

Optimal Time for Stabilization of Anterior Corneal Keratometry after Primary Pterygium Excision Adjusted for Horizontal Invasion Length

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Purpose: To determine the corneal stabilization timeline after pterygium excision adjusted for horizontal invasion length (HIL).

Methods: In this single-center retrospective cohort study, we analyzed 88 eyes of 80 patients with nasal or temporal primary pterygium who underwent excision and perioperative evaluation with anterior segment (AS) swept-source optical coherence tomography (SS-OCT; Anterior). Anterior simulated mean keratometry (SimK_{mean}; 3-mm ring) and HIL were measured on AS SS-OCT. Keratometric stabilization was assessed at postoperative cutoffs of 8, 12, 16, 20, and 24 weeks using analysis of covariance (ANCOVA) with HIL as a covariate. Subgroup analysis was performed after stratifying by the median HIL (3.82 mm).

Results: Mean anterior SimK_{mean} increased from 42.95 ± 1.79 diopters (D) preoperatively to 43.73 ± 1.53 D postoperatively ($p < 0.001$). Preoperative HIL correlated positively with the perioperative SimK_{mean} change ($r = 0.728$, $p < 0.001$). While postoperative duration showed no significant unadjusted correlation with keratometric change ($r = -0.133$, $p = 0.218$), partial correlation controlling for HIL was negative ($r = -0.248$, $p = 0.021$), indicating diminishing change over time after severity adjustment. ANCOVA demonstrated significant stabilization at 16 weeks ($p = 0.036$). In the HIL ≥3.82 mm subgroup, SimK_{mean} change was greater before 20 weeks than after 20 weeks (1.73 ± 1.59 D vs. 0.59 ± 0.74 D, $p = 0.030$), whereas no significant time-point differences were found for HIL <3.82 mm.

Conclusions: Corneal keratometric stabilization after pterygium excision depends on preoperative HIL. A minimum of 16 weeks is recommended before cataract surgery planning, with at least 20 weeks for eyes with HIL ≥3.82 mm.

Key Words: Horizontal invasion length, Keratometry, Optical coherence tomography, Pterygium

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Pterygium is characterized by a triangular growth of fibrous subconjunctival connective tissue, accompanied by thickening of the overlying conjunctival epithelium [1]. It not only causes ocular irritation, inflammation, foreign body sensation, and cosmetic concerns but, more importantly, can progressively impair the optical function of the anterior corneal surface [2]. This impairment occurs through the induction of corneal astigmatism [3,4] and in-

creased corneal topographical irregularity [5], which, in turn, leads to decreased visual acuity and reduced contrast sensitivity.

Traditional placido ring-based topography is limited in pterygium cases because the irregular corneal elevation caused by the lesion distorts ring reflections, producing unreliable data [5]. In contrast, anterior segment (AS) swept-source optical coherence tomography (SS-OCT) provides reliable measurements of anterior corneal elevation parameters even in pathologically abnormal eyes [6], demonstrating high repeatability (interclass correlation coefficient >0.98) for keratometric measurements [7]. A precise understanding of how pterygium affects corneal optical properties is therefore crucial for accurately characterizing the visual and topographic changes that occur during the perioperative period.

Pterygium excision surgery is performed more commonly in elderly patients, who frequently have coexisting cataracts and often requires cataract surgery soon after the pterygium excision. By exerting tractional forces on the cornea, pterygium flattens the corneal surface, which may eventually cause significant errors in intraocular lens (IOL) power calculation. Indeed, some studies have reported mean IOL power changes of over 1 diopter (D) following pterygium excision [8,9]. In fact, surgical excision of pterygium relieves corneal tension, resulting in a relative steepening of the corneal curvature [10,11]. Therefore, pterygium excision should precede cataract surgery, followed by a sufficient stabilization period to ensure keratometric stability [12]. In this context, determining the exact postoperative period required for stabilization of corneal keratometry is essential for appropriate subsequent surgical planning.

Traditionally, pterygium severity has been classified using the grading system based on body translucency (i.e., Tan grade) [13]. But recently, we demonstrated that among AS SS-OCT derived morphological features, the horizontal invasion length (HIL), which represents the corneal invasion extent of the pterygium, showed the strongest correlation with the Tan grade [14]. Moreover, the degree of anterior corneal astigmatic improvement after pterygium excision was shown to vary according to the preoperative HIL [14]. Although a previous study on primary pterygium has suggested the postoperative period required for corneal refractive stabilization without consideration of their severities [15], the amount and duration of perioperative ker-

atometric recovery can vary depending on disease severity. Therefore, in this study, we investigated to identify the optimal time point for stabilization of anterior corneal keratometry after primary pterygium excision, adjusted for preoperative HIL, which can provide clinicians with a valuable reference when planning subsequent cataract surgery.

