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Original Article

Changes in anterior segment parameters of normal subjects during accommodation using a Scheimpflug imaging system

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ABSTRACT

Background: Accommodation changes ocular parameters, such as the anterior chamber volume (ACV), anterior chamber depth (ACD), anterior chamber angle (ACA), and pupil diameter (PD), which can reflect a risk of angle-closure glaucoma. Previous studies of changes in ocular anterior segment parameters, have used high diopters or maximum amplitude. Here, we focused on normal accommodation at a reading distance of 30–40 cm. The aim of this study was to assess changes in anterior segment parameters during a normal accommodative state, using a Scheimpflug imaging system.

Methods: In this cross-sectional study, 40 emmetrope subjects (mean ± SD of age: 22 ± 4.0 years) who met the inclusion criteria and provided informed consent were enrolled. Clinical history, refraction, amplitude of accommodation, slit lamp examination, Goldman applanation tonometry, and Pentacam investigations were performed on all subjects. Accommodative and non-accommodative targets were induced via the Pentacam. Two seconds were allowed for accommodation or relaxation prior to measurements in each eye.

Results: Eighty normal eyes were evaluated; a small but statistically significant change in ACV, ACA, and PD during accommodation ($P < 0.01$, < 0.01, and < 0.05, respectively) was observed. The ACD did not change substantially with accommodation ($P = 0.29$). The mean ± SD values of ACV, ACD, ACA, and PD before and after accommodation were 151.85 ± 24.04 mm^3 and 145.38 ± 23.30 mm^3, 2.87 ± 0.28 mm and 2.86 ± 0.27 mm, 35.06° ± 3.68° and 33.84° ± 3.72°, and 3.46 ± 0.57 mm and 3.41 ± 0.53 mm, respectively.

Conclusions: Accommodation changes ocular parameters, such as ACV, ACA, and PD, in healthy young emmetropes. Interestingly, the ACD remains unaltered during accommodation. Nevertheless, although these changes were statistically significant, they were not clinically significant in our study.

KEY WORDS

Pentacam, ocular parameters, anterior chamber depth, anterior chamber volume, anterior chamber angle, pupil diameter, accommodation, glaucoma, emmetropia

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INTRODUCTION

Ocular anterior segment parameters, such as anterior chamber volume (ACV), anterior chamber angle (ACA), anterior chamber depth (ACD), and pupil diameter (PD), change during eye accommodation. Accommodation includes crystalline lens-based changes in the refractive power of the eye. With respect to the standard viewpoint, as illustrated by Helmholtz, accommodation occurs via contraction (inward movement) of the ciliary muscles, and relaxation of the zonules that affix the ciliary body to the crystalline lens, resulting in a thicker, steeper lens [1-3]. In this way, the dioptric power of the eye increases, thereby increasing the refractive power of the eye. Ciliary muscle contraction and variations of crystalline lens that are required to achieve accurate accommodation occur as a series of changes, and the capacity of contraction of the ciliary muscle diminishes slowly [1-3]. During the accommodation process, the anterior surface of crystalline lens experiences apparent forward movement, with a subsequent decline in the anterior segment parameters [4].

Assessment of these parameters plays a vital role in the diagnosis of some ocular diseases. Healthy people with myopic refractive error are likely to experience abrupt accommodative changes in near work [5-7]. Myopia is associated with glaucoma. Consequently there is a need to assess changes in the dimensions of the anterior segment, particularly in newly developed myopes [8]. Additionally, anterior segment parameters provide a blueprint for preoperative planning of refractive surgeries [9]. An ACV < 100 mm^3 [10] indicates the need to assess the patient for evidence of angle-closure glaucoma, as low ACV is strongly associated with this condition. This is often characterized by shallow ACA. An ACA < 25° [10] also indicates the need for evaluating patients for angle-closure glaucoma.

PD should be measured under medium illumination (mesopic pupil). ACD is defined as the space from the corneal endothelium to the anterior side of the crystalline lens [9]. ACD dimensions provide insight into diverse areas of ophthalmology. Before cataract surgery and phakic intraocular lens (IOL) insertion, the exact dimensions of ACD are essential to establish IOL power. ACD plays a key role in determining the optical zone diameter in refractive surgery. The shallow ACD may compromise corneal endothelium integrity [11]. In this study, we assessed whether there were any further noteworthy changes in anterior segment parameters during accommodation in individuals who were asymptomatic and apparently healthy.

