

Anterior Segment Optical Coherence Tomography Analysis of Clinically Unilateral Pseudoexfoliation Syndrome: Evidence of Bilateral Involvement and Morphologic Factors Related to Asymmetry

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PURPOSE. To compare the morphology of the anterior chamber angle (ACA) and iris in eyes with pseudoexfoliation (PEX) syndrome to that of their clinically unaffected fellow eyes and normal control eyes.

METHODS. Forty-two patients with unilateral PEX syndrome and 42 normal subjects were studied. Eyes were separated into those with PEX, their clinically unaffected fellow eyes, and normal eyes. The dark-light changes of the ACA and iris were documented by anterior segment optical coherence tomography (AS-OCT) video recordings. The nasal ACA parameters including the angle opening distance at 500 μm (AOD500), the trabecular-iris space at 500 μm (TISA500), and the trabecular-iris angle at 500 μm (TIA500); anterior chamber depth (ACD); iris-lens contact distance (ILCD), and iris configuration were analyzed with the built-in software and a customized program.

RESULTS. The ACA parameters were not significantly different among all three groups in the dark. The PEX eyes had significantly smaller ACA parameters than their fellow eyes and normal control eyes in the light. PEX eyes also had significantly shallower ACD, longer ILCD, and greater iris convexity (both in dark and light), and thinner iris (in dark) than their fellow eyes. The fellow eyes had significantly lower ACD both in the dark and light, and smaller angle opening distance at 500 μm and ILCD in the light than normal controls. There were no significant differences in the iris area among the three groups.

CONCLUSIONS. Differences in the anterior segmental morphology are present between PEX and fellow eyes. These disparities may be related to the asymmetry in patients with the unilateral PEX syndrome. (*Invest Ophthalmol Vis Sci.* 2011;52:5679–5684) DOI:10.1167/iops.11-7274

The pseudoexfoliation (PEX) syndrome is a common age-related disorder of the extracellular matrix that can affect 10%–20% of people older than 60 years worldwide.^{1,2} The main ocular manifestation of PEX is the production and pro-

gressive accumulation of abnormal extracellular fibrillar and pseudoexfoliation material in almost all of the inner walls of the anterior segment of the eye. There has been a renewed interest in this disease because of the better awareness of the complications accompanying PEX including phacodonesis and lens subluxation, intractable glaucoma, melanin dispersions, poor mydriasis, blood-aqueous barrier dysfunction, and posterior synechiae.^{1,2}

Up to 76% of patients with PEX are initially diagnosed as having unilateral PEX.³ However in an electron microscopic study, Parekh et al. reported that 26 of 32 patients (81%) with clinically unilateral PEX had pseudoexfoliation material on either the lens capsule or conjunctival samples of the clinically unaffected eyes.⁴ Furthermore, several reports on the follow-up of patients with unilateral PEX documented that 74% to 81.6% of the unilateral cases became bilateral.^{5–7} This suggested that unilateral PEX is in fact a bilateral but asymmetric condition, and the percentage of unilateral disease decreases with a corresponding increase in bilateral disease with increasing age. The factors affecting the conversion from unilateral to bilateral disease are not known, and the pathogenic mechanism underlying the asymmetric condition has not been determined. Subtle differences in ocular blood flow,⁸ aqueous humor dynamics, blood-aqueous barrier function, or anterior segmental morphology might be responsible for the asymmetry.^{1,2}

Ultrasound biomicroscopic (UBM) studies on the morphologic alterations of the anterior segment of PEX eyes have shown abnormalities of the zonules, lens thickening, shallow central anterior chamber depth (ACD), and occludable angles.^{9–14} In unilateral PEX patients, the PEX eyes and fellow eyes have been reported to share some similar morphologic changes.¹⁴

With the advancement of ophthalmic imaging instruments, more information has been obtained on the morphology of the structures in different ocular disorders. Fourier domain anterior segment optical coherence tomography (AS-OCT) is a representative imaging technique that provides cross-sectional views of the anterior segment with a resolution better than that of UBM.¹⁵ Images and measurements of very fine structures can be achieved rapidly and noninvasively. In addition, using the AS-OCT video mode has allowed investigators to document dynamic morphologic alterations of the anterior chamber angle (ACA) and iris during pupillary movements without being influenced by accommodation.^{16–18}

The purpose of this study was to compare the morphology of the anterior segment of affected eyes and their fellow eyes in cases of unilateral PEX. To accomplish this, we recorded images of the anterior segment by AS-OCT during pupillary dilation and constriction. Comparisons were made of the ACA

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and the iris parameters in the PEX eyes, their fellow eyes, and normal control eyes.