Materials and Methods

Ethics statement

This study was a single-center, retrospective cohort study based on medical chart review. The principles of the Declaration of Helsinki were adhered throughout the entire research process. The study protocol was approved by the Institutional Review Board of Chung-Ang University Hospital (No. 2510-028-19599). The requirement for informed consent was waived due to the use of deidentified data and the retrospective nature of the study.

Subjects

This study included 88 eyes from 80 patients with primary pterygium involving either the nasal or temporal area, who underwent pterygium excision surgery between September 2021 and June 2023. All subjects underwent assessment using AS SS-OCT (Anterior, Heidelberg Engineering) both preoperatively and postoperatively. All preoperative measurements were obtained within 4 weeks before surgery. Exclusion criteria included a history of corneal refractive surgery, corneal trauma with refractive sequelae, double-headed pterygium, corneal infection, contact lens wear within 6 months before surgery, recurrent pterygium, and systemic autoimmune disease. No subjects experienced recurrence during the entire follow up period after pterygium excision.

Study design

The study design involved the following steps: (1) data collection: acquisition of anterior simulated mean keratometry ($\text{SimK}_{\text{mean}}$) values and HIL of pterygium using AS SS-OCT; (2) cutoff period identification (determination of the postoperative cutoff period showing a significant change in

anterior $\text{SimK}_{\text{mean}}$ after pterygium excision); and (3) subgroup analysis: comparison of the cutoff period according to HIL-based severity subgroups.

Surgical procedures

All surgeries were performed by a single surgeon (KWK) using a standardized procedure under local anesthesia. After marking the target area for excision with a surgical pen, hydrodissection between the overlying epithelium and the underlying pterygial tissue was achieved by injecting 2% lidocaine into the conjunctival tissue. The fibrovascular tissue beneath the pterygial epithelium was then excised using Westcott scissors, and the pterygial head invading the cornea was meticulously peeled off the corneal surface. Following excision, the exposed scleral bed was covered with a conjunctival limbal autograft, a sliding flap or a rotational flap. The graft was fixed to the sclera using fibrin glue (Greenplast Q pre-filled syringe kit, GC Biopharma Corp.) and anchored with 10-0 nylon sutures.

Postoperatively, a combination ointment containing dexamethasone and neomycin (Maxitrol, Novartis) was applied twice daily, along with moxifloxacin eye drops (Vigamox, Novartis) four times daily. Oral prednisolone (10 mg) was administered once daily for 5 days after surgery. The ointment was gradually tapered and discontinued within 2 weeks postoperatively. To promote epithelial wound healing, 20% autologous serum eye drops were administered six times daily during the first postoperative week and gradually tapered over the following month.

Clinical severity grading and AS SS-OCT-based parameter of pterygium

All eyes affected by pterygium were assessed translucency of pterygium body stroma denoted as T grades [13]. T grading system classifies pterygia as T1 (clearly visible underlying episcleral vessels), T2 (episcleral vessels partially covered by the pterygium body), and T3 (underlying episcleral vessels completely covered by the pterygium body) based on clear visibility of episcleral vessels underneath the pterygium body.

We collected the anterior $\text{SimK}_{\text{mean}}$ at 3 mm ring before and after surgery, and the difference in anterior $\text{SimK}_{\text{mean}}$ perioperatively measured by AS SS-OCT. HIL based on AS

SS-OCT was measured as established previously [14,16,17]. Briefly, HIL was defined as a linear distance of vertical line connecting the end of the pterygium head and a reference line from the anterior chamber angle to a point vertically extended on a surface tangent line [14].

Statistical analysis

For statistical analysis, Prism software ver. 10.6.0 (Graph-Pad) was used. The normality of the data distribution was assessed with a Shapiro-Wilk test. Preoperative and postoperative corneal parameters were compared using a paired *t*-test. The relationship between postoperative duration and the change in anterior $\text{SimK}_{\text{mean}}$ was initially assessed with Spearman rank correlation test and partial correlation test controlling for HIL. To control the confounding effect of pterygium severity, an analysis of covariance (ANCOVA) was performed with the HIL as a covariate. Subgroup analysis was conducted by dividing the cohort based on the median HIL value. The Mann-Whitney *U*-test was then used to compare the change in anterior $\text{SimK}_{\text{mean}}$ of each group. Values are presented as mean $\pm$ standard deviation. A *p*-value of <0.05 was considered statistically significant.

