

Ultrasound biomicroscopic measurement of anterior chamber biometry between before and after pupil dilation in children

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PURPOSE. To evaluate anterior chamber biometry of the eyes of normal children using ultrasound biomicroscopy (UBM) and to evaluate the differences in biometry between children and adults, and before and after pupil dilation in children.

METHODS. Anterior chamber depth (ACD) and trabecular-iris angle (TIA) were measured in 94 normal children and 15 normal adults using UBM. Before and after pupil dilation were measured in 42 children with emmetropic and hyperopic eyes.

RESULTS. In 66 emmetropic children, ACD and TIA were 2.93 ± 0.18 mm and $34.42 \pm 4.02^\circ$, respectively. In 28 hyperopic children, ACD and TIA were 2.92 ± 0.21 mm and $35.05 \pm 4.42^\circ$, respectively. There was no significant difference in anterior chamber biometry associated with the refraction. ACD did not differ between children and adults, but TIA in children was wider than in adults. There was no significant difference in ACD or TIA before versus after pupil dilation in any case.

CONCLUSIONS. Anterior chamber biometry in children showed no differences before and after pupil dilation. Also, there was no difference in ACD of children as compared to adults; however, TIA in children was significantly wider than in adults. (*Eur J Ophthalmol* 2008; 18: 532-9)

KEY WORDS. Anterior chamber depth, Trabecular-iris angle, Children, Pupil dilation, Ultrasound biomicroscopy

Accepted: December 9, 2007

INTRODUCTION

Precise measurements of the anterior segment of the eye are essential for understanding the mechanism and the development of this segment. Conventional methods for evaluating the anterior chamber angle, such as ultrasonic biometry and gonioscopy, are clinically useful. However, these are not useful for quantitative analysis of the anterior chamber. The advantages of ultrasound biomicroscopy (UBM) technology are accuracy and reproducibility. High-resolution UBM provides precise measurements of the angle and makes it possible to analyze the anterior chamber quantitatively (1). Furthermore, in cases with extensive corneal opacity, UBM provides morphologic and topographic information about the anterior segment and helps us establish

an individual strategy for surgical management (2).

In adults, many reports describing research using UBM have been published (3-8); however, there are few reports using UBM in children as far as we know (6, 9-11). In the present study we used UBM to investigate the anterior chamber in groups of children based on refractive error and compared the results with those obtained in adults. Furthermore, the change between pre- and post-pupil dilation was examined in groups of children based on their refraction values.

METHODS

We studied 94 emmetropic or hyperopic eyes in 94 children with strabismus or entropion who underwent surgery

under general anesthesia at Kanagawa Children's Medical Center between June 2005 and May 2006. Informed consent for each child was obtained from at least one parent. The patients ranged in age from 1 to 15 years (mean, 6.62 ± 3.03 years). Patients with intraocular diseases were excluded. Emmetropia was defined as a deviation of ± 0.75 diopter from the average refraction in the individual's age group (12). Hyperopia was defined as a deviation of more than $+1.0$ diopter from the average refraction of individuals in the pertinent age group (12). Myopic children were excluded because they for whom the operations are needed were very few. For comparison, measurements were performed on 15 emmetropic adult volunteers aged between 23 and 51 years (mean, 33.44 ± 7.80 years).

In children under stable anesthesia in a supine position, bilateral anterior segments were measured using UBM (Tomey UD-6010, Tomey Corporation, Nagoya, Japan) prior to surgery. UBM scanning was performed with the eyes in central position and along the temporal meridian, because under general anesthesia the eyes are generally directed superomedially or inferiorly. Just before surgery, tropicamide 0.5% was instilled into the eye contralateral to the eye to be operated upon in 42 children. After surgery, the eyes were scanned when ample dilation was confirmed, about 30–60 min after the instillation of tropicamide. We chose tropicamide for short length of effectiveness to reduce the patient's load when they awake after surgery. In adults, all measurements were performed in a supine position. All measurements in both children and adults were performed three times by the same surgeon. Each variable was measured three times, and the mean was calculated. When both eyes were measured, the eye with the least instrumentation error was chosen for analysis.