SUBJECTS AND METHODS

Patients and Control Subjects

We studied 45 consecutive patients with unilateral PEX syndrome who visited the Department of Ophthalmology, Ehime University from January 2009 to November 2010. All eyes were examined by slit-lamp biomicroscopy after pupillary dilation. PEX eyes had clinically evident PEX material at the pupillary border or on the anterior lens capsule in one eye. These eyes were placed in the PEX eye group. Their clinically unaffected fellow eyes were placed in the fellow eye group. Forty-five age- and sex-matched normal subjects were also studied and one eye was randomly selected as the normal control.

The exclusion criteria included: prior intraocular surgery, e.g., laser trabeculoplasty, laser iridotomy, laser iridoplasty, or ocular trauma; evidence of peripheral anterior synechiae on indentation; iris dystrophy or dyscoria; lymphoma, sarcoidosis, diabetic mellitus, inflammation; eyes using anti-glaucoma medications or having abnormal intraocular pressure; or use of systemic medications that could affect the ACA or pupillary reflex.

All participants underwent a complete ophthalmic examination, including best-corrected visual acuity, autorefractometry, slit-lamp microscopy, and intraocular pressure measurements by applanation tonometry (Goldmann; Haag-Streit, K oniz, Switzerland). The ocular axial length was measured (IOL Master; Carl Zeiss, Jena, Germany). Gonioscopy was performed with a 4-mirror lens at high magnification ($\times 16$) with the eye in the primary position of gaze. All investigated eyes had open-angles and all structures anterior to the scleral spur were identified by gonioscopy (Shaffer grade ≥ 2).

The procedures used conformed to the tenets of the Declaration of Helsinki. An informed consent was obtained from all subjects after an explanation of the nature and possible consequences of the procedures. The protocol used was approved by the Ethics Committee of Ehime University School of Medicine.

Anterior Segment Optical Coherence Tomography

An experienced operator who was masked to the results of the ophthalmic examinations performed the AS-OCT (Swept-source 1000

CASIA AS-OCT, Tomey, Nagoya, Japan). This AS-OCT system had a 30 kHz axial scan rate with an axial resolution of 10 μm . The use of 1310 nm wavelength coupled with high resolution Fourier domain-OCT improved the resolution and penetration of the measuring beam into turbid tissues with a scan depth of 6 mm. This was sufficient to image the entire anterior segment in one frame.¹⁵ The scan of the anterior chamber was a noncontact procedure during which the subject fixated on an internal target.

The AS-OCT real-time video recording mode (4 frames per second) was used to study the changes of the ACA and the iris during pupillary dilation and light-induced constriction. The scan was centered on the pupil, and the scan passed along the nasal-temporal axis, i.e., 0° to 180° . After one minute at 50 lux of dark-adaptation, a LED pen light (Gentos, Tokyo, Japan), fixed at a distance of 20 cm, 45° from the optic axis of the examined eye, was turned on. The illuminance of the light was standardized at 2000 lux, and it was kept on for 4 seconds to induce pupillary constriction. AS-OCT scans were recorded for 10 seconds and the operator chose the best video frame with good centering to analyze. Data were excluded if the scleral spur could not be identified or the frame was of suboptimal quality because of blinks and eye movements. Each eye was examined three times with an interest interval of at least 10 minutes.

Image Processing

All images were processed separately and analyzed by two observers (XZ and KN) who were masked to the clinical findings of the eye. The video file was reviewed and one frame of the images in the dark (most dilated pupil) and the light (most constricted pupil) were selected for each subject. The morphology of structures on the nasal side of the eye was analyzed. Images were first analyzed with the built-in software for the ACA parameters: angle opening distance at 500 μm (AOD500), trabecular-iris space at 500 μm (TISA500), and trabecular-iris angle at 500 μm (TIA500). The central anterior chamber depth (ACD) and the pupillary diameter were also measured (Fig. 1A).

