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Long-term effect of orthokeratology on the anterior segment length

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ABSTRACT

Purpose: To compare the effects of normal growth and longer term use of orthokeratology (ortho-k) on ocular biometric parameters in the anterior segment, including central corneal thickness (CCT), anterior chamber depth (ACD), crystalline lens thickness (CLT), and anterior segment length (ASL).
Methods: Baseline and six monthly data were retrieved from 78 subjects (aged 7–10 years, with myopia $\leq$ 4.00 D and astigmatism $\leq$ 1.25 D) who had completed a two-year randomized clinical trial using ortho-k for myopia control. They were randomly assigned to wear ortho-k lenses or single-vision spectacles (control). Anterior segment parameters were measured with the Pentacam after cycloplegia.
Results: No significant changes in CLT and ASL over time were observed in either group of subjects (37 ortho-k; 38 control). In the control group, CCT remained unchanged during the study period but in the ortho-k group, it was significantly reduced by an average of 0.009 mm by the 6-month visit ($p < 0.001$) and remained unchanged thereafter. No significant changes in ACD was found in the ortho-k group but it was significantly increased by an average of 0.04 mm ($p = 0.001$) in the control group.
Conclusion: CLT nor ASL did not change over time in either control or ortho-k subjects. Although ACD significantly increased in the control subjects and CCT significantly reduced in the first six months of ortho-k lens wear, these changes were small and did not affect the overall ASL.

1. Introduction

The human eye grows from infancy to childhood leading to changes in refractive power during childhood. Infants are usually hyperopic with short axial length (AL). This refractive error of the eye reduces when the eye starts to grow accompanied by change in shape of the cornea and the crystalline lens [1,2]. Central corneal thinning generally stabilizes at the age of three years [3,4]. During childhood, the eye becomes longer resulting in deeper vitreous chamber depth, whereas the crystalline lens becomes flatter and thinner [3–9]. Crystalline lens thickness tends to remain stable after reaching 10 years of age but may be influenced by refractive errors of the eye [1,8]. Decrease in crystalline lens thickness (CLT) is accompanied by an increase in anterior chamber depth (ACD) [3,5,8,9]. These changes are usually small in hyperopes and emmetropes, but are more significant in myopes. The more myopic the eye, the larger the magnitude of change [5,8].

Orthokeratology (ortho-k) can slow axial elongation of the eye [10–13]. Our previous study determining the short-term effects (six months) of ortho-k treatment on refractive correction revealed that there was thinning of central corneal thickness (CCT) which did not affect ACD, CLT and the overall anterior segment length (ASL) [14]. A different pattern of change in ACD in children on ortho-k treatment compared to those using spectacles was observed. While ACD increased with time in subjects using single-vision spectacles, ACD remained unchanged in subjects on ortho-k treatment. This implies that ortho-k not only modifies axial elongation, but may also affect the growth pattern of the interior structure. The effect of ortho-k on AL has been reported elsewhere [11]. This paper focused on the longer term effects of ortho-k lens wear on ocular parameters in the anterior segment.

2. Methods

Data were retrieved from subjects who had completed the ROMIO study, a two-year randomized clinical trial evaluating the effectiveness of myopia control using ortho-k [11]. The study was registered at ClinicalTrials.gov, number NCT00962208. It followed the tenets of Declaration of Helsinki and was approved by the Ethics Committee of the School of Optometry of The Hong Kong Polytechnic University. Informed consent was obtained from the subjects and their parents prior to the commencement of the

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study. Biometric measurements performed at the 6 monthly cycloplegic visits (i.e., baseline, 6 months, 12 months, 18 months and 24 months) were retrieved.

Seventy-eight subjects, who had been randomly assigned to the two treatment groups, completed the ROMIO study. Of these, 37 received ortho-k and 41 were in the control (single-vision spectacles) group. The subjects were aged from seven to 10 years, with low-to-moderate myopia (−0.50 to −4.00 DS) and low refractive astigmatism (≤1.25 DC) in the test eyes. The right eye was selected as the test eye if both eyes were eligible. Refractive error (Shin-Nippon NVision K5001, Shin-Nippon Commerce Inc., Tokyo, Japan), anterior segment dimensions (CCT, ACD and CLT) (Pentacam, ver 1.14; Oculus, Wetzlar, Germany) and AL (IOLMaster; Zeiss Humphrey, Dublin, CA) were determined after cycloplegia with 1 drop of 0.5% proparacaine, followed by 1 drop of 1% tropicamide, and 1 drop of 1% cyclopentolate, administered five minutes apart. The effectiveness of cycloplegia was checked at least 30 min after instillation of all eyedrops and the tests were performed when residual accommodation was found not to exceed 2.00 D. The operation procedures and data retrieval for Pentacam and IOLMaster were as previously reported in the previous short-term study [10]. In order to differentiate the refractive correction effect of ortho-k on corneal thickness from the myopia control effect on AL, ACD was defined as the distance from the posterior corneal surface to the anterior crystalline lens surface and ASL was the distance from the anterior cornea to the posterior crystalline lens, i.e. ASL was derived as the summation of CCT, ACD and CLT obtained from Pentacam.