The UBM parameters were measured as defined by Pavlin et al (1) and the anterior chamber depth (ACD) was measured as the axial distance from the internal corneal surface to the lens surface. Scanning was performed with the pupil at the center of the scanning area, comparing the same position in each case. The trabecular-iris angle (TIA) was measured with the apex of the angle in the iris recess and the arms of the angle passing through a point on the trabecular meshwork 500 μ m from the scleral spur, the point on the iris being perpendicularly opposite. Before instillation of tropicamide, scanning was performed along the temporal meridian, i.e., perpendicular to the corneal limbus, where the pupillary area is located centrally. After pupil dilation, a temporal scan was performed, i.e., perpendicular to the corneal limbus, where the iris is the thickest, so that the angle was reproducible.

The rates of change in ACD and TIA were evaluated according to the value before pupil dilation and age in 42 children (42 eyes) who were examined before and after instillation of tropicamide. The amounts and rates of change of ACD and TIA were defined as follows:

Amount of change = value before pupil dilation – value after pupil dilation.

Rate of change (%) = (amount of change/value before pupil dilation) \times 100.

Statistical analyses were performed using Student *t*-test. Results were considered statistically significant at $p < 0.05$.

RESULTS

Anterior chamber depth and trabecular-iris angle in children

ACD and TIA in relation to age in 66 emmetropic children are shown in Figure 1 (top). The mean ACD was 2.93 ± 0.18 mm and the mean TIA was $34.42 \pm 4.02^\circ$. ACD and TIA in relation to age in 28 children with hyperopia are shown in Figure 1 (bottom). The mean ACD in hyperopia was 2.92 ± 0.21 mm and the mean TIA was $35.05 \pm 4.42^\circ$. Regardless of refraction, ACD tended to increase with age and TIA tended to decrease with age. However, TIA tended to decrease with age in emmetropia but to increase with age in hyperopia. A comparison between emmetropia and hyperopia is shown in Table I. The differences were not statistically significant ($p > 0.05$ for both ACD and TIA).

Comparison of ACD and TIA between emmetropic children and adults

The comparison between emmetropic children and adults is shown in Table II. ACD was 2.97 ± 0.21 mm in adults. The difference in ACD between children and adults was not statistically significant ($p = 0.50$). The TIA of adults was $31.35 \pm 7.78^\circ$. The difference between children and adults in TIA was statistically significant ($p = 0.03$).

Comparison of ACD and TIA before and after pupil dilation in children

The mean ACD increased from 2.91 ± 0.19 to 3.04 ± 0.23 mm after mydriasis in 31 emmetropic eyes (Tab. III, Fig. 2, top left). The rate of change was $-4.25 \pm 3.53\%$.