All images were then exported and analyzed with a customized software program written for the following iris parameters (Fig. 1B): the iris thickness in the dilator muscle region (DMR) which was set at one-half of the distance between the scleral spur and the pupillary margin was measured as described¹⁹; and the iris thickness in the sphincter muscle region (SMR) which was set at 0.75 mm from the pupillary margin was also measured. The ratio of the thickness at

AS-OCT Analyses of Anterior chamber Angle and Iris Configuration

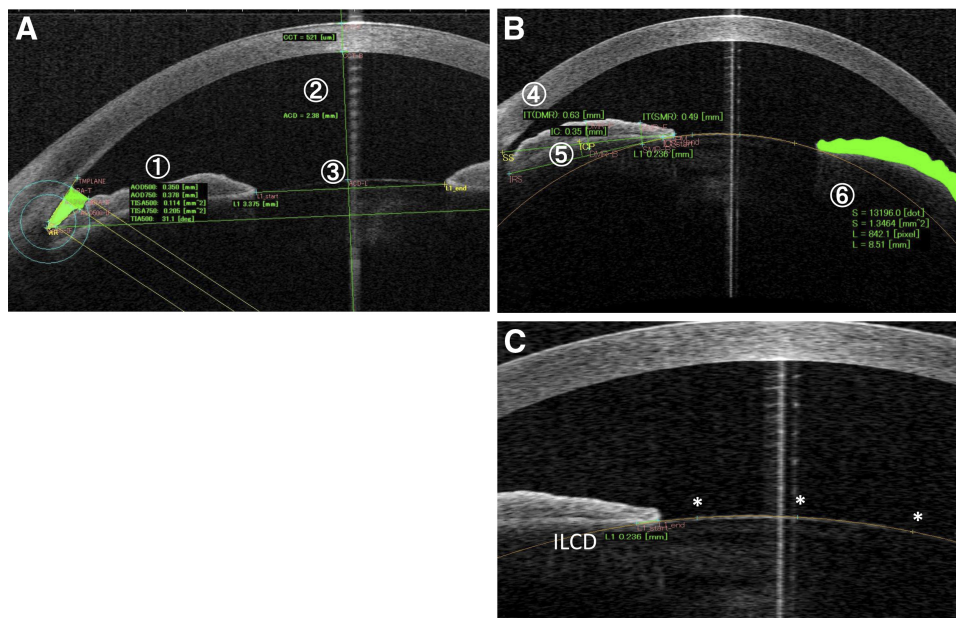


FIGURE 1. Anterior segment optical coherence tomographic (AS-OCT) images from which the morphologic parameters of the structures in the anterior chamber and the iris were measured. (A) Anterior chamber parameters of (1) angle measurements (AOD500, TISA500, and TIA500 were used), (2) central anterior chamber depth (ACD), and (3) pupillary diameter. (B) Iris configurations of (4) iris thickness (IT) at the dilator muscle region (DMR) measured at one-half of the distance between the scleral spur (SS) and the pupillary margin; iris thickness at the sphincter muscle region (SMR) measured at 0.75 mm from the pupillary margin, (5) iris convexity (IC), and (6) iris area (indicated by green shading over the right half of the iris). (C) Iris-lens contact distance (ILCD) measurement. Asterisks represent three points selected on the lens surface for generating estimated curved line of the anterior lens capsule. The ILCD was measured along the iris pigment epithelium from the papillary border to the point at which the iris was seen to separate from the anterior lens capsule.

the DMR and SMR (DMR/SMR) was used for the statistical analyses to reduce the intersubject variability.

