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Tomographical Analyses of Cornea and Anterior Chamber in Eyes with Posterior Embryotoxon

Posterior Embriyotokson'lu Gözlerde Kornea ve Ön Kamara Parametreleri'nin Tomografik Analizi

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ABSTRACT

Objectives: To evaluate anterior and posterior corneal surface and anterior chamber parameters in eyes with posterior embryotoxon (PE) among refractive surgery candidates, and to investigate their associations with age, gender, and refractive status.

Materials and Methods: This retrospective, cross-sectional study included 48 eyes with PE and 50 control eyes. Corneal keratometry, pachymetry, asphericity, elevation, corneal volume (CV), pupil-offset, higher-order aberrations (HOAs), point-spread function (PSF), and anterior chamber depth (ACD), volume (ACV), and angle (ACA) parameters were analyzed using Scheimpflug–Placido tomography.

Results: The mean age was similar between PE and control groups (34.0±13.86 years vs. 30.0±5.87 years, p=0.618). The gender and mean refractive error and visual acuity were comparable between groups (p>0.05 for all). The PE group exhibited significantly steeper posterior K1 (p=0.036) and greater CV (p=0.046). The ACD and ACV were significantly lower, and both nasal and temporal ACAs were significantly narrower in PE eyes (p<0.05 for all). Among PE eyes, females showed steeper posterior K1, K2, and Kmean, higher anterior asphericity, pupil-offset, root-mean-square of HOAs (RMS-HOAs), and coma values than males (p<0.05 for all). Age was negatively correlated with the posterior K1, CV, anterior chamber, and pachymetric parameters and positively with the anterior K1 and PSF (p<0.05 for all). Spherical equivalent was negatively correlated with the anterior chamber parameters, y-component of the pupil-offset, and RMS-HOAs, while it positively correlated with x-component of the pupil-offset (p<0.05 for all).

Conclusion: Eyes with PE demonstrate distinctive anterior chamber and subtle posterior corneal alterations compared with normal eyes. These differences, influenced by age, gender, and refractive status, may have clinical relevance for diagnosing, monitoring, and surgical planning.

Keywords: Posterior embryotoxon, cornea, anterior chamber, topography.

ÖZET

Amaç: Refraktif cerrahi adaylarında posterior embriyotokson (PE) bulunan gözlerde ön ile arka korneal yüzey ve ön kamara parametrelerini değerlendirmek ve bu parametrelerin yaş, cinsiyet ve refraktif durum ile ilişkisini araştırmak.

Gereç ve Yöntem: Bu retrospektif, kesitsel çalışmaya 48 PE'li ve 50 kontrol göz dahil edilmiştir. Scheimpflug–Placido tomografi kullanılarak korneal keratometri, pakimetri, asferisite, elevasyon, kornea hacmi (KH), pupil ofset, yüksek-sıralı aberasyonlar (HOA'lar), nokta-saçılım fonksiyonu (NSF) ile ön kamara derinliği (ÖKD), hacmi (ÖKH) ve açısı (ÖKA) parametreleri analiz edilmiştir.

Bulgular: Ortalama yaş PE ve kontrol grupları arasında benzerdi (34,0±13,86 yıl - 30,0±5,87 yıl, p=0,618). Cinsiyet, ortalama refraksiyon kusuru ve görme keskinliği açısından gruplar arasında anlamlı fark bulunmamıştır (tümünde p>0.05). PE grubunda arka K1 değeri anlamlı düzeyde daha dik (p=0.036) ve KH daha yüksek bulunmuştur (p=0.046). ÖKD ve ÖKH PE grubunda anlamlı olarak daha düşük; nazal ve temporal ÖKA değerleri ise anlamlı düzeyde daha dardı (tümünde p<0.05). PE'li gözlerde kadınlarda, erkeklere kıyasla arka K1, K2 ve Kortalama değerleri daha dik; ön asferisite, pupil ofset, karekök-HOA ve koma değerleri daha yüksekti (tümünde p<0.05). Yaş ile arka K1, KH, ön kamara ve pakimetrik parametreler arasında negatif; ön K1 ve NSF arasında pozitif korelasyon saptandı (tümünde p<0.05). Sferik ekivalan, ön kamara parametreleri, pupil ofsetin y-bileşeni ve karekök-HOA değerleri ile negatif; pupil ofsetin x-bileşeni ile pozitif korelasyon gösterdi (tümünde p<0.05).