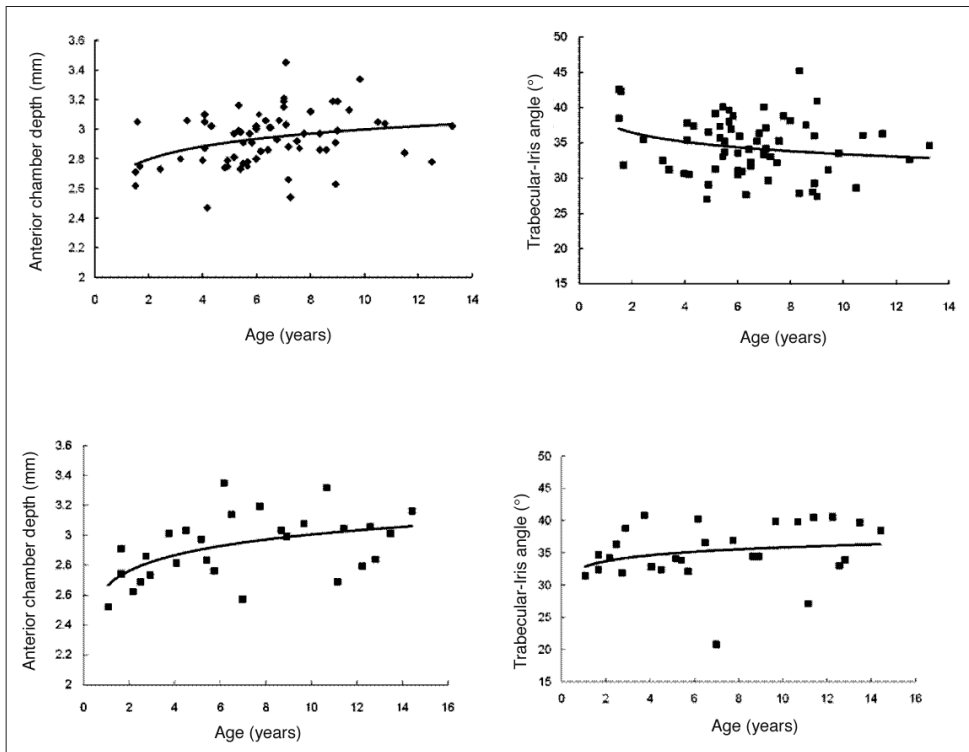


Fig. 1 - Anterior chamber depth and trabecular-iris angle in emmetropic and hyperopic children. (Top left) Anterior chamber depth in emmetropia is plotted with the approximation curve in relation to age. (Top right) Trabecular-iris angle in emmetropia is plotted with the approximation curve in relation to age. (Bottom left) Anterior chamber depth in hyperopia is plotted with the approximation curve in relation to age. (Bottom right) Trabecular-iris angle in hyperopia is plotted with the approximation curve in relation to age.

TABLE I - COMPARISON OF ACD AND TIA BETWEEN EMMETROPIA AND HYPEROPIA IN CHILDREN (mean ± SD)

	Emmetropia (66 eyes)	Hyperopia (28 eyes)	p value*
Age (years)	6.44±2.46	7.03±4.05	—
Refraction (diopters)	0.00±0.53	2.48±1.03	—
ACD (mm)	2.93±0.18	2.92±0.21	0.44
TIA (°)	34.42±4.02	35.05±4.42	0.78

*Student t-test.

ACD = Anterior chamber depth; TIA = Trabecular-iris angle

TABLE II - COMPARISON OF ACD AND TIA BETWEEN CHILDREN AND ADULTS WITH EMMETROPIA (mean ± SD)

	Children (66 eyes)	Adults (15 eyes)	p value*
Age (years)	6.44±2.46	33.83±7.67	—
Refraction (diopters)	0.00±0.53	-0.35±0.33	—
ACD (mm)	2.93±0.18	2.97±0.21	0.50
TIA (°)	34.42±4.02	31.35±7.78	0.03

*Student t-test.

ACD = anterior chamber depth; TIA = Trabecular-iris angle

The R^2 value was 0.0009 when compared with the ACD value before dilation (Fig. 2, top right). The R^2 value was 0.0034 according to age (Fig. 2, bottom left).

The mean TIA increased from 35.38±4.19 to 35.95±4.32° after mydriasis in emmetropic eyes (Tab. III, Fig. 3, top

left). The rate of change was $-2.31±11.72\%$. The R^2 value was 0.2442 when compared with the TIA value before dilation (Fig. 3, top right). The R^2 value was 0.001 when compared according to age (Fig. 3, bottom left). The mean ACD increased from 2.89±0.16 before to

Fig. 2 - Comparison of anterior chamber depth before and after pupil dilation in emmetropia. (Top left) Anterior chamber depth before and after pupil dilation are plotted with the approximation curve. ■ Before pupil dilation; □ after pupil dilation; — approximation curve before pupil dilation; - - - approximation curve after pupil dilation. (Top right) Rate of change of anterior chamber depth is shown with the approximation curve in relation to anterior chamber depth before pupil dilation. (Bottom left) Rate of change of anterior chamber depth is shown with the approximation curve in relation to age.

