

Comparative effects of orthokeratology and defocus incorporated multiple segment lenses on axial length elongation in children with bilateral myopic anisometropia

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Abstract

• **AIM:** To compare the effect of orthokeratology (OK) and defocus incorporated multiple segment (DIMS) lenses on axial length (AL) elongation in bilateral myopic anisometropic children.

• **METHODS:** This retrospective study enrolled bilateral myopic anisometropic children categorized into two groups: OK lenses and DIMS lenses. The eyes with more myopia (MM) were divided into MM eyes and the fellow eyes with less myopia (LM) into LM eyes. According to the myopia degree in MM eyes, the subjects were further assigned to -0.50 to -3.00 D subgroup and -3.25 to -6.00 D subgroup. The *t*-test was used to analyze the changes in AL elongation between groups and AL differences in both eyes, and the relationship between AL changes and baseline data was evaluated by Pearson linear correlation analysis.

• **RESULTS:** Totally 202 children (8-14y) were divided into OK group with mean age 10.97±1.91y (46 males and 50 females) and DIMS group with mean age 11.05±2.06y (58 males and 48 females). After 1y, the changes of AL in OK-MM eyes (0.14±0.18 mm) were significantly slower than that in OK-LM eyes (0.20±0.19 mm) and DIMS-MM eyes (0.19±0.18; $P<0.001$, $P=0.037$). The OK-LM eyes and DIMS-LM eyes, DIMS-MM eyes and DIMS-LM eyes showed no statistically significant difference in AL changes ($P=0.337$, 0.381). In the -0.50 to -3.00 D subgroups, DIMS-LM eyes had better effect of AL control than OK-LM eyes, the changes of AL in OK-MM eyes and DIMS-MM eyes were

no statistically significant. In the -3.25 to -6.00 D subgroups, the results were similar in total group. The change of AL in four subgroups was negatively correlated with age ($P<0.05$).

• **CONCLUSION:** OK lens can reduce binocular anisometropia; DIMS lens has similar effect on the control of binocular myopia in children with myopic anisometropia. The OK lenses are more effective than DIMS lenses with higher degrees of myopia, while DIMS lens retard AL elongation more effectively than OK lens when the spherical equivalent refraction of MM eyes is lower than -3.00 D.

• **KEYWORDS:** orthokeratology lens; defocus incorporated multiple segments; myopic anisometropia; axial length

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INTRODUCTION

The incidence of myopia among Chinese children and adolescents has been increasing^[1-2], with some individuals developing anisometropia due to imbalances in binocular refractive development^[3]. Myopic anisometropia is defined as a binocular spherical equivalent refraction (SER) difference of at least 1.00 D^[3]. Studies have reported that the prevalence of anisometropia in children ranges from 5.3% to 7.0%^[4]. High degrees of anisometropia can lead to significant differences in retinal image size, resulting in visual fatigue, amblyopia and impaired stereopsis^[5-6]. This refractive condition exerts profound impacts on the formation and maturation of binocular vision, particularly when it occurs during childhood, potentially leading to long-term consequences in visual development^[7-8]. Furthermore, the incidence of anisometropia and interocular differences in myopia tend to increase with age and overall severity of myopia^[9-10].

Orthokeratology (OK) lenses have been widely used for correcting anisometropic myopia and for controlling its progression^[11-13]. Studies have demonstrated that OK lenses can effectively slow axial length (AL) growth and reduce anisometropia to some extent^[14-16]. Similarly, defocus incorporated multiple segments (DIMS) lenses have shown efficacy in controlling myopia progression in children^[17-19]. A large real-world study^[17] found that the efficacy of DIMS lenses in slowing myopia progression varied with baseline refractive status, with greater benefits observed in patients with lower baseline SER, while those with higher baseline SER exhibited a weaker effect in slowing myopia progression. Despite the growing clinical use of DIMS lenses, it remains unclear whether patients with myopic anisometropia wearing DIMS lenses experience a more rapid myopia progression in the more myopic (MM) eyes than in less myopic (LM) eyes, which potentially exacerbates anisometropia. Furthermore, there is limited research evaluating the trends in binocular diopter and AL change in children with myopic anisometropia using either OK or DIMS lenses.

In light of the above, this study aimed to investigate the effects of OK and DIMS lenses on AL elongation in children with bilateral myopic anisometropia, specifically assessing AL growth rate in both eyes and changes in interocular anisometropia over time.

PARTICIPANTS AND METHODS

Ethical Approval The study was approved by the Ethics Committee of Aier Eye Hospital of Wuhan University (HKAIER2022IRB-011-01) and conducted in accordance with the Declaration of Helsinki and clinical practice guidelines. Due to its retrospective design and the data was taken from the electronic medical record system, it was waived the need for informed consent.

Participants This retrospective study included children diagnosed with bilateral myopic anisometropia (defined as a binocular SER difference ≥ 1.00 D) who were fitted with OK lenses (96 cases) or DIMS lenses (106 cases) between October 2021 and October 2022. The inclusion criteria were as follows: age 8–14y; cycloplegic SER between -0.50 and -6.00 D; best-corrected visual acuity (BCVA) in both eyes of better than or equal to 0.1 logMAR; availability of 1-year follow-up data; absence of prior or concurrent myopia control interventions; intraocular pressure (IOP) between 10 and 21 mm Hg in both eyes; and no history of ocular diseases or surgery. The exclusion criteria included: prior or concurrent use of other myopia control interventions such as low-concentration atropine eye drops and red-light therapy apparatus; strabismus or any ocular surface disease; and systemic disease or mental illness. Participants in both the OK and DIMS lens groups were categorized based on the eye with the greater degree of myopia

(MM eyes) and that with the lower degree of myopia (LM eyes). The OK lens group was divided into two groups: OK-MM eyes and OK-LM eyes, while the DIMS lens group was divided into DIMS-MM eyes and DIMS-LM eyes. Participants were further classified into two subgroups based on the degree of myopia in the MM eye: -0.50 to -3.00 D subgroup and -3.25 to -6.00 D subgroup.

