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ORIGINAL PAPER

Comparison of anterior segment parameters and axial lengths of myopic, emmetropic, and hyperopic children

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Abstract
Purpose To compare the anterior segment parameters of myopic, hyperopic, and emmetropic children by using optical biometry.
Methods This prospective cross-sectional study included 150 eyes of 150 children between 6 and 16 years old. The eyes were divided into three groups according to their spherical equivalent (SE) refractive error values as myopic [between − 1.0 and − 6.0 diopter (D)], emmetropic (between + 0.50 and − 0.50 D), and hyperopic (between + 1. 0 and + 3.0 D). Axial length (AL), central corneal thickness, anterior chamber depth (ACD), lens thickness (LT), and mean keratometry (*K* mean) measurements were obtained by an optical biometry (LenStar LS 900, Haag Streit Diagnostics) were compared between the groups.
Results There were no statistically significant differences regarding the ages and genders of the participants between the groups ($p > 0.05$). The mean SE refractive error values were − 2.20 ± 0.71 D in myopic, − 0.08 ± 0.49 D in emmetropic, and + 2.06 ± 0.53 D in hyperopic eyes. The mean AL values were 24.50 ± 0.69, 23.41 ± 0.61, and 22.33 ± 0.61 mm, respectively, in myopic, emmetropic, and hyperopic eyes ($p < 0.001$). The mean ACD values were 3.94 ± 0.22, 3.78 ± 0.23, and 3.45 ± 0.20 mm, respectively, in myopic, emmetropic, and hyperopic eyes ($p < 0.001$). The mean LT values were 3.56 ± 0.20, 3.43 ± 0.17, and 3.31 ± 0.12 mm, respectively, in myopic, emmetropic, and hyperopic eyes ($p < 0.001$). There were no significant differences in the other parameters between the groups.
Conclusions Refractive errors are the main factors those affect anterior segment parameters and AL in children and the most severely affected parameters were found to be the AL, ACD, and LT values.

Keywords Anterior segment parameters · Axial length · Optical biometry

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Introduction

The prevalence of myopia, hyperopia, and astigmatism may differ in children related to some factors like age, sex, and ethnicity [1–4]. In a study from Turkey, 21,062 children between 6 and 14 years old were observed for their refractive error [5]. Myopia was detected in 3.2%, hyperopia in 5.9%, and astigmatism ≥ 0.5 D in 14.3%. According to the same study, myopia was found to be related to older age, female gender, and high education level, whereas hyperopia was found to be inversely proportional with older age [5].

During the normal ocular growth, ocular structures go through continuous development and remodeling before and after birth [6–8]. Refractive errors are considered to be consequences of mismatch of ocular parameters during this process. As a result of a normal healthy ocular development, the refractive errors tend to drift naturally toward emmetropia. This emmetropization process is seemingly dependent on normal visual input; thus, the failure of clear visual input might result in a disturbance of emmetropization, leading to refractive errors [6–10].

Myopia is an escalating public health problem in worldwide, especially in many urban Asian countries [11]. During the past several decades, the prevalence and severity of childhood myopia have increased and the age of onset of myopia has decreased [11–13]. Strategies to prevent or slow childhood myopia are dependent on a clear understanding of the changes in different ocular components in childhood. However, most studies have investigated the anterior segment parameters in myopic children [14–16]. The patterns and characteristics of how different ocular components change among children with myopia compared with those who are emmetropic or hyperopic are not fully understood.

To obtain accurate measurement of the ocular parameters is essential in many clinical and research applications such as intraocular lens calculations prior to cataract surgery and intraocular pressure correction according to corneal thickness [17]. Optical biometry is a noncontact biometry that works by low-coherence reflectometry method and it can provide some anterior segment measurements including central corneal thickness (CCT), anterior chamber depth (ACD), lens thickness (LT), axial length (AL), pupillary diameter, and K1 and K2 keratometry values [18, 19].