Sonuç: PE'li gözlerde normal gözlerle karşılaştırıldığında ön kamara yapısında belirgin ve arka korneada hafif değişiklikler gözlenmektedir. Yaş, cinsiyet ve refraktif durumdan etkilenebilen bu farklılıklar, klinik tanı, izlem ve cerrahi planlama açısından önem taşıyabilir.

Anahtar Kelimeler: Posterior embriyotokson, kornea, ön kamara, topografi.

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Introduction

Posterior embryotoxon (PE) is a corneal abnormality observed on slit-lamp biomicroscopy without gonioscopy as a thin, gray-white, arcuate ridge on the inner surface of the cornea, adjacent to the limbus (1, 2). During late gestation, primordial corneal endothelium is typically resorbed; disruption of this developmental process has been implicated in the formation of the PE and iris abnormalities (3). It represents an anteriorly displaced Schwalbe's line, the anatomical junction between Descemet's membrane and the uveal trabecular meshwork (2). However, immunohistopathological evidence suggests that, the PE represents a direct extension of the corneal stroma (a 'peripheral corneal stromal nub') lined by Descemet's membrane in some cases (4).

The PE is a nonspecific indication that may be observed in a range of conditions, including ocular anomalies (e.g. Axenfeld–Riegers syndrome) or systemic disease (e.g. Alagille's syndrome), but can also occur in otherwise healthy individuals. It is reported as an incidental finding in approximately 5–32% of the general population and is frequently unassociated with ocular or systemic abnormalities, including glaucoma (1, 2, 5-7).

Corneal refractive surgery, phakic intraocular lens implantation in either the anterior or posterior chamber, and cataract surgery are increasingly performed worldwide, necessitating precise corneal and anterior chamber measurements for optimal outcomes. However, to date, no studies have evaluated corneal and anterior chamber parameters using Scheimpflug–Placido tomography in eyes with PE. This is the first investigation to address this topic. The aim of this study was to assess alterations in anterior and posterior corneal surface and anterior chamber parameters in eyes with PE compared to normal eyes, and to explore their associations with age, gender, and refractive status.

Materials and Methods

This retrospective, cross-sectional study included patients with PE and healthy controls who were evaluated as candidates for corneal refractive surgery because of their refractive error at our clinic between August 2024 and August 2025. The study received ethical approval from local Ethics Committee (Approval number: 2025/242). Written informed consent was obtained from each participant in accordance with the principles of the Declaration of Helsinki.

All participants underwent a comprehensive ophthalmologic examination performed by a single examiner (BT), including autorefraction, corrected-distance visual acuity (CDVA), slit-lamp biomicroscopic examination with applanation tonometry, gonioscopy, and fundoscopy. The visual acuity was measured with a standard Snellen chart and converted to decimal units for analysis.

Definition and Grading of Posterior Embryotoxon

The PE was defined as a prominent Schwalbe's line visible at the limbus at slit-lamp examination without the need for gonioscopy, characterized by a distinct ridge of tissue on the inner corneal surface rather than the common golden reflex of the trabecular region (2, 5). For study inclusion, PE was required to involve at least two consecutive clock hours located in the nasal and/or temporal quadrant. Both right and left eyes involvement was mandatory, and subjects with unilateral PE were excluded. Gonioscopy was systematically performed in all participants to confirm the absence of associated subtle angle or iris abnormalities.

Inclusion and Exclusion Criteria

Inclusion criteria were age older than 18 years, SE between +4.00 and -8.00 diopters (D), manifest astigmatism up to -4.00 D, intraocular pressure below 21 mmHg, no history of refractive, intraocular, or strabismus surgery, discontinuation of soft contact lens wear for at least 2 weeks, and absence of systemic disease.