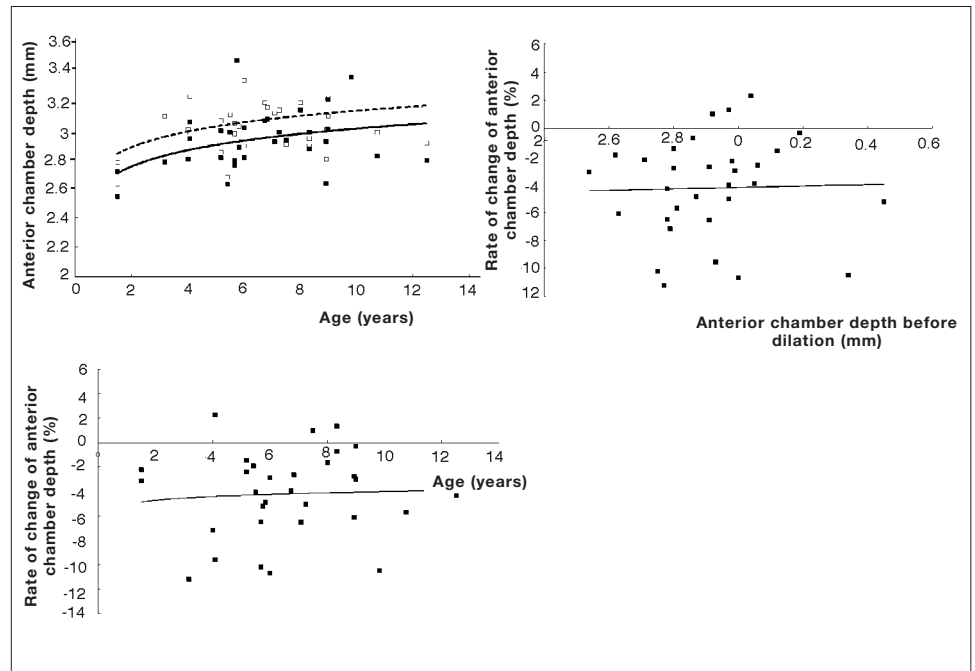
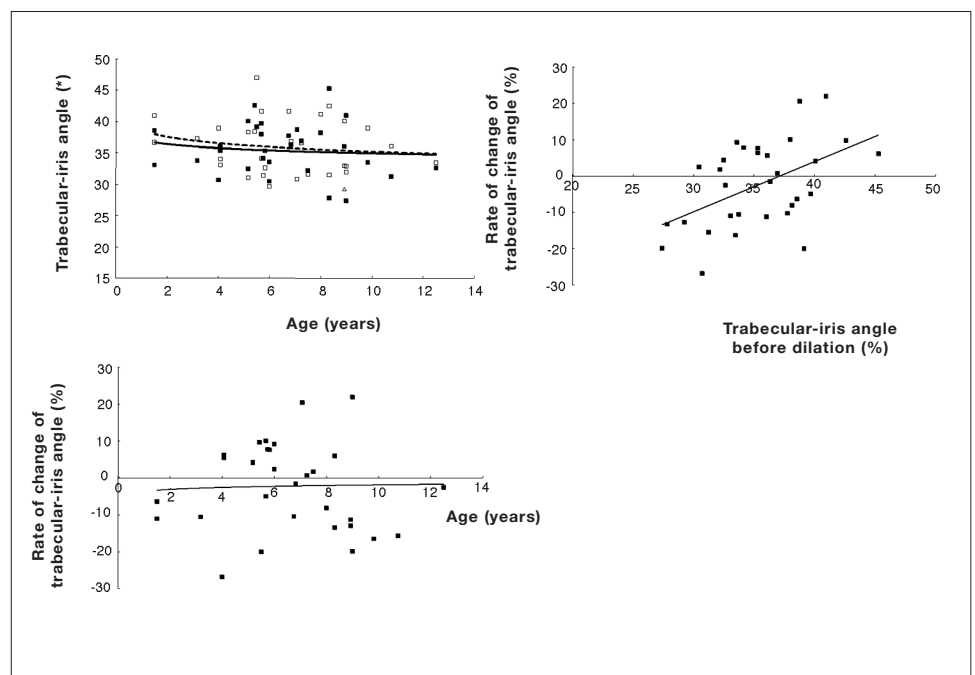


Fig. 3 - Comparison of trabecular-iris angle between before and after pupil dilation in emmetropia. (Top left) Trabecular-iris angle before and after pupil dilation are plotted with the approximation curve. ■ Before pupil dilation; □ after pupil dilation; — approximation curve before pupil dilation; - - - approximation curve after pupil dilation. (Top right) Rate of change of trabecular-iris angle is shown with the approximation curve in relation to anterior chamber depth before pupil dilation. (Bottom left) Rate of change of trabecular-iris angle is shown with the approximation curve in relation to age.