Although a kind of published studies have investigated ocular biometric characteristics in older populations and revealed significant data [20–22], there are not many studies including children with different refractive status and comparing their ocular biometry measurements [23, 24]. Therefore, we aimed to compare the anterior segment parameters and AL measurements of myopic, hyperopic, and emmetropic children by using optical biometry. Additionally, it is known that ocular biometric status varies in different ethnicities and the data belong to different areas and ethnicities should be studied. Thus, we also aimed to contribute to the literature by studying the Caucasian pediatric population with different refractive status.

Patients and methods

One hundred and fifty eyes of 150 children, who had applied for routine ophthalmological examination to the policlinics of Ulucanlar Eye Training and Research Hospital between September 2014 and May 2016, were included in this prospective cross-sectional study. Our study was approved by Ethics Committee of Ankara Numune Training and Research Hospital, and written informed consents were taken from the parents of the participants.

All subjects underwent a comprehensive ophthalmic examination including best-corrected visual acuity tests using the Snellen charts, slit-lamp biomicroscopy, and fundus examinations. To calculate the cycloplegic autorefractometry values, three drops of cyclopentolate hydrochloride 1%, a cycloplegic agent, were administered 5 min apart and autorefraction was performed using an RK-F1 autorefractor (Canon, Tokyo, Japan) approximately 30 min after the last drop.

Children between 6 and 16 years old were enrolled to the study. We excluded the cases > 16 years old and < 6 years old, the cases with any ocular problems other than simple refractive errors, blepharitis, and simple allergic conjunctivitis including seasonal and perennial such as cataracts, uveitis, corneal diseases, glaucoma, ocular surgery or trauma. Moreover, we excluded the eyes with high myopia (> -6 D), high hyperopia ($> +3$ D), astigmatism > 1 D, amblyopia, and anisometropia. The eyes were divided into three groups according to their cycloplegic spherical equivalent (SE) refractive error values as emmetropic (between $+0.50$ and -0.50 D), myopic (between -1.0 and -6.0 D) and hyperopic (between $+1.0$ and $+3.0$ D).

Measurements of AL, CCT, ACD, LT, and *K* mean values were obtained by optical biometry (LenStar LS 900, Haag Streit Diagnostics) by the same experienced physician (MD) 1 h before cycloplegia.

Statistical analysis

Study data were analyzed using the Statistical Package for Social Sciences (SPSS) for Windows version 22.0 (SPSS Inc., Chicago, IL). Descriptive statistics were presented as mean ± standard deviation, frequency distribution, and percentages. Chi-square test was used in the analysis of categorical variables. Normal distribution of the variables was tested by visual (histogram and probability graphs) and analytical methods (Kolmogorov–Smirnov/Shapiro–Wilk Test). Equality of variances was checked by the Levene test. The one-way analysis of variance, Welch analysis of variance, and Kruskal–Wallis tests were used to determine whether there are any significant differences between the three groups. A probability level of $p < 0.05$ was considered statistically significant.

Results

This study included 65 (43.3%) male and 85 (56.7%) female cases with a mean age of 11.6 ± 2.96 (range: 6–16) years. The mean age was 12.7 ± 2.4 years in myopic cases, 11.7 ± 2.6 years in emmetropic cases, and 10.4 ± 3.3 years in hyperopic cases. There were no statistically significant differences regarding the ages and genders of the participants between the groups ($p > 0.05$, for all). Participant characteristics are displayed in Table 1.

The mean SE refractive error values were − 2.20 ± 0.71 D in myopic, − 0.08 ± 0.49 D in emmetropic and + 2.06 ± 0.53 D in hyperopic eyes. The anterior segment parameters and the AL of the groups are summarized in Table 2. The mean AL values were 24.50 ± 0.69, 23.41 ± 0.61, and 22.33 ± 0.61 mm, respectively, in myopic, emmetropic, and hyperopic eyes ($p < 0.001$). The mean AL values were longer in myopic eyes and shortest in hyperopic eyes. (post hoc Tukey's test, $p < 0.001$). Additionally, we observed statistically significant correlations between myopia and AL (Pearson correlation tests, r = 0.348, $p = 0.001$) in our study. The mean ACD values were 3.94 ± 0.22, 3.78 ± 0.23, and 3.45 ± 0.20 mm in myopic, emmetropic and hyperopic eyes, respectively ($p < 0.001$). The mean LT values were 3.56 ± 0.20, 3.43 ± 0.17, and 3.31 ± 0.12 mm, respectively in myopic, emmetropic, and hyperopic eyes ($p < 0.001$). There were no significant differences in the other parameters between the groups (Table 2).