Exclusion criteria included previous ocular trauma or corneal scar, unilateral PE, ocular comorbidities such as glaucoma, any iris or angle abnormalities detected on gonioscopy (including stromal hypoplasia, polycoria, corectopia, or iris strands attached to the Schwalbe line), dry eye, uveitis, strabismus, anisometropia, or retinal disease, systemic diseases including diabetes mellitus, liver disease, or connective tissue disorders, and pregnancy or lactation.

Corneal and Anterior Segment Tomographic Evaluation

Corneal tomographic assessments were performed using the corneal tomography (Sirius topography, CSO, Italy) prior to gonioscopy and applanation tonometry. All tomographical measurements were obtained by the same experienced technician under standardized conditions, including mesopic lighting, at a fixed time window between 9:00 and 11:00 AM to minimize the effect of diurnal variation. For each eye, at least three consecutive scans were acquired, and the scan with the highest image quality was selected for analysis. Only measurements meeting the device's predefined quality criteria (i.e., scans labeled with an "OK" quality status) were included in the study.

Parameters recorded included flat (K1), steep (K2), and average (Kmean) keratometry, corneal astigmatism and degree of anterior and posterior surface of the cornea, anterior Kmax, central (CCT) and thinnest corneal thickness (ThCT), anterior and posterior elevation, corneal volume (CV), pupil-offset (x-, y-component, and total), anterior and posterior asphericity (Q-value), horizontal visible iris diameter (HVID), and anterior chamber parameters [aqueous depth/anterior chamber depth (ACD), anterior chamber volume (ACV), temporal and nasal anterior chamber angle (ACA) degree, and horizontal anterior chamber diameter (HACD)]. Additionally, total, anterior, and posterior values of corneal higher-order aberrations (HOAs) [including the root-mean-square of HOAs (RMS-HOAs), coma, spherical aberration, and trefoil at central 5.0 mm cornea], and Strehl ratio of point-spread function (PSF) were also analysed.

Statistical Analysis

Sample size calculation was performed using G*Power (version 3.1.9.2). A large effect size was assumed based on Cohen's conventional criteria and the magnitude of differences reported in similar anterior chamber–related parameters in previous studies. With an assumed large effect size (Cohen's d = 0.8), α = 0.05, and power = 0.80, the minimum required sample size was 21 subjects per group (total n = 42), yielding an actual power of 0.816.

Statistical analyses were performed using SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA). The normality of data distribution was evaluated using the Shapiro–Wilk test. The Pearson Chi-square test was used to analyze categorical variables. Between-group (PE vs. control) or gender subgroup comparisons were conducted using the Mann–Whitney U test. Spearman's rank correlation test was used to evaluate correlations between variables. Statistical significance was set at $p < 0.05$.

Results

Between-group comparisons

In this comparative study, 48 eyes of 24 patients (14 females and 10 males) with PE were compared with 50 eyes of 25 healthy controls (14 females and 11 males). The mean age, SE refraction, and CDVA and gender were similar between groups ($p>0.05$ for all). The anterior and posterior corneal keratometric and astigmatic parameters did not differ significantly between the two groups ($p>0.05$ for all), except for posterior K1. The posterior K1 was significantly steeper in the PE group compared to the control group (Table 1). While the corneal pachymetry, asphericity, pupil offset, and elevation values were comparable between both groups ($p>0.05$ for all), the mean CV was significantly greater in the PE group compared to the controls ($p=0.046$).

Regarding anterior chamber–related parameters, the ACD and ACV were significantly lower in the PE group compared with controls ($p<0.001$ for both). Both nasal and temporal anterior chamber angles were significantly narrower in the PE group than in the control group ($p<0.001$ and $p=0.013$, respectively). While the HVID was comparable between the groups ($p=0.248$), the mean HACD was also significantly lower in the PE group when compared to the control group ($p<0.001$) (Table 1).