Results

Demographics and baseline characteristics of pterygia

This study included 88 eyes from 80 subjects with primary pterygium. Table 1 summarizes the demographic information and clinical characteristics of pterygium, including HIL and severity. Among the 80 patients, 41 (51.2%) were male, and 39 (48.8%) were female. The average age of the subjects was 57.3 ± 11.5 years. For the T grades of the pterygium, 14 eyes (15.9%) were classified as T1, 62 eyes (70.5%) were classified as T2, and 12 eyes (13.6%) were classified as T3. The baseline value of HIL was 4.02 ± 1.27 mm.

Perioperative changes in anterior corneal keratometry

The mean preoperative anterior $\text{SimK}_{\text{mean}}$ value for all subjects was 42.95 ± 1.79 D, and the mean postoperative value of anterior $\text{SimK}_{\text{mean}}$ was 43.73 ± 1.53 D (Table 2).

Accordingly, the perioperative change in anterior SimK_{mean} was 0.78 ± 1.37 D. Following surgery, the mean anterior SimK_{mean} value showed a statistically significant increase ($p < 0.001$). The mean postoperative follow-up duration after pterygium excision was 15.3 ± 12.8 weeks.

Table 1. Demographic and clinical characteristics of subjects with pterygium

Characteristic	Value
No. of patients	80
No. of eyes	88
Age (yr)	57.3 ± 11.5
Sex	
Male	41 (51.2)
Female	39 (48.8)
T grade	
T1	14 (15.9)
T2	62 (70.5)
T3	12 (13.6)
Horizontal invasion length (mm)	4.02 ± 1.27

Values are presented as number only, mean $\pm$ standard deviation, or number (%).

Table 2. Changes in anterior SimK_{mean} based on anterior segment swept-source optical coherence tomography after pterygium excision surgery

Variable	Value	p-value
Preoperative anterior SimK _{mean} (D)	42.95 ± 1.79	$<0.001^*$
Postoperative anterior SimK _{mean} (D)	43.73 ± 1.53	$<0.001^*$
Perioperative change of anterior SimK _{mean} (D)	0.78 ± 1.37	-
Postoperative duration (wk)	15.3 ± 12.8	-

Values are presented as mean $\pm$ standard deviation.

SimK_{mean} = simulated mean keratometry; D = diopters.

*Paired *t*-test ($p < 0.05$).

Table 3. Correlation analysis of postoperative duration after pterygium excision and perioperative change of anterior SimK_{mean} measured by anterior segment swept-source optical coherence tomography

	Perioperative change of anterior SimK _{mean} (D)	
	r	p-value
Postoperative duration (wk)	-0.133^*	0.218
	$-0.248^\dagger$	$0.021^\ddagger$

SimK_{mean} = simulated mean keratometry; D = diopters.

*Spearman rank correlation test and † partial correlation test while controlling horizontal invasion length; ‡ Statistically significant ($p < 0.05$).

Influence of postoperative duration on the stabilization of the perioperative anterior keratometric change

The postoperative duration time did not correlate with the perioperative change of anterior SimK_{mean} ($r = -0.133$, $p = 0.218$) (Table 3). However, because the preoperative HIL showed a significant positive correlation with the amount of perioperative SimK_{mean} increase ($r = 0.728$, $p < 0.001$) (Supplementary Table 1), we further analyzed whether adjusting for HIL could influence the relationship between postoperative duration and the perioperative anterior SimK_{mean} change. After adjusting HIL as a confounder, partial correlation analysis revealed that anterior corneal steepening after pterygium excision progressively decreased with increasing postoperative duration ($r = -0.248$, $p = 0.021$) (Table 3).

Determination of the postoperative stabilization period for the perioperative anterior keratometric change

ANCOVA with HIL as a covariate was performed to compare perioperative anterior SimK_{mean} changes among groups with different postoperative durations. At the cutoff points of 8 and 12 weeks, HIL-adjusted anterior SimK_{mean} changes did not differ significantly between groups ($p = 0.760$ and $p = 0.220$, respectively) (Table 4). In contrast,

Table 4. Analysis of perioperative changes in anterior SimK_{mean} based on anterior segment swept-source optical coherence tomography according to postoperative duration with adjustment for preoperative HIL

Cutoff (wk)	Group (wk)	No. of eyes	Perioperative change of anterior SimK _{mean} (D)	Adjusted for preoperative HIL		
				Estimated marginal mean	F	p-value
8	<8	32	0.74 ± 1.17	0.82 (0.19)	0.094	0.760
	≥8	56	0.80 ± 1.47	0.75 (0.14)		
12	<12	48	0.85 ± 1.21	0.90 (0.15)	1.527	0.220
	≥12	40	0.68 ± 1.54	0.62 (0.17)		
16	<16	62	0.95 ± 1.53	0.93 (0.13)	4.563	0.036*
	≥16	26	0.35 ± 0.70	0.41 (0.20)		
20	<20	68	0.94 ± 1.49	0.93 (0.12)	6.564	0.012*
	≥20	20	0.23 ± 0.58	0.26 (0.23)		
24	<24	70	0.93 ± 1.47	0.91 (0.12)	5.993	0.016*
	≥24	18	0.19 ± 0.60	0.25 (0.24)		

Values are presented as number only, mean ± standard deviation, or mean (standard error).

