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Effects of orthokeratology on axial length growth in myopic anisometropes

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ABSTRACT

Purpose: To investigate the effect of orthokeratology (ortho-k) lens wear on axial length (AL) growth in juvenile myopic anisometropes.

Methods: This retrospective study consisted of two parts. In Part One, 25 anisometropic participants (mean age, 11.2 ± 1.9 years; 11 females and 14 males) were fitted with ortho-k lenses in the more myopic eye only, and the rate of AL growth was compared between the ortho-k lens wearing eye and the untreated contralateral eye over an average period of 23.1 ± 8.3 months. In Part Two, 8 participants who developed myopia in the contralateral eye received ortho-k treatment in both eyes for an average of 12 months; the rate of AL growth before and after ortho-k treatment in the newly developed myopic eye was compared.

Results: In Part One, the rate of AL elongation in the ortho-k treated eye (0.08 ± 0.15 mm/year) was significantly slower than in the contralateral eye (0.39 ± 0.32 mm/year) ($P < 0.001$). At the completion of Part One, 16 out of 25 participants (64%) developed myopia in the initially non-myopic eye. In Part Two, the rate of AL elongation after ortho-k treatment in the newly developed myopic eye (0.20 mm/year) was significantly slower than that before ortho-k treatment in the same eye (0.49 mm/year) ($P = 0.012$).

Conclusion: Ortho-k treatment slows AL growth in the more myopic eye of anisometropic patients; should the contralateral eye develop myopia in the future, ortho-k is capable of slowing down AL growth in that eye as well.

Anisometropia, typically defined as an interocular difference in spherical equivalent refractive errors (SERE) of 1.00 D or more, is a unique refractive condition, in which the fellow eyes of an individual grow to two different endpoints [1,2]. Studies of large clinical populations over a wide range of age groups and refractive errors have revealed that the prevalence of anisometropia is relatively high during infancy, rapidly decreases during the early years of life, followed by an increase from childhood to adulthood, and stabilizes during adulthood [2,3].

Several longitudinal studies have examined the development of anisometropia during childhood and typically reported an increase in the magnitude of interocular difference in refraction with age [1,2,4,5]. For example, Parssinen[1] followed the change in refraction of 238 myopic anisometropic children aged 9 to 11 years over a three-year period and found that anisometropia remained stable in 67%, increased in 27%, and decreased in 6% of the enrolled participants. As myopia increased over time (mean SERE changed from −1.43 to −3.06 D), the magnitude of anisometropia increased from 0.30 to 0.51 D. Similarly, Tong and colleagues[4] followed 2000 Singaporean children aged 7 to 9 years for three years and found that the mean anisometropia increased slightly over time from 0.29 D at baseline to 0.44 D at study completion. Of those children with 1.00 D or more of anisometropia, 5.1% had an increase in anisometropia of at least 0.50 D, whereas 3.4% had a decrease of at least 0.50 D; the remaining 91.5% of the participants had no significant change in anisometropia compared to the baseline level.

While severe anisometropia is usually associated with genetic flaws and resultant structural abnormalities such as optic nerve hypoplasia [6], macular hypoplasia [7], coloboma [8], etc., lower amounts of anisometropia are more likely to be a result of a combination of genetic and environmental factors such as asymmetric visual experience. A few clinical trials have shown that deliberate unilateral manipulation of the retinal image in young humans can alter axial elongation between the two eyes [9–12]. For example, Cheung et al. [10] observed asymmetric ocular growth in an 11-year-old myopic anisometrope undergoing unilateral orthokeratology (ortho-k) treatment in the more myopic eye. Over a two-year treatment period, the less myopic eye grew 0.34 mm compared with the treated more myopic eye, which grew only

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0.13 mm, suggesting that ortho-k slowed myopic progression in the treated eye. Interestingly, clinical observations revealed that the less myopic contralateral eye might experience a faster-than-normal myopia progression, in this case, resulting in a decrease of anisometropia. However, this finding needs consolidation from a study with a larger sample size.

Therefore, the aims of the current study were 1) to investigate the axial length growth rate in myopic anisometropic juveniles undergoing ortho-k therapy in one eye (the other eye did not wear ortho-k lens), and 2) to compare the axial length growth rate before and after ortho-k treatment in the less myopic eye should it become myopic during the follow-up process.

1. Methods

1.1. Study design

This retrospective study consecutively included 25 Chinese participants who visited the Fudan University Eye and ENT Hospital between March 2013 and September 2013 and who met the following criteria: 1) aged between 8 and 15 years; 2) initial anisometropia in SERE no less than 1.00 D, with the more myopic eye being greater than −1.00 D, and the contralateral eye being between −0.50 and +2.00 D; 3) had been wearing ortho-k lenses in the more myopic eye and no optical correction for the contralateral eye for at least 1 year; 4) had at least two AL recordings (including baseline and final follow-up visit).