Gender subgroup analysis

The mean age of eyes with PE were comparable between gender subgroups ($p>0.05$ for all) (Table 2). The mean anterior keratometric and corneal astigmatism values were similar between groups ($p>0.05$ for all), whereas the mean posterior keratometric values were significantly steeper in females than in males ($p<0.05$

Table 1. Refractive, visual, and tomographical parameters in posterior embryotoxon and control groups

	Posterior embryotoxon group (n=48)	**Control group** (n=50)	*p value**
Age (years)	34.0 ± 13.86	30.0 ± 5.87	***0.618***
Refractive error (D)			
Sphere	-1.28 ± 1.93	-1.33 ± 1.53	***0.075***
Cylinder	-0.56 ± 0.75	-0.67 ± 0.80	***0.126***
Spherical equivalent	-1.56 ± 2.16	-1.59 ± 0.98	***0.066***
CDVA (Decimal)	0.99 ± 0.02	0.99 ± 0.03	***0.305***
Anterior			
K1 (D)	43.13 ± 1.07	42.96 ± 1.19	***0.482***
K2 (D)	44.33 ± 1.21	44.11 ± 1.26	***0.286***
Kmean (D)	43.73 ± 1.09	43.53 ± 1.19	***0.346***
Corneal astigmatism (D)	-1.20 ± 0.70	-1.14 ± 0.60	***0.966***
Corneal astigmatism degree (°)	71.56° ± 79.79°	83.12° ± 78.91°	***0.131***
Kmax (D)	44.91 ± 1.35	44.87 ± 1.25	***0.974***
Posterior			
K1 (D)	-6.00 ± 0.21	-5.90 ± 0.20	***0.036***
K2 (D)	-6.41 ± 0.27	-6.34 ± 0.25	0.198
Kmean (D)	-6.21 ± 0.23	-6.12 ± 0.22	0.072
Corneal astigmatism (D)	-0.41 ± 0.15	-0.43 ± 0.13	0.398
Corneal astigmatism degree (°)	90.94° ± 8.54°	90.54° ± 15.10°	0.572
Cornea thickness (µm)			
Central	545.56 ± 29.43	537.18 ± 40.42	***0.079***
Thinnest	541.13 ± 30.07	533.46 ± 40.99	***0.096***
Elevation (µm)			
Anterior	4.29 ± 2.96	3.86 ± 1.84	***0.537***
Posterior	11.48 ± 3.29	10.28 ± 2.90	***0.075***
Corneal volume (mm^3)	58.53 ± 2.95	57.05 ± 3.95	***0.046***
HVID (mm)	11.84 ± 0.33	11.88 ± 0.38	***0.248***
Anterior chamber			
Anterior chamber depth (mm)	3.06 ± 0.33	3.35 ± 0.26	***<0.001***
Anterior chamber volume (mm^3)	162.00 ± 31.43	194.74 ± 27.57	***<0.001***
Nasal angle (degree)	45.98° ± 5.54°	50.67° ± 4.45°	***<0.001***
Temporal angle (degree)	39.88° ± 7.45°	43.53° ± 8.00°	***0.013***
HACD (mm)	11.98 ± 0.50	12.49 ± 0.45	***<0.001***
Asphericity			
Anterior	-0.128 ± 0.11	-0.152 ± 0.11	***0.376***
Posterior	0.008 ± 0.21	0.048 ± 0.24	***0.522***
Pupil offset (µm)			
Total	229.36 ± 108.24	218.64 ± 116.43	***0.529***
x-component	168.54 ± 124.21	167.40 ± 112.88	***0.926***
y-component	116.25 ± 84.86	113.80 ± 88.24	***0.918***

RMS-HOAs (µm)			
Total	0.261 ± 0.062	0.253 ± 0.081	0.362
Anterior	0.270 ± 0.068	0.269 ± 0.088	0.749
Posterior	0.077 ± 0.022	0.074 ± 0.025	0.403
Coma (µm)			
Total	0.142 ± 0.056	0.142 ± 0.067	***0.980***
Anterior	0.154 ± 0.068	0.156 ± 0.070	***0.957***
Posterior	0.030 ± 0.019	0.027 ± 0.021	***0.481***
Spherical aberration (µm)			
Total	-0.111 ± 0.040	-0.101 ± 0.032	***0.240***
Anterior	-0.127 ± 0.038	-0.119 ± 0.032	***0.317***
Posterior	0.016 ± 0.010	0.019 ± 0.011	***0.366***
Trefoil (µm)			
Total	0.135 ± 0.069	0.133 ± 0.078	***0.784***
Anterior	0.134 ± 0.068	0.140 ± 0.082	***0.870***
Posterior	0.035 ± 0.021	0.032 ± 0.018	***0.591***
Strehl ratio of PSF	0.171 ± 0.085	0.177 ± 0.067	***0.458***