METHODS

A cross-sectional study was conducted at Sankara College of Optometry (Sankara Eye Hospital), Bangalore, India between November 2016 and August 2016. The relevant institutional review board approved the study protocol before enrolment of subjects in the study. All participants signed written informed consent before proceeding with the study. The inclusion criteria were as follows: emmetrope (≤± 0.5-diopter [D]), age 17–34 years, intraocular pressure (IOP) 10–21 mmHg [12], and without systemic illness. Exclusion criteria were presbyopia, any ailment affecting the anterior chamber, cataract, history of ocular surgery, subjects under treatment for any ocular or systemic diseases, and lack of consent.

Those who met the inclusion criteria received an explanation of the different tests. After each subject signed the consent form provided, their clinical history was obtained and the visual acuity of each eye was measured using a logarithm of the minimum angle of resolution (LogMAR) chart for distance and a reduced Snellen chart for near testing. Retinoscopy (Heine Beta-200 streak retinoscope; Heine Optotechnik, Herrsching, Germany) and subjective refraction testing were performed.

This was followed by measurement of the amplitude of accommodation of each eye individually, by using the push-up method. Subjects were given a target of one line above their best-corrected visual acuity. For example, if near acuity was N6, then N8 acuity was given as a target. The target N8 was moved from a distance of 40 cm toward the subject's eye until they reported a sustained blur. The distance from the temporal canthus/spectacle frame of the subject's eye to the target was measured. The test was performed both monocularly and binocularly. The distance was measured in centimeters [13].

Slit lamp examination (SLIT LAMP AIA 11–3SL, Appasamy, India) was then performed prior to a Pentacam evaluation, which was performed with a WaveLight Oculyzer™ II (Alcon, Fort Worth TX, USA). The Oculyzer is a Pentacam camera with high-resolution technology (Oculus Optikgeräte GmbH, Wetzlar, Germany), which conducts non-contact assessment and measurement of the entire anterior eye structure. The light source consisted of an ultraviolet-free blue light-emitting diode with a wavelength of 475 nm. The Scheimpflug module has a red light-emitting diode (LED) that acts as a fixation mark and can be programmed to stimulate an accommodation stimulus varying from + 1.00 D to – 5.00 D, in 1.00-D steps [14, 15].

The anterior segment variables were measured by inducing an accommodative target inside the Pentacam. The anterior segment parameters (ACV, ACD, ACA, and PD) were measured during the accommodative and non-accommodative states. After Pentacam evaluation, IOP was measured using a Goldman applanation tonometer (AT900 Applanation Tonometer, Haag Streit, Koeniz, Switzerland) mounted on a slit-lamp biomicroscope. After installation of fluorescein with 0.5% proparacaine hydrochloride in each eye, three sequential measurements were performed. If the results were within 2 mmHg, no further testing was performed, and the final IOP was the average value of three measurements [12].

Statistical analyses were performed with Excel (Microsoft Office 365; Microsoft Inc., Redmond, WA, USA). Descriptive data were presented as percentages or as means and standard deviations (SDs). Probability (*P*) values were obtained using a one-tailed paired *t*-test.

Table 1. Demographic characteristics of the subjects.

Age group, years	n (%)	Male/Female, n	Occupation	n (%)
15–20	21 (52.5)	**3/18**	**Student**	16 (40)
21–25	15(37.5)	**12/3**	**Data Entry Clerk**	10 (25)
26–30	2 (5)	**0/2**	**Optometrist**	7 (17.5)
31–35	2 (5)	**1/1**	**Ophthalmologist**	4 (10)
Total, n (%)	40 (100)	**16 (40)/24 (60)**	**IT Professional**	3 (7.5)

Table 2. Summary of anterior chamber parameters that changed with induction of accommodation via the Pentacam.

Parameters	ACV, mm³		ACD, mm		ACA, Degree		PD, mm	
Accommodative state	Mean ± SD	*P*-Value	Mean ± SD	*P*-Value	Mean ± SD	*P*-Value	Mean ± SD	*P*-Value
Without Accommodation	151.85 ± 24.04	**< 0.01**	2.87 ± 0.28	0.29	35.06° ± 3.68°	**< 0.01**	3.46 ± 0.57	**< 0.05**
With Accommodation	145.38 ± 23.30		2.86 ± 0.27		33.84° ± 3.72°		3.41 ± 0.53	

Abbreviations: ACA, anterior chamber angle; ACD, anterior chamber depth; ACV, anterior chamber volume; CV, chamber volume; mm, millimeter; mm^3, millimeter cube; PD, Pupil diameter; SD, standard deviation. P <0.05 is statistically significant. Data were analyzed by paired *t*-test

RESULTS

Forty subjects (80 eyes) with an age range of 17 to 34 years (mean ± SD of age: 22 ± 4.0 years), underwent clinical evaluation. Sixteen (40%) were male, and 24 (60%) were female. Table 1 summarizes the demographic characteristics of all subjects.