2. Study protocol

2.1. Part one

All the participants wore spherical 4-zone ortho-k lenses (Hiline Optics, China; Euclid, USA) in the more myopic eye only and the non-myopic eye received no treatment. In brief, for the first trial lens selection, flat K and corneal eccentricity were used to determine the alignment curve radius. A proper fitting was confirmed according to fluorescein pattern and corneal topography. Over-refraction was done to ensure all lenses were fitted with a refractive target of plano. Follow-up visits were scheduled for 1 day, 1 week, 1 month, 3 months, and every 3 months after ortho-k lens wear. During regular follow-up visits, if the unaided visual acuity of the ortho-k treated eye dropped below 20/25, over-refraction with the original ortho-k lens would be done and a new lens ordered to retain 20/20 and above visual acuity, otherwise, lenses were replaced routinely every 12 to 18 months.

AL measurement using the IOL-Master (Carl Zeiss, Germany) was done in both eyes at baseline and periodically after ortho-k lens wear, either during routine follow-up visits or upon lens replacement every 12 to 18 months. In cases where the non-myopic fellow eye was found to develop a myopic SERE greater than −1.00 D during follow-up, participants and their parents were given the option to have that eye also fitted with the correcting modality. Those who opted to use ortho-k lens in this fellow eye (ortho-k in both eyes) were included in Study Part Two, otherwise this constituted an endpoint for this retrospective study.

2.2. Part two

Eight participants out of 25 in Study Part One developed myopic SERE greater than −1.00 D in the originally non-myopic fellow eye and were fitted with ortho-k lenses with the same paradigm as in the more myopic eye. The follow-up protocol resembled Part One except that the ortho-k related examinations were now done in both eyes. AL was checked in both eyes periodically till the completion of this study on September 2016.

3. Statistical analysis

Baseline sphere, cylinder, SERE, and AL were compared between the two eyes in all the participants using paired-samples *t*-test. In Study Part One, the rate of AL elongation was defined as the change in AL from baseline to the endpoint divided by the time interval in between and expressed in mm per year. AL growth rate of the two fellow eyes was compared using paired-samples *t*-test. SERE in the less myopic fellow eye at the endpoint of Study Part One was compared to its baseline value using paired-samples *t*-test. In Study Part Two, AL growth rate in the secondary myopic fellow eye before and after ortho-k treatment was compared using Wilcoxon signed rank test. A $P < 0.05$ was considered to be statistically significant.

For sample size calculation, the only study published on the effect of orthokeratology in anisometropic children was conducted by Cheung et al., [10] though they reviewed only one subject. Therefore, details were taken from another study in which participants were treated with ortho-k binocularly and compared with single-vision lens counterparts. [13] Setting the P value to 0.05 and power to 0.80, and assuming that the mean difference in AL elongation between the two groups is 0.27 mm over two years with a SD of 0.27 mm, [13] the estimated sample size was 16 per group. Considering that the two eyes of each participant were categorized into two respective groups, only 16 participants were needed in total.

4. Results

4.1. Part one

The mean age of the participants (11 females and 14 males) was 11.2 ± 1.9 years (range, 9–15 years). The mean baseline refractive sphere, cylinder, SERE, and AL of both eyes are listed in Table 1. All these parameters significantly differed between the two eyes (all $P < 0.001$) except for refractive cylinder ($t = -0.440$, $P = 0.664$). Ortho-k treatment was uneventful for all participants with no significant complications throughout the study period.

The mean follow-up period for Part One was 23.1 ± 8.3 months (range, 12 to 34 months). The inter-ocular AL difference over time in all participants is shown in Fig. 1. The rate of AL elongation in the *ortho*-k treated eye (0.08 ± 0.15 mm/year) was significantly slower than the contralateral eye (0.39 ± 0.32 mm/year) ($t = -4.792$, $P < 0.001$). At the completion of Part One, the mean difference in AL between the two eyes decreased from 1.09 ± 0.48 mm at baseline to 0.67 ± 0.52 mm (Table 1). Sixteen out of the 25 participants (64%) developed myopia (defined as SERE greater than −0.75D) in the initially non-myopic eye. The mean SERE for this eye became

Table 1
Baseline and endpoint biometrics in the two eyes of the anisometropic subjects in Part One (n = 25).

Time Point			More myopic eye	Fellow eye
Baseline, Part One	Sphere (D)	Range	−4.00–−1.00	−0.50–1.75
		Mean ± SD	−2.32 ± 0.94	0.24 ± 0.50
	Cylinder (D)	Range	−0.50–0.00	−0.50–0.00
		Mean ± SD	−0.12 ± 0.22	−0.10 ± 0.20
	SERE (D)	Range	−4.25–−1.00	−0.50–1.75
		Mean ± SD	−2.38 ± 0.99	0.22 ± 0.50
	AL (mm)	Range	23.03–25.77	22.12–24.63
		Mean ± SD	24.56 ± 0.72	23.47 ± 0.65
Endpoint, Part One	SERE (D)	Range	N/A*	−3.50–0.50
		Mean ± SD	N/A*	−1.15 ± 0.92
	AL (mm)	Range	23.17–25.92	22.38–25.69
		Mean ± SD	24.70 ± 0.67	24.03 ± 0.74

SERE = spherical equivalent refractive error; AL = axial length.
*Ortho-k treatment in the more myopic eye was not stopped so that end-of-treatment refractive data was not available.