SimK_{mean} = simulated mean keratometry; HIL = horizontal invasion length; D = diopters.

*Analysis of covariance ($p < 0.05$).

Table 5. Subgroup analysis of perioperative anterior SimK_{mean} change by preoperative horizontal invasion length of pterygium (cutoff 3.82 mm) at different postoperative time cutoffs

Cutoff (wk)	HIL (mm)	Group (wk)	No. of eyes	Perioperative change of anterior SimK _{mean} (D)	p-value
8	<3.82	<8	17	0.17 ± 0.35	0.508
		≥8	27	-0.05 ± 0.64	
	≥3.82	<8	15	1.38 ± 1.44	0.764
		≥8	29	1.59 ± 1.59	
12	<3.82	<12	24	0.16 ± 0.32	0.268
		≥12	20	-0.12 ± 0.73	
	≥3.82	<12	24	1.55 ± 1.38	0.458
		≥12	20	1.49 ± 1.73	
16	<3.82	<16	29	0.04 ± 0.66	0.520
		≥16	15	0.03 ± 0.26	
	≥3.82	<16	33	1.76 ± 1.63	0.054
		≥16	11	0.80 ± 0.87	
20	<3.82	<20	32	0.05 ± 0.63	0.197
		≥20	12	-0.01 ± 0.28	
	≥3.82	<20	36	1.73 ± 1.59	0.030*
		≥20	8	0.59 ± 0.74	
24	<3.82	<24	33	0.06 ± 0.62	0.089
		≥24	11	-0.04 ± 0.28	
	≥3.82	<24	37	1.70 ± 1.57	0.032*
		≥24	7	0.55 ± 0.79	

Values are presented as number only or mean ± standard deviation.

SimK_{mean} = simulated mean keratometry; HIL = horizontal invasion length; D = diopters.

*Mann-Whitney U-test ($p < 0.05$).

when the groups were divided using cutoff points of 16, 20, or 24 weeks, the perioperative change in anterior SimK_{mean} was significantly smaller after each cutoff threshold than before ($p = 0.036$, $p = 0.012$, and $p = 0.016$, respectively) (Table 4). Among these, the intergroup difference became more pronounced at 20 weeks.

Determination of the postoperative stabilization period for the perioperative anterior keratometric change according to pterygial HIL

Subjects were stratified by the median HIL value of 3.82 mm to verify pterygium severity. Perioperative changes in anterior SimK_{mean} were then compared between subjects with HIL <3.82 mm and those with HIL ≥3.82 mm at different postoperative time points, in order to determine the optimal postoperative period according to pterygium severity. In the subgroup with HIL <3.82 mm, perioperative anterior SimK_{mean} changes did not differ significantly across postoperative duration cutoffs at any time point (Table 5). In contrast, in the subgroup with HIL ≥3.82 mm, significant differences in perioperative anterior SimK_{mean} were observed between periods before and after the 20- and 24-week cutoffs ($p = 0.030$ and $p = 0.032$, respectively) (Table 5). These findings suggest that in eyes with pterygia of HIL ≥3.82 mm, the anterior corneal keratometry stabilizes after early postoperative corneal steepening beyond approximately 5 to 6 months.

Discussion

It is well established that pterygium induces irregularity of the anterior corneal surface and consequently causes corneal astigmatism [3,4], while its surgical removal results in relative steepening of the corneal curvature [18]. Accordingly, patients indicated for both pterygium and cataract surgery should undergo pterygium excision first, allowing sufficient time for corneal keratometry stabilization before cataract surgery [19]. In this study, we sought to determine the postoperative stabilization timeline of anterior corneal keratometry after primary pterygium excision, while adjusting for preoperative severity using HIL as an AS SS-OCT-based morphological parameter. Our goal was to provide an evidence-based reference for optimal scheduling of subsequent cataract surgery and we found that

corneal keratometric stability was achieved around 16 weeks postoperatively, particularly after adjusting for preoperative severity using HIL.