In addition, the iris convexity was defined as the distance between the posterior point of greatest iris curvature to a line drawn from the most peripheral to the most central points of the iris pigment epithelium. The area of the iris was determined by the cumulative cross-sectional area of the iris from the scleral spur to the edge of the pupil.²⁰ A program was also written for the calculation of iris-lens contact distance (ILCD). To measure this, 3 points were manually designated on the lens surface and a curved line of the anterior lens capsule was automatically generated by the software. The ILCD was measured along the iris pigment epithelium from the pupillary border to the point at which the iris was seen to separate from the anterior lens capsule (Fig. 1C). These measurements had good reliability with the intraobserver and interobserver intraclass correlation coefficients ranging between 0.96 to 0.98 and 0.97 to 0.99, respectively.

Statistical Analyses

All data are expressed as the means ± standard deviations (SDs). Gender differences between PEX patients and normal subjects were evaluated by the χ^2 test. Comparisons of other demographic data, biometric characteristics, and AS-OCT parameters were evaluated by paired *t*-tests (PEX eye versus fellow eye) or two-tailed Student's *t*-tests (PEX eye versus normal control eye or fellow eye versus normal control eye). The ACA and iris parameters were compared with adjustment for pupil size. The significance of the differences in the DMR/SMR ratio among the three groups was determined by the Tukey-Kramer test. A probability level of *P* < 0.05 was considered statistically significant. Data were analyzed with statistical software (JMP version 9.0 for Windows; SAS Japan Inc., Tokyo, Japan).

RESULTS

Three patients with unilateral PEX and three normal subjects were excluded due to a poor imaging of the scleral spur. Forty-two patients (17 men and 25 women with a mean age of 72.7 ± 7.4 years and a range of 61 to 92 years) and 42 normal subjects (16 men and 26 women with a mean age of 73.6 ± 8.9 years and a range of 64 to 90 years) were analyzed. The mean age of the PEX patients was not significantly different from that of the normal controls (*P* = 0.886, two-tailed Student's *t*-test). Slit-lamp biomicroscopy showed that all eyes with PEX had typical whitish exfoliation material at the pupillary edge and on the anterior lens capsule. The fellow eyes and normal control eyes did not have these deposits. The differences in the visual acuity, gender distribution, refractive error (spherical equivalent), axial length, intraocular pressure, and gonioscopic grading (Shaffer) of the ACA among the three groups were not significant. The data are summarized in Table 1.

Comparisons of AOD 500 for PEX, Fellow and Normal Control Eyes

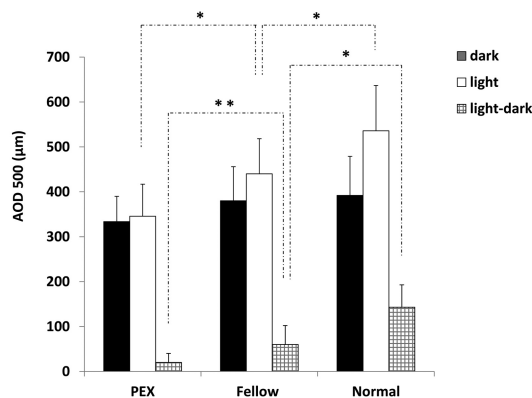


FIGURE 2. Comparisons of AOD500 for eyes with the PEX syndrome, their unaffected fellow eyes, and normal control eyes. Dark, values measured in the dark when pupils were mostly dilated; Light, values measured in the light when pupils were mostly constricted; Light-dark, AOD500_(light) - AOD500_(dark). Statistical significance is denoted by ***P* < 0.01, and **P* < 0.05.

Anterior Chamber Angle (ACA) Morphology

In the dark when pupils were dilated, the mean AOD500 was 333.6 ± 56.5 µm in the PEX eyes, 380.1 ± 76.4 µm in the fellow eyes, and 392.6 ± 87.2 µm in the normal control eyes (Fig. 2). The differences between the three groups were not significant (PEX versus fellow, *P* = 0.225, paired *t*-tests; PEX versus normal, *P* = 0.133; and fellow versus normal, *P* = 0.416, both two-tailed Student's *t*-test). When the pupils were constricted by light, the AOD500 in the PEX eyes was significantly smaller than that of the fellow eyes (*P* = 0.021) and the normal eyes (*P* = 0.008). The AOD500 in the fellow eyes was also significantly smaller than that of the normal eyes (*P* = 0.037). In addition, the mean dark-to-light change of the AOD500 for the PEX eyes was also significantly less than that of the fellow eyes (20.5 ± 16.6 µm vs. 60.8 ± 42.2 µm; *P* = 0.007) and of the normal control eyes (*P* = 0.004). The difference in the changes of the AOD500 between the fellow and normal control eyes was also significant (*P* = 0.033).