Additionally, we divided participants according to their age decade, and this resulted in two subgroups starting from the first decade (Table 3). The number of the participants who aged between 6 and 10 years was 22 for myopic group, 25 for emmetropic group, and 27 for hyperopic group. Accordingly, the number of the subjects who aged between 11 to 16 years was 28 for myopic, 25 for emmetropic, and 23 for hyperopic groups. As illustrated in Table 3, there were statistically significant differences in regarding AL, ACD, and LT values between the groups even in accordance with age decades.

Discussion

Ocular biometric parameters are known to be greatly correlated with refractive errors [25]. Donnell et al. [25] investigated myopic and non-myopic eyes by optical biometry and observed significant differences in anterior segment parameters between the groups. Here, in this study, we investigated 100 emmetropic eyes of 50 children, 100 myopic eyes of 50 children, and 100 hyperopic eyes of 50 children, and compared the AL and the other anterior segment parameters between the groups.

Optical biometry can also be used easily in children because of its noncontact nature, and it makes measurements on the principal of partial coherence

Table 1 The demographic characteristics of the participants

	Myopic	Emmetropic	Hyperopic	*p*
Number	50	50	50	
Age (mean ± SD)	12.7 ± 2.44	11.7 ± 2.6	10.4 ± 3.32	0.105*
Sex				
Female	24(%48)	22(%44)	27(%54)	0.204**
Male	26(%52)	28(%56)	23(%46)	

SD Standard deviation

*One-way Anova test; **Chi-square test

Table 2 The anterior segment parameters of myopic, emmetropic, and hyperopic cases

	Myopic	Emmetropic	Hyperopic	p*
AL (mean ± SD) mm	24.50 ± 0.69	23.41 ± 0.61	22.33 ± 0.61	**< 0.001**
CCT (mean ± SD) µm	539.5 ± 33.5	548.6 ± 36.4	546.6 ± 33.5	0.852
ACD (mean ± SD) mm	3.94 ± 0.22	3.78 ± 0.23	3.45 ± 0.20	**< 0.001**
LT (mean ± SD) mm	3.56 ± 0.20	3.43 ± 0.17	3.31 ± 0.12	**< 0.001**
Mean *K* (mean ± SD) D	43.32 ± 1.39	43.05 ± 4.45	43.84 ± 1.83	0.152

Bold values indicate $p < 0.05$

AL axial length, *CCT* central corneal thickness, *ACD* anterior chamber depth, *LT* lens thickness, *mean K* mean keratometry

*One-way Anova test

Table 3 The anterior segment parameters of myopic, emmetropic, and hyperopic cases according to decades

	Myopic	Emmetropic	Hyperopic	p*
AL (mean ± SD) mm				
6–10 years	24.32 ± 0.56	23.13 ± 0.55	22.30 ± 0.57	**< 0.001**
11–16 years	24.56 ± 0.72	23.58 ± 0.59	22.34 ± 0.62	**< 0.001**
CCT (mean ± SD) µm				
6–10 years	540.5 ± 23.6	540.7 ± 35.5	547.9 ± 31.1	0.407
11–16 years	539.25 ± 35.7	553.85 ± 36.2	544.7 ± 37.1	0.101
ACD (mean ± SD) mm				
6–10 years	3.85 ± 0.16	3.75 ± 0.22	3.44 ± 0.21	**< 0.001**
11–16 years	3.97 ± 0.23	3.80 ± 0.24	3.46 ± 0.22	**< 0.001**
LT (mean ± SD) mm				
6–10 years	3.55 ± 0.19	3.42 ± 0.16	3.29 ± 0.11	**< 0.001**
11–16 years	3.57 ± 0.20	3.44 ± 0.18	3.33 ± 0.12	**< 0.001**
Mean *K* (mean ± SD) D				
6–10 years	43.50 ± 1.02	42.59 ± 6.06	43.68 ± 1.89	0.182
11–16 years	43.27 ± 1.48	43.33 ± 1.31	44.07 ± 1.72	0.588

Bold values indicate $p < 0.05$

AL axial length, *CCT* central corneal thickness, *ACD* anterior chamber depth, *LT* lens thickness, *mean K* mean keratometry

*One-way Anova test

interferometry [26]. Şahin et al. [26] investigated 152 school-age children by optical biometer (LenStar) and three consecutive measurements were performed by two physicians. They stated that the instrument was highly reproducible and tolerable in pediatric population with no anesthesia or discomfort. We also used optical biometry (LenStar) in our study.