Previous studies have attempted to characterize the postoperative course of corneal keratometric changes after pterygium excision and to identify the time point of stabilization [15,20]. Kim et al. [20] divided patients into two groups based on a pterygial invasion length of 2.0 mm and evaluated horizontal, vertical, and mean K values at 1 and 3 months postoperatively. They observed significant increases in keratometric values at both 1 and 3 months in pterygia with corneal invasion ≥2.0 mm, whereas no significant changes occurred in those with corneal invasion <2.0 mm. Although their follow-up period was limited to 3 months and thus insufficient to determine the stabilization time, their findings, similar to ours, highlight the importance of stratifying patients according to disease severity. In contrast, Kam et al. [15] monitored refractive power changes for up to 18 months after primary pterygium excision and reported no significant variation starting from 1 week to 18 months postoperatively. This result appears inconsistent with our finding that anterior corneal keratometry stabilized after at least approximately 4 months. However, their analysis did not account for preoperative severity, which likely contributed to this discrepancy. Collectively, these comparisons underscore that postoperative keratometric stabilization cannot be uniformly defined without adjusting for pterygium severity, as the extent of corneal involvement substantially influences the recovery timeline.

A previous study has shown that HIL correlates strongly with both pre and postoperative corneal astigmatism [14]. In our cohort, we also found a robust positive correlation between preoperative HIL and the magnitude of perioperative SimK_{mean} change, confirming that HIL is a meaningful indicator of disease severity and surgical impact. After controlling for this factor, the change in SimK_{mean} demonstrated a significant negative correlation with postoperative duration, suggesting that corneal stability progressively increases over time as remodeling proceeds.

To quantify this stabilization process, we performed an ANCOVA with HIL as a covariate. The results revealed a significant reduction in adjusted mean SimK_{mean} change beyond 16 weeks postoperatively, with the difference becoming more pronounced at the 20- and 24-week cutoffs. These findings indicate that corneal refractive stability is

generally achieved around 16 to 20 weeks after surgery in the overall cohort. This timeline corresponds to the upper range of previously reported stabilization periods, which varied from several weeks to several months [12,15,18,21], likely reflecting differences in study design and lack of severity adjustment in earlier work.

Recognizing that a uniform stabilization period may not apply to all patients, we conducted a subgroup analysis based on the median preoperative HIL (3.82 mm). In eyes with less severe pterygia (HIL <3.82 mm), no significant differences in SimK_{mean} change were observed across postoperative time points up to 24 weeks, implying relatively rapid stabilization or minimal curvature change. In contrast, in eyes with more severe pterygia (HIL ≥3.82 mm), significant stabilization was first observed at 20 weeks and persisted thereafter. These findings suggest that eyes with larger lesions require at least 5 months for reliable keratometric stabilization—an interval consistent with prior observations that corneal recovery is delayed when the pterygium extends more than 3.0 mm from the limbus [22]. Allowing adequate time between pterygium excision and cataract surgery is therefore essential to minimize postoperative refractive surprises.

Certain limitations should be acknowledged. A key limitation of this investigation's retrospective design is the lack of uniform follow-up intervals for postoperative AS SS-OCT measurements across the study cohort. While we collected data at an average of 15.3 ± 12.8 weeks, the time range varied among subjects. Nevertheless, by defining the postoperative duration as the interval between surgery and the examination date, we were able to analyze temporal changes and obtain consistent results. To our knowledge, this study is the first to define corneal stabilization timing after pterygium excision while adjusting for preoperative HIL as a quantitative severity marker.

In conclusion, postoperative corneal stabilization after pterygium excision varies with preoperative severity quantified by HIL. Significant keratometric stabilization occurred around 16 weeks overall, but eyes with larger pterygia (HIL ≥3.82 mm) required about 20 weeks. These results highlight the need to confirm corneal stability, particularly in severe cases, before cataract surgery to ensure accurate IOL power calculation.

Conflicts of Interest: None.

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Supplementary Materials

Supplementary Table 1. Correlation between preoperative HIL of pterygium and perioperative change in SimK_{mean} measured by anterior segment swept-source optical coherence tomography

Supplementary materials are available from <https://doi.org/10.3341/kjo.2025.0171>.

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Supplementary Table 1. Correlation between preoperative HIL of pterygium and perioperative change in SimK_{mean} measured by anterior segment swept-source optical coherence tomography

	Perioperative change of anterior SimK _{mean} (D)	
	r	p-value
HIL (mm)	0.728	<0.001*

HIL = horizontal invasion length; SimK_{mean} = simulated mean keratometry; D = diopters.

*Spearman rank correlation test ($p < 0.05$).