2.97±0.21 mm after mydriasis in 11 hyperopic eyes (Tab. III, Fig. 4, top left). The rate of change was -2.56±3.04%. The R^2 value was 0.1059 compared with the ACD value before dilation (Fig. 4, top right). The R^2 value was 0.1632 according to age (Fig. 4, bottom left). The mean TIA increased from 32.93±4.56 to 36.45±6.70° after mydriasis in hyperopic eyes (Tab. III, Fig. 5, top left).

The rate of change was -15.17±39.49%. The R^2 value was 0.7492 compared with the TIA value before dilation (Fig. 5, top right). The R^2 value was 0.2677 according to age (Fig. 5, bottom left).

The rates of change in ACD and TIA were compared between emmetropia and hyperopia (Tab. IV). The differences were not statistically significant.

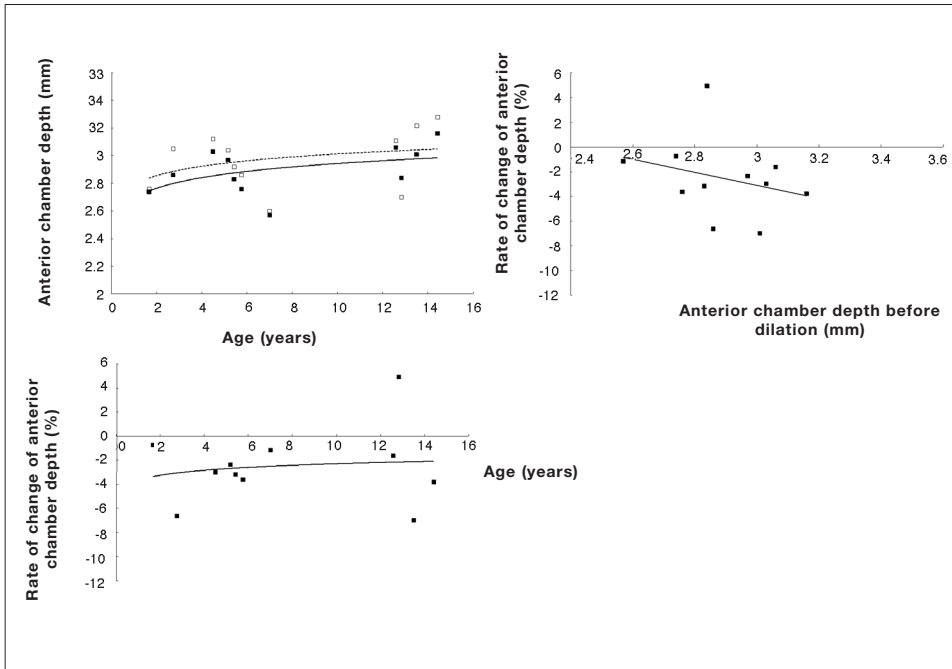


Fig. 4 - Comparison of anterior chamber depth before and after pupil dilation in hyperopia. (Top left) Anterior chamber depth before and after pupil dilation are plotted with approximation curve. ■ Before pupil dilation; □ after pupil dilation; — approximation curve before pupil dilation; - - - approximation curve after pupil dilation. (Top right) Rate of change of anterior chamber depth is shown with the approximation curve in relation to anterior chamber depth before pupil dilation. (Bottom left) Rate of change of anterior chamber depth is shown with the approximation curve in relation to age.