Axial length is one of the most important parameters for intraocular lens power calculation, and its conventional method for measurement is A-scan ultrasound biometry which is non-practical in children because of its contact nature [27]. Hussin et al. [28] compared the AL values measured by optical biometry and A-scan ultrasound biometry in 20 children with a mean age of 11.4 years and found that optical biometry was more accurate and reproducible. AL rapidly increases in the postnatal period until third year of life and reaches the adult size at 10 years old [29]. AL is known to be one of the most important parameters those highly correlated with refractive errors [25]. Bhardwaj and Rajeshbhai [30] showed that myopic eyes tend to have longer axial lengths, whereas hyperopic eyes tend to have shorter axial lengths as compared to those with emmetropic eyes. Donnell et al. [25] found significant correlations between myopia and increased AL in their study. Conversely, short AL is thought to be related to the degree of hyperopia in children [31]. Similarly, in our study, we observed significant correlations between myopia and increased AL.

Anterior chamber depth is another important parameter correlated with refractive errors. Lee et al.

[32] observed the deepest ACD in myopic and the shallowest ACD in hyperopic eyes in children. They also found associations between deeper ACD, more myopic SE values and thinner retinal nerve fiber layer thickness. Donnell et al. [25] also found deeper ACD in myopic eyes in their study. In our study, we found similar results like the previous one and found associations between myopia and deeper ACD and hyperopia and shallower ACD in children. Cheung et al. [33] investigated the correlations between these parameters measured by optical biometer and accommodation. They observed that cycloplegia had no effect on AL measurements, but ACD was found to be significantly affected by cycloplegia. We performed our measurements before cycloplegia in order to eliminate the effects of cycloplegia on these parameters. Gul et al. [29] stated that LT decreases during the first 12 years of life. But they did not investigate the differences related to refractive error. Shih et al. [34] revealed that the AL and ACD increases with the severity of myopia, in contrast, the LT decreases. They hypothesized that lens thinning appeared to be a compensatory mechanism in nature with respect to increased AL during the normal ocular growth and excessive ocular growth in myopia induce the lens to compensate by becoming much thinner. We also found thinner LT in myopic and thicker LT in hyperopic eyes in our study like Donnell et al.'s study in which LT was thicker in non-myopic eyes [25].

Gul et al. [29] stated that CCT measurements did not have a linear algorithm related to age and also they did not investigate the differences related to refractive error in their study. Chen et al. [35] also investigated the relationship between CCT, refractive error, corneal curvature, ACD, and AL in an adult population. Their results revealed that CCT is an independent factor and not associated with refractive error, corneal curvature, ACD, and AL. However, Linke et al. [36] observed some opposite findings in their study. They investigated the relationship between the thinnest point in corneal thickness and refractive state in adult cases. They found that the thinnest point in corneal thickness is smaller in myopic eyes than hyperopic eyes. We observed no significant differences in CCT between emmetropic, myopic, and hyperopic eyes similar to Donnell et al.'s study [25]. Zhang et al. [37] investigated the corneal curvature and its associated factors in children. They found correlations with higher corneal curvature radius (flatter corneas), male sex, younger age, taller body height, maternal myopia, longer axial length and larger corneas, but we found no associations between the mean keratometric values and refractive states of our subjects.

In conclusion, refractive state in children was found to have some effects on anterior segment parameters in children. According to our study, myopia is related to longer AL, deeper ACD, and thicker LT in children, whereas hyperopia has relations with just the opposite ocular structures. These facts should be kept in mind in children, especially in the need for biometry for cataract surgery.

Compliance with ethical standards

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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