Table 2 shows a summary of the measured values of all anterior segment variables in study participants. The accommodative plus non-accommodative states of the lens were measured in all 80 eyes. The accommodative amplitude was set to +3.00 D as standard and non-accommodative states at 0 D. The mean ± SD values of ACV, ACD, ACA, and PD before and after accommodation were 151.85 ± 24.04 mm3 and 145.38 ± 23.30 mm^3, 2.87 ± 0.28 mm and 2.86 ± 0.27 mm, 35.06° ± 3.68° and 33.84° ± 3.72°, and 3.46 ± 0.57 mm and 3.41 ± 0.53 mm, respectively. The mean ACV, ACA, and PD were significantly smaller with, than without, accommodation (P < 0.01, < 0.01, and 0.05, respectively). The mean ACD was similar with and without accommodation (P = 0.29).

DISCUSSION

During the process of accommodation, the ciliary body, crystalline lens, and iris change actively, resulting in an increase in lens power [16]. This may be associated with an increase in the anterior curvature of the lens [17-20]. Thus, the change in the crystalline lens affects the anterior segment parameters. This study showed that fluctuations in the anterior segment parameters during accommodation were statistically significant. The parameters that showed statistically significant changes during accommodation were ACV, ACA, and PD, while the ACD remained essentially unchanged with and without accommodation.

The ACV decreased significantly during accommodation: mean ACV with accommodation was 145.38 ± 23.30 mm3, whereas it was 151.85 ± 24.04 mm^3 without accommodation. Ni et al. [18] found that mean ACV changed by 4.12 mm^3 in younger subjects and by 2.06 mm^3 in presbyopic subjects with a 5.00-D accommodation.

The lack of significant change in ACD with accommodation may be because the maximum accommodative depth was set to +3.00 D. Previous studies have also shown similar findings [20-24]. Ni et al. [18] and Read et al. [24] investigated the variations in ACD with accommodation in young eyes using Pentacam HR with -5.00 D accommodation. They found that the mean ACD decreased by about 0.11 mm and 0.14 mm, respectively. However, Yan et al. [20] observed greater changes, like Tsorbatzoglou et al [19] and Baikoff et al [25].

The ACA has rarely been studied. The mean ACA with accommodation was 33.84. ± 3.72° and that without accommodation was 35.06. ± 3.68°, which was statistically significantly different. A similar study [26], in which dimensions were attained using an anterior segment optical coherence tomography, the mean ACA of young emmetropes changed by 1.7° with 3.0 D accommodative stimuli. In a study [17] that used the ultrasound biomicroscopy, a slight decrease was observed in the changes in vertical ACA of pseudophakic patients during accommodation.

Synkinetic miosis caused during accommodation reduces the measured PD [20]. The PD is more markedly influenced by accommodation [20]. PD measured with accommodation was 3.41 ± 0.53 mm and that without accommodation was 3.46 ± 0.57 mm (P < 0.05). The changes in PD values were 0.95 and 0.15 mm in studies by Yan et al. [20] and Baikoff et al. [25] that employed anterior segment optical coherence tomography performed, respectively. The reason for these changes is the change in the curvature and shape of the lens. The anterior bulge of the crystalline lens pushes other anterior chamber structures, resulting in some changes in dimensions. Due to the accommodative reflex of the pupil, the PD also changes [18-20, 25, 27]. These changes may be clinically significant for patients with accommodative excess, they were not clinically significant in our study.

The study was limited by the small sample size. Nevertheless, this study pointed out some noteworthy markers of the anterior segment during accommodation. This study was conducted only in emmetropes. Further studies are needed to understand real change occurring in subjects with various refractive error conditions, accommodation excess, angle-closure glaucoma, and pesudophakic glaucoma patients.

CONCLUSIONS

Accommodation causes changes in certain ocular parameters: ACV, ACA, and PD, which may indicate the risk of glaucoma. However, the ACD remained essentially unchanged with accommodation. Although the changes noted above were statistically significant, they were not clinically significant in our study.

ETHICS DECLARATION

Ethical approval: Before enrolment of subjects in the study, permission was obtained from the Sankara Academy of Vision Institutional Review Board. All subjects signed a written informed consent before proceeding with the study.

Conflict of interest: None.

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