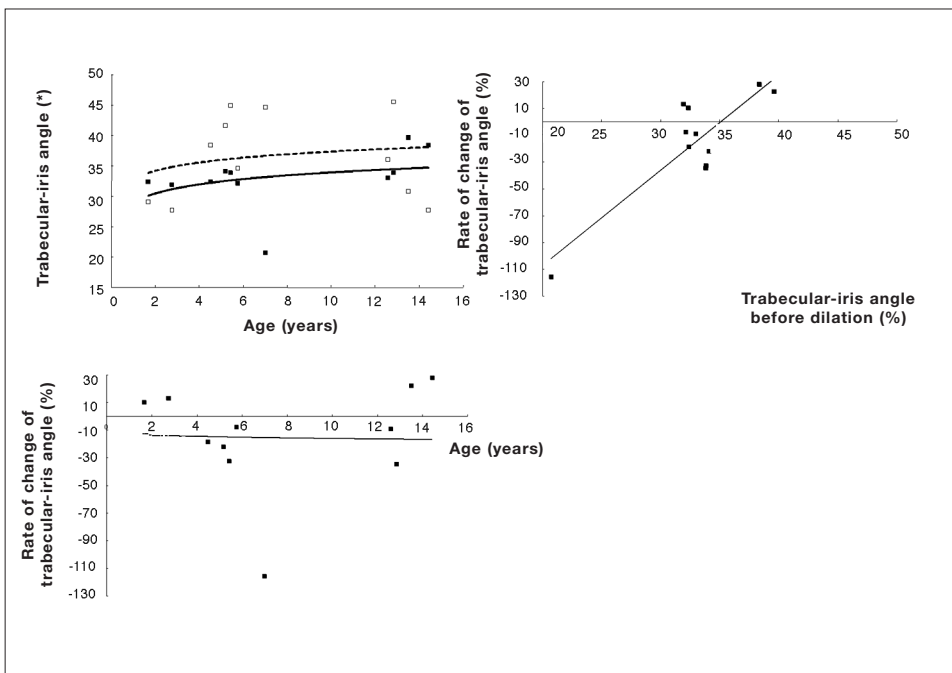


Fig. 5 - Comparison of trabecular-iris angle between before and after pupil dilation in hyperopia. (Top left) Trabecular-iris angle of before and after pupil dilation are plotted with the approximation curve. ■ Before dilation; □ after dilation; — approximation curve of before dilation; - - - approximation of after dilation. (Top right) Rate of change of trabecular-iris angle is shown with the approximation curve in relation to anterior chamber depth before pupil dilation. (Bottom right) Rate of change of trabecular-iris angle is shown with the approximation curve in relation to age.

DISCUSSION

Our data show that ACD tends to increase with age in both emmetropic and hyperopic children. However, the trend in TIA differs according to the refraction. TIA tends to increase slightly with age in hyperopic children, whereas it tends to decrease with age in emmetropic children.

Kobayashi et al (9) evaluated the anterior segment in 46 children aged from 1 month to 5 years. They reported that both ACD and TIA increased with age. We found similar results in hyperopic children, but a different TIA tendency in emmetropic children. This difference might be related to differences in methods between the two studies and the age range of the participants. Kobayashi et al used in-

TABLE III - COMPARISON BETWEEN BEFORE AND AFTER PUPIL DILATION ACCORDING TO REFRACTION (mean \pm SD)

	Before pupil dilation	After pupil dilation	Rate of change (%)
Emmetropia (31 eyes)			
Age (years)	6.37 \pm 2.26	—	—
Refraction (diopters)	-0.05 \pm 0.48	—	—
ACD (mm)	2.91 \pm 0.19	3.04 \pm 0.23	-4.25 \pm 3.53
TIA ($^{\circ}$)	35.38 \pm 4.19	35.95 \pm 4.32	-2.31 \pm 11.72
Hyperopia (11 eyes)			
Age (years)	7.78 \pm 4.43	—	—
Refraction (diopters)	2.52 \pm 0.93	—	—
ACD (mm)	2.89 \pm 0.16	2.97 \pm 0.21	-2.56 \pm 3.04
TIA ($^{\circ}$)	32.93 \pm 4.56	36.45 \pm 6.70	-15.17 \pm 39.49

ACD = Anterior chamber depth; TIA = Trabecular-iris angle

TABLE IV - COMPARISON BETWEEN THE RATE OF CHANGE IN ACD AND TIA ACCORDING TO REFRACTION (mean \pm SD)

	Emmetropia (31 eyes)	Hyperopia (11 eyes)	p value*
Rate of change in ACD (%)	-4.25 \pm 3.53	-2.56 \pm 3.04	0.18
Rate of change in TIA (%)	-2.31 \pm 11.72	-15.17 \pm 39.49	0.11

*Student t-test.