*Mann-Whitney U test

D: Diopters, CDVA: Corrected distance visual acuity, K1: Flat keratometry, K2: Steep keratometry, Kmean: Average keratometry, Kmax: Maximum keratometry, HVID: Horizontal visible iris diameter, HACD: Horizontal anterior chamber diameter, RMS-HOAs: Root-mean-square of higher order aberrations, PSF: Point-spread function

for all). The anterior chamber parameters, CV, and pachymetry measurements were similar across subgroups ($p>0.05$ for all). The mean anterior asphericity, anterior elevation, total pupil-offset, RMS-HOAs, and coma were significantly higher in females ($p<0.05$ for all), while the mean total and anterior spherical aberration values were significantly more negative in females compared to males ($p<0.05$ for all).

Correlations with age and spherical equivalent

In the PE group, age showed a positive correlation with anterior K1 and a negative correlation with posterior K1 ($p < 0.05$ for all) (Table 3). The anterior chamber–related measurements, pachymetric parameters, HVID, and CV were all negatively correlated with age, whereas the x-component of pupil offset and PSF demonstrated positive correlations with age ($p < 0.05$ for all). The SE was significantly negatively correlated with anterior K2, anterior chamber–related parameters (excluding nasal angle), total and anterior RMS-HOAs, posterior spherical aberration, and total and anterior trefoil ($p < 0.05$ for all).

Discussion

The PE was first described by Axenfeld in 1920 (1). Axenfeld anomaly described as a prominent and anteriorly displaced Schwalbe line (PE) with the adhesion of peripheral iris strands (8), whereas Rieger anomaly includes the PE in combination with iris hypoplasia, polycoria, and corectopia (9). In contemporary medical terminology, these distinctions are no longer commonly used; instead, these ocular findings, along with systemic abnormalities (such as dental anomalies, cardiac defects, craniofacial dysmorphism, and abdominal wall defects) are classified within the Axenfeld-Rieger syndrome spectrum. Notably, approximately half of affected individuals develop glaucoma, which often necessitates surgical intervention (1). Previous studies have primarily examined the prevalence of the PE and its association with systemic or ocular diseases, particularly glaucoma (2, 5-7). In contrast, the present study provides a detailed Scheimpflug–Placido–based comparative analysis of anterior and posterior corneal surfaces, higher-order aberrations, and anterior chamber parameters in eyes with incidentally detected PE and a healthy control group, while also examining their relationships with age, gender, and refractive status.

In this study, eyes with PE demonstrated a slightly steeper posterior flat keratometry value compared to normal eyes. Furthermore, the CV was greater in

Table 2. Refractive, visual, and tomographical parameters in gender subgroups of posterior embryotoxon