In the dark, the TISA500 was not significantly different among the three groups. However in light, the TISA500 of the PEX eyes was significantly smaller than that of the fellow eyes and normal control eyes (Fig. 3). In the light, the PEX eyes also had significantly narrower TIA500 than that of the fellow and normal control eyes. Similarly, the dark-to-light change of the TIA500 of the PEX eyes was significantly less than that of the

TABLE 1. Demographic and Biometric Characteristics of PEX Eye, Fellow Eye, and Normal Control Eye Groups

	PEX	Fellow	Normal	<i>P</i>
Age, y	72.7 ± 7.4	—	73.6 ± 8.9	0.886*
Sex, male/female	17/25	—	16/26	0.763†
Spherical equivalent, D	-0.34 ± 2.8	-0.22 ± 1.76	-0.28 ± 1.52	0.521‡
BCVA, LogMAR	0.04 ± 0.05	0.03 ± 0.04	0.00 ± 0.03	0.554‡
Axial length, mm	23.71 ± 0.94	24.06 ± 0.81	24.5 ± 1.01	0.669‡
Intraocular pressure, mm Hg	14.8 ± 3.1	13.6 ± 3.8	13.1 ± 4.8	0.375‡
Gonioscopy grading (Shaffer)	2.9 ± 0.68	3.1 ± 0.77	3.1 ± 0.82	0.428‡

Data are given as mean ± SD. All groups, *n* = 42. BCVA, best-corrected visual acuity; D, Diopter; LogMAR, logarithm of the minimum angle of resolution.

* PEX patients versus normal control subjects (two-tailed Student's *t*-test).

† PEX patients versus normal control subjects (χ^2).

‡ PEX eye versus fellow eye (paired *t*-test).

Comparisons of TISA 500 for PEX, Fellow and Normal Control Eyes

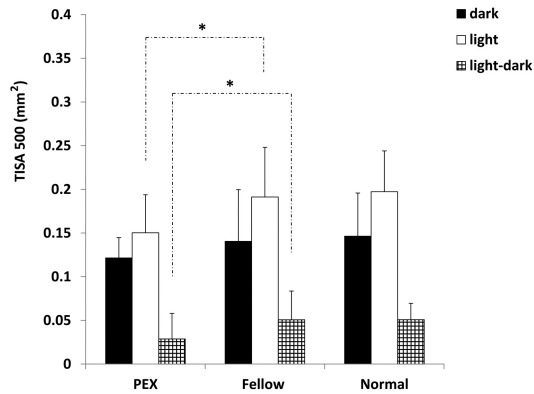


FIGURE 3. Comparisons of TISA500 for eyes with the PEX syndrome, their unaffected fellow eyes, and normal control eyes. Dark, values measured in the dark when pupils were mostly dilated; Light, values measured in the light when pupils were mostly constricted; Light-dark, $TISA500_{(light)} - TISA500_{(dark)}$. Statistical significance is denoted by $*P < 0.05$.

fellow eyes (Fig. 4). The PEX eyes had significantly smaller ACD than that of the fellow eyes both in dark and light ($P = 0.021$ and $P = 0.018$, respectively; paired *t*-tests; Table 2). The ACD of the fellow eyes was also significantly smaller than that of normal control eyes ($P = 0.038$ and $P = 0.032$ for dark and light respectively; two-tailed Student's *t*-test).

The pupillary diameter in dark for the PEX eyes was significantly smaller than that of fellow eyes ($P = 0.011$). When the dark-to-light change was analyzed, the PEX eyes had significantly less pupillary change than that of the fellow eyes ($P = 0.025$) and the normal control eyes ($P = 0.008$).

