounted for 24.37% of the total number of keratoplasty, and the proportion of DALK in the eastern region was significantly higher than that in the central and western regions, highlighting the substantial disparities in corneal transplantation techniques among different economic regions in China. Moreover, the clinical application of DALK has enabled a single donor cornea to be used for multiple individuals [57], which helps alleviate the disease burden of blindness caused by corneal lesions. Therefore, the effective promotion of widespread and technically proficient training in corneal transplantation, coupled with advanced techniques for optimal utilization of corneal resources, remains a crucial pursuit in the current stage of corneal transplantation in China.

Our research inevitably has some limitations. Firstly, since it is based on hospital records, it only reflects the severe complications leading to unplanned readmission within 90 days after DALK, and the reported complication rates may be lower than the actual occurrence in reality. Secondly, the lack of long-term follow-up data after DALK prevents us from further studying the final visual prognosis and transplant survival rate of DALK. Finally, this study exclusively incorporated readmission records from the same hospital, which may introduce potential omissions. However, the ophthalmic centers included in this study hold significant clinical authority within their respective regions, the omission rate of data remains within an acceptable range.

Conclusions

In conclusions, the main causes of unplanned readmission within 90 days after DALK were infectious keratitis, corneal epithelial defects, and immune-related keratitis. The indications for DALK were associated with 90-day readmissions. Additionally, DALK is still relatively limited in China, and there still exists significant variation across different regions.

Abbreviations

WHO	World Health Organization
DALK	Deep Anterior Lamellar Keratoplasty
PK	Penetrating Keratoplasty
LK	Lamellar Keratoplasty
HR	Hazard Ratio
CI	Confidence Interval
EDC	Electronic Data Capture
CRF	Case Report Form

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12886-025-04010-1.

Supplementary Material 1: Fig. 1. Geographical distribution map of the centers in study.

Supplementary Material 2: Fig. 2 Timing of 90-day readmission by discharge day in patients readmitted after index hospitalization related to deep anterior lamellar keratoplasty.

Supplementary Material 3: Fig. 3. The anterior segment photographed images of patients at readmission. Legends: a. bacterial keratitis; b.fungal keratitis; c.viral keratitis; d.mixed infectious keratitis; e.corneal epithelial defect; f.recurrence of marginal corneal ulcer; g.corneal trauma; h.corneal descemet membrane detachment; i.unknown graft opacity

Supplementary Material 4 Table 1. the number of keratoplasty in centers enrolled in the study(eyes)

Supplementary Material 5 Table 2. The specific disease classification of indications for deep anterior lamellar keratoplasty

Supplementary Material 6: Fig. 4 The proportions of readmission causes among patients with different indications for deep lamellar keratoplasty (%).

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Author contributions

WC, YC: concept and design, critical revision and final approval of the article; CW, HX: concept and design, analysis and interpretation, writing the article; BS, KT, HW, ZZ, QZ: data acquisition and critical revision of manuscript; JW, QZ, BC, HD, JY, HL, FW, TS, JX, SZ, LC, ZL, YY, XS, PW, YH, WQ, QX, YX, HL, MY, LH, HL, RW, MW, GC: provision of materials, patients or resources and data collection. All authors reviewed the manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the ethics committee of Eye Hospital, Wenzhou Medical University, Zhejiang, China (approval no.2020-217-K-197-01). Otherwise, the study protocol was approved by the ethics committee at each participating centre, the study used data collected from inpatient medical records while maintaining patient anonymity, and the institutional review board approved waiver of patient informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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