	Female (n=28)	**Male** (n=20)	*p value*
Age (years)	34.43 ± 13.35	33.40 ± 14.87	***0.557***
Refractive error (D)			
Sphere	-1.42 ± 2.19	-1.06 ± 1.27	***0.071***
Cylinder	-0.59 ± 0.69	-0.52 ± 0.85	0.409
Spherical equivalent	-1.71 ± 2.46	-1.34 ± 1.45	0.097
CDVA (Decimal)	0.99 ± 0.02	0.99 ± 0.02	***0.765***
Anterior			
K1 (D)	43.37 ± 1.02	42.80 ± 1.08	***0.072***
K2 (D)	44.60 ± 1.00	43.96 ± 1.40	***0.070***
Kmean (D)	43.98 ± 0.96	43.38 ± 1.18	***0.058***
Corneal astigmatism (D)	-1.23 ± 0.62	-1.16 ± 0.80	***0.385***
Corneal astigmatism degree (°)	59.32 ±78.20	88.70 ± 80.80	***0.124***
Kmax	45.24 ± 1.21	44.44 ± 1.43	***0.057***
Posterior			
K1 (D)	-6.08 ± 0.20	-5.88 ± 0.18	***0.002***
K2 (D)	-6.52 ± 0.27	-6.26 ± 0.27	***0.001***
Kmean (D)	-6.30 ± 0.19	-6.07 ± 0.22	***0.001***
Corneal astigmatism (D)	-0.43 ± 0.15	-0.38 ± 0.15	***0.296***
Corneal astigmatism degree (°)	91.00 ± 8.57	90.85 ± 8.71	***0.572***
Cornea thickness (µm)			
Central	539.64 ± 32.12	553.85 ± 23.51	***0.143***
Thinnest	535.07 ± 33.45	549.60 ± 22.74	***0.174***
Elevation (µm)			
Anterior	4.82 ± 3.47	3.55 ± 1.87	***0.029***
Posterior	12.07 ± 3.46	10.65 ± 2.92	***0.135***
Corneal volume (mm^3)	58.80 ± 3.56	58.16 ± 1.79	***0.523***
HVID (mm)	11.80 ± 0.37	11.89 ± 0.27	***0.148***
Anterior chamber			
Anterior chamber depth (mm)	3.07 ± 0.31	3.03 ± 0.35	***0.786***
Anterior chamber volume (mm^3)	159.50 ± 27.96	165.50 ± 36.21	***0.397***
Nasal angle (degree)	45.96 ± 5.22	46.00 ± 6.10	***0.850***
Temporal angle (degree)	39.11 ± 7.10	40.95 ± 7.97	***0.325***
HACD (mm)	11.91 ± 0.50	12.06 ± 0.51	***0.503***
Asphericity			
Anterior	-0.096 ± 0.12	-0.173 ± 0.08	***0.038***
Posterior	-0.002 ± 0.23	0.025 ± 0.18	***0.722***
Pupil offset (µm)			
Total	262.65 ± 105.03	182.75 ± 96.88	***0.011***
x-component	193.21 ± 130.04	134.00 ± 109.46	0.096
y-component	128.21 ± 99.51	99.50 ± 56.89	0.530

RMS-HOAs (µm)			
Total	0.281 ± 0.057	0.233 ± 0.059	***0.009***
Anterior	0.296 ± 0.059	0.233 ± 0.063	***0.001***
Posterior	0.077 ± 0.023	0.076 ± 0.020	*0.907*
Coma (µm)			
Total	0.163 ± 0.053	0.112 ± 0.048	***0.002***
Anterior	0.176 ± 0.072	0.123 ± 0.050	***0.005***
Posterior	0.031 ± 0.020	0.027 ± 0.018	*0.539*
Spherical aberration (µm)			
Total	-0.125 ± 0.039	-0.091 ± 0.031	***0.004***
Anterior	-0.141 ± 0.038	-0.109 ± 0.030	***0.005***
Posterior	0.016 ± 0.012	0.017 ± 0.008	*0.991*
Trefoil (µm)			
Total	0.137 ± 0.072	0.131 ± 0.065	*0.975*
Anterior	0.140 ± 0.075	0.126 ± 0.059	*0.516*
Posterior	0.035 ± 0.023	0.034 ± 0.018	*0.882*
Strehl ratio of PSF	0.160 ± 0.070	0.187 ± 0.102	*0.464*

*Mann-Whitney U test

D: Diopters, CDVA: Corrected distance visual acuity, K1: Flat keratometry, K2: Steep keratometry, Kmean: Average keratometry, Kmax: Maximum keratometry, HVID: Horizontal visible iris diameter, HACD: Horizontal anterior chamber diameter, RMS-HOAs: Root-mean-square of higher order aberrations, PSF: Point-spread function

the PE group compared to the controls, although central corneal pachymetry was comparable between groups. This finding may reflect measurement artifacts or true anatomical alterations. Recent histopathological analyses have shown that PE is often associated with peripheral stromal nodules and abnormal extracellular matrix deposition, rather than being solely an anterior displacement of Schwalbe's line (4), potentially leading to localized steepening of the posterior corneal surface and increased overall volume without affecting central thickness. In a case series of nine eyes with PE, increased posterior elevation and a steeper corneal thickness spatial profile compared to normal eyes were reported and it was suggested that the anterior elevation mapping may serve as a useful parameter for distinguishing forme-fruste keratoconus (10). In our study, anterior and posterior elevation, thinnest pachymetry, and corneal aberration values were also comparable to those of normal eyes. The use of complementary techniques, including epithelial thickness mapping and anterior segment optical coherence tomography, may help differentiate structural changes from measurement-related discrepancies, ensuring more accurate biometric assessment in this patient population.