Iris Configuration

The difference in the area of the iris was not significant among the three groups either in dark or light. The mean iris convexity of the PEX eyes was $286.3 \pm 63.7 \mu\text{m}$ in the dark and $251.5 \pm 72.4 \mu\text{m}$ in the light. The mean iris convexity of the fellow eyes was $239.4 \pm 86.6 \mu\text{m}$ in the dark and $195.1 \pm 59.3 \mu\text{m}$ in the light. The iris convexity was significantly greater in the PEX eyes than that of their fellow eyes both in the dark and the light ($P = 0.029$ and $P = 0.038$, respectively; paired *t*-tests). The convexity of the iris of the fellow eyes was also larger than that of the normal controls but the difference was not significant.

The DMR/SMR ratio in dark for PEX eyes was significantly less than that of the fellow eyes ($P = 0.037$; Tukey-Kramer test). The differences in the DMR/SMR ratio among the three groups in light were not significant (Table 2).

Iris-Lens Contact Distance (ILCD)

The mean ILCD of PEX eyes was $0.523 \pm 0.14 \text{ mm}$ in the dark and $0.908 \pm 0.15 \text{ mm}$ in the light. The mean ILCD of the fellow eyes was $0.346 \pm 0.12 \text{ mm}$ in the dark and $0.732 \pm 0.11 \text{ mm}$ in the light. The differences in the ILCD between PEX and fellow eyes were significant both in dark and light ($P < 0.001$ for both; paired *t*-tests; Figure 5). In the light, the ILCD of the fellow eyes was also significantly longer than that of normal control eyes ($P = 0.035$; two-tailed Student's *t*-tests; Fig. 5).

DISCUSSION

Our findings showed that AS-OCT can be used for noninvasive, quantitative, and reliable analyses of the ACA and iris morphol-

ogy in eyes with the PEX syndrome. These findings would probably not be obtained by regular gonioscopy or slit-lamp examination. Analyzing the video files provided us with a useful method to accurately examine the ACA and iris configuration when the pupil was most dilated or constricted. This then allowed us to detect subtle changes between the dark and light conditions.

The differences in the ACA parameters, namely, the AOD500, TISA500, and TIA500, among the three groups were not significant in the dark. However, when the pupil was constricted by light, the PEX eyes had significantly smaller values for all the ACA parameters indicating that the widening of the ACA was significantly more impaired in PEX eyes than in their fellow eyes or normal controls. These findings combined with the smaller ACD in PEX eyes indicate the possibility of a weakness of the zonular fibers and forward shifting of the lens, which is consistent with the previous UBM studies.¹⁰⁻¹⁴ For our PEX patients, although the lens shifting was too small to cause a statistically significant change in the refraction, this alteration could be detected by the highly sensitive AS-OCT analysis.

It is known that melanin granules derived from the iris pigment epithelium and PEX deposits form posterior synechiae starting from the early stages of the PEX process.^{1,2} These morphologic changes may account for the poor mydriasis, increased iridolenticular contact, and decreased ability of ACA widening during pupillary constriction.

On the other hand, these morphologic alterations may be pathogenic factors for PEX development or the cause for PEX progression in the PEX process. The morphologic changes may also lead to decreased blood flow or circulatory disturbances resulting in abnormalities in the microenvironment of the anterior chamber such as hypoxia and elevation of cellular stress.^{1,2,8} Increased pathologic cytokine or chemokine levels, hypoxic conditions, and circulatory factors in the anterior segment of the eye may also play pivotal roles in the progression of PEX. The relationships among these factors with the morphologic changes need to be investigated.

The iris-lens contact distance (ILCD) was also compared among the three groups. Although ultrasound microscopy can be used for direct measurements of ILCD,²¹⁻²³ our study provided a rapid, noncontact method in evaluating this parameter by AS-OCT imaging. The use of Fourier domain AS-OCT provided excellent images of the iris configuration and in combi-