ACD = Anterior chamber depth; TIA = Trabecular-iris angle

fant Bangaeter speculums instead of eye cups. This might have led to a slight transform in the eyes of the infants. The age range of the children in our study was from 1 year to 15 years, whereas the range in their study was from 1 month to 5 years. Hyperopic children might predominate in the younger age group (12, 13). Therefore our results in hyperopic children are consistent with their results.

A comparative study of the mean ACD and TIA between 66 emmetropic and 28 hyperopic eyes resulted in p values of 0.44 for ACD and 0.78 for TIA. To our regret, we were not able to comment about the myopia because the number of patients was small. These results in our study suggest that there is no difference in anterior chamber biometry of young children based on the refraction (Tab. I). Generally, the refractive error is believed to be influenced by axial length (14). Therefore, these results lead us to conclude that anterior chamber biometry of young children is not influenced by axial length. Axial length increases up to about 13 years of age (13). On the other hand, growth of the anterior segment is completed by 5 years of

age (13). This difference in the growth process might explain the lack of difference in mean ACD and TIA between emmetropia and hyperopia.

Previous reports on the anterior chamber angle of normal adult eyes have found ACD in the range of 2.73–3.12 mm and TIA in the range of 30.0–32.9 $^{\circ}$ (3-7). These findings are consistent with our results (ACD 2.97 \pm 0.21 mm, TIA 31.35 \pm 0.7.78 $^{\circ}$). When ACD and TIA were compared between emmetropic children and emmetropic adults, we found that ACD was not statistically different (p=0.50), but a significant difference was observed in TIA (p=0.03). This result indicates that the angle was wider in young children than that in adults. This might be a reason why infants are not highly susceptible to glaucoma. To our knowledge, all cases of acute angle-closure glaucoma in children are accompanied by ophthalmic diseases (retinopathy of prematurity [11, 15], after buckling surgery [11] and nanophthalmos [11]), systemic disease (11, 16, 17), and the use of drugs (18, 19). We could not find any reports referring to accidental glaucoma attacks in children. In adults, primary angle-closure glaucoma (PACG) accounts for about

6% of all cases of glaucoma (20). PACG typically occurs in hyperopic eyes, which have an axial length shorter than average, a shallow anterior chamber, a thicker lens, a more anterior lens position, and a smaller radius of corneal curvature (21, 22). Children's eyes often have similar features. However, TIA in children is wider than that in adults; moreover, the difference remains after mydriasis. Regardless of the value before pupil dilation, ACD showed an increasing trend after pupil dilation in both emmetropia and hyperopia (Figs. 2 and 4). TIA values, which were small before pupil dilation, showed a tendency to increase after pupil dilation (Figs. 3 and 5). This tendency was stronger in cases of hyperopia ($R^2=0.74$), though this was not statistically significant ($p=0.11$). This result leads to a reason for the absence of angle-closure glaucoma in young children, in spite of their shallow anterior chamber and short axial length. The difference between children and adults might be a result of the difference in the power of ciliary muscle. This shows a continuous and significant decrease with age (23). Using UBM, we can observe images of the iris contracting and pressing back on the lens at the time of pupil dilation in children.

In the comparison between before and after pupil dilation data on 15 adults (average age 53.4), Presti et al (8) found

no significant difference in ACD or TIA before versus after pupil dilation. Nissirios et al (24) reported no post-pupil dilation change in ACD in their study of 14 rat eyes but found that TIA became narrow. Gao et al (25) reported that ACD increased after pupil dilation in their study of 136 children using computerized video keratoscope. We found that there were no statistically significant differences in ACD and TIA between pre- and post-pupil dilation even in hyperopic children. (The rate of change is $-2.56\pm 3.04\%$ in ACD, $-15.17\pm 39.49\%$ in TIA).

Our findings indicate that TIA in children is wider than that in adults and that the difference before and after pupil dilation in children is not statistically significant. Additional studies in young age groups are necessary to evaluate the characteristics of infant's eyes. In order to study younger infants, the development of smaller eye cups and probes is expected.

The authors received no grants and have no proprietary interest.

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