In the PE group, the ACD, ACV, and HACD were significantly lower compared with controls with an approximate reduction of 0.3 mm in the ACD, 32.7 mm^3 in the ACV, and 0.5 mm in the HACD. Both nasal and temporal ACAs were significantly narrower (approximately 4°) in the PE group than in controls. Additionally, anterior chamber-related parameters did not differ by gender, but demonstrated a negative correlation with age and SE refraction. Although isolated PE without iris abnormalities carries a lower glaucoma risk compared to Axenfeld–Rieger syndrome (11), our findings suggest that age-related changes in anterior chamber parameters may increase susceptibility in older patients, underscoring the importance of regular glaucoma monitoring in this population. Moreover, the ACD measurement is crucial intraocular lens (IOL) calculations and phakic IOL planning (12-14). It has been shown that, the ACD and HVID are critical for phakic IOL sizing, and preoperative ACV has been shown to negatively correlate with postoperative vault height (14). Age-related reductions in ACV should be carefully considered

Table 3. Correlations in posterior embryotoxon group

	Age (years)		**SE** (D)	
	r	*p value**	r	*p value**
Anterior				
K1 (D)	0.335	***0.020***	-0.031	*0.834*
K2 (D)	0.092	*0.536*	-0.287	***0.048***
Kmean (D)	0.178	*0.227*	-0.179	*0.223*
Kmax (D)	0.159	*0.279*	-0.257	*0.078*
Posterior (D)				
K1	-0.343	***0.017***	0.052	0.725
K2	-0.112	*0.447*	0.253	0.083
Kmean	-0.197	*0.181*	0.189	0.198
Cornea thickness (µm)				
Central	-0.330	***0.022***	0.213	*0.146*
Thinnest	-0.347	***0.016***	0.182	*0.216*
Elevation (µm)				
Anterior	0.158	*0.284*	0.051	*0.731*
Posterior	-0.100	*0.497*	0.007	*0.963*
Corneal volume (mm^3)	-0.389	***0.006***	-0.114	*0.438*
HVID (mm)	-0.293	***0.043***	-0.094	*0.525*
Anterior chamber				
Anterior chamber depth (mm)	-0.627	***<0.001***	-0.356	***0.013***
Anterior chamber volume (mm^3)	-0.622	***<0.001***	-0.421	***0.003***
Nasal angle (degree)	-0.530	***<0.001***	-0.252	*0.084*
Temporal angle (degree)	-0.506	***<0.001***	-0.357	***0.013***
HACD (mm)	-0.518	***<0.001***	-0.373	***0.009***
Asphericity				
Anterior	0.150	*0.309*	-0.081	*0.586*
Posterior	-0.110	*0.458*	-0.233	*0.110*
Pupil offset (µm)				
Total	0.260	*0.075*	0.101	*0.496*
x-component	0.403	***0.004***	0.358	***0.013***
y-component	-0.082	*0.580*	-0.347	***0.016***
RMS-HOAs (µm)				
Total	-0.060	*0.684*	-0.499	***<0.001***
Anterior	-0.005	*0.974*	-0.446	***0.001***
Posterior	-0.191	*0.193*	-0.145	*0.325*
Coma (µm)				
Total	-0.067	*0.653*	-0.272	*0.062*
Anterior	-0.076	*0.671*	-0.229	*0.117*
Posterior	0.063	*0.671*	0.282	*0.052*

Spherical aberration (µm)				
Total	-0.209	***0.155***	0.108	***0.466***
Anterior	-0.189	***0.199***	0.186	***0.206***
Posterior	-0.144	***0.327***	-0.308	***0.033***
Trefoil (µm)				
Total	-0.063	***0.670***	-0.383	***0.007***
Anterior	0.079	***0.592***	-0.373	***0.009***
Posterior	-0.235	***0.108***	-0.052	***0.727***
Strehl ratio of PSF	0.393	***0.006***	0.281	***0.053***

*Spearman rank correlation test

SE: Spherical equivalent, D: Diopters, CDVA: Corrected distance visual acuity, K1: Flat keratometry, K2: Steep keratometry, Kmean: Average keratometry, HVID: Horizontal visible iris diameter, HACD: Horizontal anterior chamber diameter, RMS-HOAs: Root-mean-square of higher order aberrations, PSF: Point-spread function

when planning phakic IOL implantation, particularly in younger patients with PE.