Comparisons of TIA 500 for PEX, Fellow and Normal Control Eyes

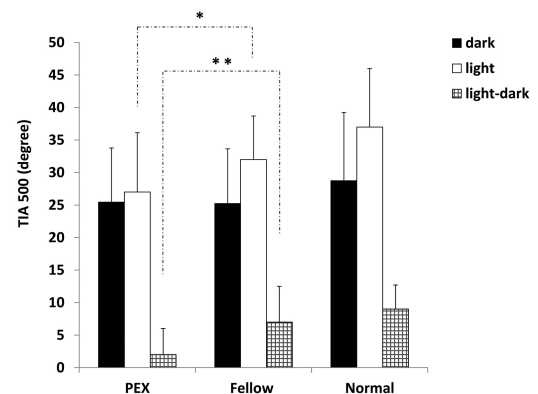


FIGURE 4. Comparisons of TIA500 for eyes with the PEX syndrome, their unaffected fellow eyes, and normal control eyes. Dark, values measured in the dark when pupils were mostly dilated; Light, values measured in the light when pupils were mostly constricted; Light-dark, $TIA500_{(light)} - TIA500_{(dark)}$. Statistical significance is denoted by $**P < 0.01$, and $*P < 0.05$.

TABLE 2. Comparisons of Anterior Chamber Depth and Iris Configuration Parameters for PEX, Fellow, and Normal Control Eyes

	PEX	Fellow	Normal	P
ACD				
Dark, mm	2.52 ± 0.36	2.71 ± 0.34*	2.89 ± 0.36	0.021†
Light, mm	2.52 ± 0.29	2.72 ± 0.23*	2.89 ± 0.48	0.018†
Pupillary diameter				
Dark, mm	3.61 ± 0.46	5.08 ± 0.41	5.86 ± 0.71	0.011†
Light, mm	2.73 ± 0.53	2.68 ± 0.55	2.61 ± 0.52	0.489†
Pupil change (Dark-Light, mm)	1.04 ± 0.48	1.57 ± 0.62	1.55 ± 0.51	0.025†
Iris area				
Dark, mm ²	1.371 ± 0.27	1.368 ± 0.26	1.473 ± 0.24	0.117†
Light, mm ²	1.635 ± 0.36	1.589 ± 0.31	1.688 ± 0.21	0.276†
Iris Convexity				
Dark, μm	286.3 ± 63.7	239.4 ± 86.6	212.7 ± 81.4	0.029†
Light, μm	251.5 ± 72.4	195.1 ± 59.3	180.3 ± 87.3	0.038†
DMR/SMR Ratio				
Dark	0.81 ± 0.12	0.92 ± 0.17	0.97 ± 0.21	0.037‡
Light	0.86 ± 0.21	0.88 ± 0.14	0.87 ± 0.13	0.133‡

Data are given as mean ± SD. Each group, n = 42. ACD and iris area analyses were adjusted by pupil size.

* Significantly different compared with normal control eye (P < 0.05; two-tailed Student's t-test).

† PEX eye versus fellow eye (paired t-test).

‡ PEX eye versus fellow eye (Tukey-Kramer test).

nation with our customized software, we were able to measure the ILCD reliably with high intra- and interobserver intraclass correlation coefficients.

Our findings showed that the ILCD was significantly longer in the PEX eyes than that of their fellow eyes both when the pupil was dilated and when it was constricted. The difference was also found when fellow eyes were compared with normal control eyes with the pupil constricted. The fact that PEX material is often observed at the pupillary border and on the lens capsular area of pupillary movements suggest the production of visible PEX material may be associated with iridolenticular friction. In a separate study, our data showed that PEX eyes with longer intermediate zone, the area between central

disc of PEX material on the lens capsule and peripheral granular zone, tended to have longer ILCD (r = 0.584, Spearman's correlation coefficient; P = 0.006) and higher iris convexity (r = 0.649; P = 0.002). The relationship between the morphologic alterations of the iris and the progression of PEX syndrome remains to be investigated. We suggest that the increased iris-lens contact and iris convexity may be related to increased iridolenticular friction and increased PEX material formation leading to inflammatory responses. As a result, PEX-related cytokines or chemokines can be released to trigger or further accelerate the process.²⁴⁻²⁶