2.1. Statistical analysis

Statistical analyses were performed using the SPSS software (ver. 18.0; SPSS Inc., Chicago, IL). The distributions of the ocular biometric values and their changes were not significantly different from normal (Kolmogorov–Smirnov tests, $p > 0.05$), therefore, parametric tests were used for data analysis. Repeated-measures ANOVAs were used to evaluate the effect of time on CCT, ACD, CLT, and ASL in the two groups of subjects. Post-hoc analyses were performed (paired and unpaired t tests with Bonferroni corrections) where appropriate.

3. Results

Data from three subjects were excluded due to missing Pentacam data, one at baseline, one at the 12-month visit and one at the 18-month visit. Table 1 shows the demographic data of the remaining 75 subjects (37 ortho-k; 38 control). There were no significant differences in the initial age, gender, refractive error and ocular parameters between the two groups of subjects at baseline visit ($0.92 \geq p \geq 0.42$). The two-year changes in ocular parameters are shown in Tables 2 and 3.

Table 1
Demographic data and ocular parameters of the 75 subjects at the baseline visit.

	Ortho-k ($n = 37$)	Control ($n = 38$)
Age (years)	8.86 ± 0.95	8.74 ± 1.06
Sex	18F/19M	17F/21M
Refractive sphere (D)	−2.05 ± 0.72	−2.16 ± 0.80
Refractive cylinder (D)	−0.23 ± 0.30	−0.27 ± 0.35

Two-way repeated measures ANOVA analyses revealed no significant changes in CLT and ASL over time ($0.42 \geq p \geq 0.25$) in all subjects and no significant interaction between time and treatment ($0.48 \geq p \geq 0.30$). However, there was significant effect of time ($p \leq 0.004$) and significant interaction of time and treatment ($p \leq 0.005$) on CCT and ACD. Therefore, the effect of time on the ocular parameters was assessed for each group using repeated measures ANOVA.

In the ortho-k group, CCT significantly reduced by 0.009 mm at the 6-month visit ($p < 0.001$) and remained unchanged thereafter ($p = 0.53$). ACD, CLT and ASL showed no significant changes ($p > 0.64$) over time. In the control group, ACD was significantly increased with time ($p < 0.001$) whereas no significant changes ($p > 0.28$) were found in CCT, CLT and ASL during the study period. However, changes observed in these parameters did not affect the overall ASL.

4. Discussion

The current study was an extension of our previous study on the short-term changes in ocular biometric parameters after ortho-k [14]. We confirmed a different pattern of change in ACD with time in subjects wearing ortho-k lenses and single-vision spectacles (Table 3). The increase in ACD with time observed in subjects wearing single-vision spectacles was not observed in those wearing ortho-k lenses. CLT and ASL remained unchanged in both groups of subjects. Different pattern of change in CCT was observed in the two groups of subjects (Table 3). However, it was only due to the initial reduction in CCT during the refractive correction effect of ortho-k treatment. CCT on ortho-k subjects then remained stable once maximum refractive correction has been achieved (Table 2).

This study is the first report on the long-term changes in the anterior components of the eye in subjects receiving myopia control treatment. Refractive error and axial length are the most commonly reported parameters in myopia control studies [10–13,15–19]. We found three myopia control studies, using three different active and control interventions, which reported the results of changes in ACD and CLT over time [10,15,17]. However,

Table 2
Ocular parameters (mm) of the 75 subjects at different visits.

	Baseline	6 months	12 months	18 months	24 months
Ortho-k					
Central corneal thickness	0.577 ± 0.025	0.568 ± 0.024	0.570 ± 0.023	0.568 ± 0.027	0.569 ± 0.024
Anterior chamber depth	3.39 ± 0.21	3.38 ± 0.21	3.39 ± 0.21	3.39 ± 0.20	3.39 ± 0.21
Crystalline lens thickness	3.29 ± 0.20	3.30 ± 0.19	3.30 ± 0.17	3.28 ± 0.20	3.30 ± 0.21
Anterior segment length	7.25 ± 0.25	7.25 ± 0.24	7.26 ± 0.22	7.24 ± 0.24	7.25 ± 0.24
Axial length	24.52 ± 0.71	24.61 ± 0.70	24.72 ± 0.70	24.82 ± 0.70	24.88 ± 0.72
Control					
Central corneal thickness	0.578 ± 0.032	0.579 ± 0.030	0.578 ± 0.030	0.578 ± 0.031	0.580 ± 0.030
Anterior chamber depth	3.38 ± 0.19	3.40 ± 0.20	3.41 ± 0.20	3.41 ± 0.20	3.42 ± 0.20
Crystalline lens thickness	3.31 ± 0.16	3.30 ± 0.17	3.30 ± 0.16	3.29 ± 0.17	3.30 ± 0.17
Anterior segment length	7.27 ± 0.25	7.27 ± 0.28	7.28 ± 0.26	7.29 ± 0.26	7.30 ± 0.26
Axial length	24.37 ± 0.84	24.57 ± 0.86	24.75 ± 0.90	24.89 ± 0.89	25.02 ± 0.90