Gender-related variations in corneal and anterior chamber structures have been well documented in healthy eyes. In a study with Scheimpflug–Placido tomography, Orucoglu et al. (15) reported that females exhibited steeper anterior and posterior K1, K2, and Kmean values, as well as lower ACV, ACD, and anterior chamber angle measurements, compared with males. They found no significant gender differences were observed in corneal astigmatism, CCT, or CV. In this study, anterior keratometry values were slightly steeper in females compared to males, although the difference was insignificant, whereas posterior keratometry values were significantly steeper in females. It has been shown that pupil-offset shows the strongest correlation with the coma, followed by weaker associations with trefoil and astigmatic aberrations (16). Similarly, in this study, the higher total pupil-offset observed in females could account for the greater RMS-HOAs and coma in this subgroup. Additionally, vision quality and sharpness improve as the asphericity and spherical aberration decrease (17). The finding that anterior spherical aberration magnitude was higher in females, whereas anterior asphericity was higher in males, might be consistent with a compensatory optical mechanism aimed at maintaining overall visual quality. The ACD, ACV, and both nasal and temporal ACAs values were comparable between genders, which may reflect the already reduced anterior chamber parameters in eyes with PE, thereby minimizing gender-related differences.

In normal eyes, the cornea undergoes various age-related structural and optical changes, including a decrease of approximately 4.6 µm in the CCT and 0.6 mm^3 in the CV per decade (18). Consistent with the literature, a significant negative correlation was observed between CCT, ThCT, and CV and age in eyes with PE in the present study. Additionally, anterior K1 increased with age, whereas posterior K1 decreased [like normal eyes (15)]. The Strehl ratio of PSF, an established indicator of optical quality, has been shown to decrease with age in normal eyes (19). In this study, the PSF values were comparable between eyes with PE and normal eyes. Interestingly, while aberration values did not show a significant age-related change in eyes with PE, PSF values increased with age. This may arise from opposing anterior–posterior corneal curvature changes, which help maintain or even enhance optical quality despite aging-related structural changes. This finding should be confirmed in future prospective studies with larger patient cohorts and longer follow-up periods.

In this study, the total pupil-offset remained unchanged despite variations in SE in eyes with PE. However, as myopia increased (i.e., as the SE decreased), the magnitude of the x-component of the pupil offset decreased, while that of the y-component increased. Moreover, given the negative correlation between SE and RMS-HOAs as well as trefoil, this relationship should be considered when planning corneal (wavefront-guided or wavefront-optimized ablation) or intraocular refractive surgery (multifo-

cal or phakic IOL implantation) in especially myopic eyes with PE to achieve optimal visual outcomes.

This study has certain limitations. Due to retrospective design, this study was unable to analyze the thickness of corneal layers, particularly the epithelium and stroma, across different corneal zones. In addition, the number and morphology of endothelial cells could not be evaluated. Axial length could not be measured, precluding assessment of its potential impact on corneal and anterior chamber parameters. Our findings encompass eyes with isolated PE, precluding generalization to syndromic PE or glaucomatous populations. Despite these limitations, our study provides a comprehensive analysis of both anterior and posterior corneal and anterior chamber changes in eyes with PE compared to normal eyes. It also explores their associations with age, gender, and refractive status.

In conclusion, several corneal parameters and particularly anterior chamber–related measurements obtained using Scheimpflug-Placido tomography differ between eyes with PE and normal eyes. These differences, potentially influenced by age, gender, and refractive status, should be carefully considered during the diagnosis, follow-up, and surgical planning of eyes with PE.

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