The clinical significance of our results are: first, the AS-OCT parameters, e.g., increased ILCD and decreased widening of the angle during pupillary movements, may be used as additional evidence for an early diagnosis of PEX. In addition, identifying these patients before surgery can help the cataract surgeon be prepared for potential problems, and glaucoma specialist to better manage the ocular pressure and reduce the progression of eyes that would ordinarily be diagnosed as normal, ocular hypertensive, or having primary open angle glaucoma.²⁷ Second, our AS-OCT analysis indicates that it is a rapid, noninvasive, and quantitative method for following and evaluating the severity of the PEX process. It would be interesting to conduct a prospective study on PEX suspects with AS-OCT to follow the conversion from unilateral PEX to bilateral disease. Third, if the morphologic alterations are the pathogenic factors for PEX development or progression, cataract extraction to reduce the ILCD and to widen the angle might be considered to prevent the progression of ocular PEX. Evidence is accumulating to show the effects of cataract surgery on a reduction of intraocular pressure and possibly reducing the number of patients with PEX glaucoma who progress to medication or surgery.^{28,29} Future studies are needed for long-term follow-up on PEX patients to observe the PEX progression after cataract surgery.

There are some limitations of this study. First, this was a comparative correlation study, and a causal relationship between alterations of the morphologic parameters and the PEX development was not determined. The argument certainly remains that the morphologic alterations observed in this study could be the result of the asymmetric manifestation. Thus, a

Comparisons of Iris-Lens Contact Distance for PEX, Fellow and Normal Control Eyes

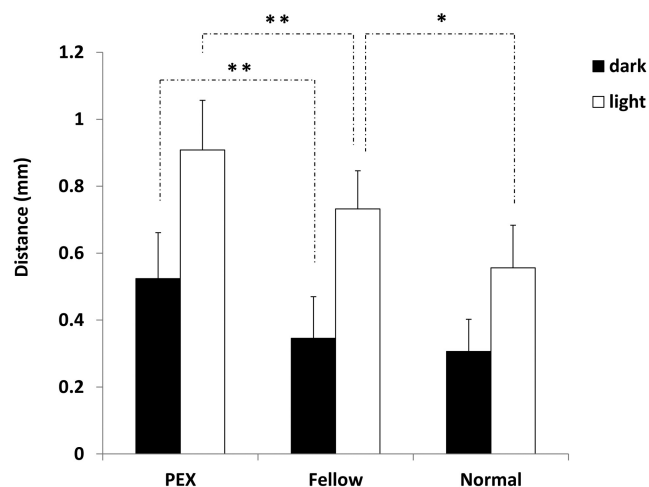


FIGURE 5. Comparisons of iris-lens contact distance for eyes with the PEX syndrome, their unaffected fellow eyes, and normal control eyes. Dark, values measured in the dark when pupils were mostly dilated; Light, values measured in the light when pupils were mostly constricted. Statistical significance is denoted by **P < 0.01, and *P < 0.05.

study designed to test the null hypothesis that the morphologic parameters of the structures in the anterior chamber do not cause or promote PEX must be tested before the "chicken-or-egg" question can be solved. However, our findings showed that the fellow eyes also had the same tendency of morphologic alterations. Therefore, it is reasonable to suggest that the morphologic alterations might take place earlier at least before the clinically evident PEX manifestation.

Second, although the morphologic changes observed might be caused by PEX, they might be the clinical features of the shallow ACD with poor pupillary dilation. In our study, comparing with PEX eyes and their fellow eyes, because PEX is the most discernible difference that can be appreciated by slit-lamp microscopy, it is possible to correlate the morphologic changes to be PEX-related.

Third, our study is limited because it is a cross-sectional study, and was performed on the morphology of structures on the nasal side of the eye. Because this affected all groups equally, our study also showed similar results in other radial directions, and changes in nasal direction are known to take place earlier in the PEX process.³⁰ Therefore, we believe that this limitation has a small effect on our results.

In summary, our study showed that PEX eyes had narrower anterior chamber angle, decreased angle widening during pupillary movements, and increased iridolenticular contact and iris convexity. The fellow eyes shared similar features to some degree. PEX is bilaterally involved; the morphologic differences in the anterior segmental anatomy between the two eyes may be related to the asymmetric manifestation in clinically unilateral PEX.

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