Examination Baseline refraction was performed using compound topical eye drops (0.5% topical amide and 0.5% phenylephrine hydrochloride, Santen, Japan) instilled three times at 5-minute intervals for initial optometry examination. Cycloplegia was confirmed 30min after the final instillation by the absence of pupillary light reflex. SER was measured using an autorefractometer (Topcon RM 8000A, Topcon, Japan), with three consecutive measurements averaged. Subjective refraction without cycloplegia was used during the follow-up visit. AL was measured using an IOLMaster-500 (Carl Zeiss, Germany), with five repeated measurements averaged for analysis.

The OK lenses used in this study were Alpha lenses (Boston EM material, Alpha Corp., Japan) with a Dk value of 100×10^{-11} cm²/s (mL O₂/mL \times mm Hg), a conventional vision shaping treatment (VST) design, and an optical zone diameter of 6.0 mm. Lens fitting was performed by an experienced ophthalmic technician according to the manufacturer's instructions. Lens centration and tightness were assessed using fluorescein. Participants were scheduled for routine follow-up visits at 1d, 1wk, 1 and every 3mo after lens delivery, with additional unscheduled visits as needed to monitor ocular health and treatment response.

The DIMS lenses consisted of a central optical area (9 mm diameter) for refractive error correction and clear vision, and a peripheral multiple focal zone (33 mm diameter) containing 396 segments (+3.50 D). These peripheral segments generated periretinal myopic defocus to slow axial elongation and myopia progression. The final lens prescription was determined after a trial fitting, ensuring optimal correction based on individual refractive errors. Patients were instructed to wear the lenses for at least 12h per day, to ensure proper lens placement, and to attend regular 3-month follow-up appointments. Lenses were replaced if significant wear was detected or if myopia progression exceeded 0.50 D.

Statistical Analysis Statistical analysis was performed using SPSS 23.0. The normality of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed data are presented as mean \pm standard deviation (SD). An independent sample *t*-test was used for intergroup comparisons, while a paired sample *t*-test was used for within-group comparisons of binocular parameters. The relationship between AL changes and baseline characteristics was assessed using

Pearson correlation analysis. A P value <0.05 was considered statistically significant.

RESULTS

Baseline Characteristics A total of 202 children with bilateral myopic anisometropia were included in this study, consisting of 96 participants in the OK group and 106 in the DIMS group. Among the MM eyes, 67% were right eyes. The OK group comprised 46 males and 50 females, while the DIMS group included 58 males and 48 females. The mean age of participants was 10.97 ± 1.91 y in the OK group and 11.05 ± 2.06 y in the DIMS group. Table 1 summarizes the baseline characteristics and demographic data of all participants. At baseline, no statistically significant differences were observed between the OK and DIMS groups, or their respective subgroups, for sex, age, SER, AL, anisotropic SER, or anisotropic AL (all $P > 0.05$).

AL Change in Different Groups After 1y of follow-up (Table 2), AL elongation was significantly slower in OK-MM eyes than in OK-LM eyes ($P < 0.001$) and DIMS-MM eyes ($P = 0.037$). However, no statistically significant difference was observed in AL changes between DIMS-LM eyes and OK-LM eyes ($P = 0.337$) or DIMS-MM eyes ($P = 0.381$).

In the subgroup with baseline myopia between -0.50 and -3.00 D, axial elongation was significantly slower in DIMS-LM eyes than in OK-LM eyes ($P = 0.020$). However, there was no significant difference in AL changes between OK-MM eyes and DIMS-MM eyes ($P = 0.545$). In the subgroup with baseline myopia between -3.25 D and -6.00 D, AL elongation was significantly slower in OK-MM eyes than in OK-LM eyes and DIMS-MM eyes ($P < 0.001$; $P = 0.003$, respectively), consistent with the overall group findings. In LM eyes, no significant difference in AL elongation was observed between the OK and DIMS lens groups ($P = 0.940$).

These findings indicate that OK lenses effectively slow AL elongation in MM eyes more than in LM eyes across all groups and subgroups, while the DIMS lenses demonstrated a similar effect on binocular AL control in myopic anisometropia.

Distribution of Myopia Progression After 1y Figure 1 illustrates the distribution of AL changes after 1y among the study groups. The proportion of eyes with AL elongation less than 0.2 mm was higher in the OK-MM (67.71%) and DIMS-LM (64.15%) groups than in the OK-LM (56.25%) and DIMS-MM (55.66%) groups. Conversely, the proportion of eyes exhibiting AL elongation greater than 0.4 mm was lower in the OK-MM (7.29%) and DIMS-LM (7.55%) groups than in the OK-LM (12.50%) and DIMS-MM (11.32%) groups.

Correlation Analysis Between Baseline Characteristics and AL Changes After 1y The correlation between baseline characteristics and AL changes after 1y are shown in Table 3. In the OK group, AL change was negatively correlated with

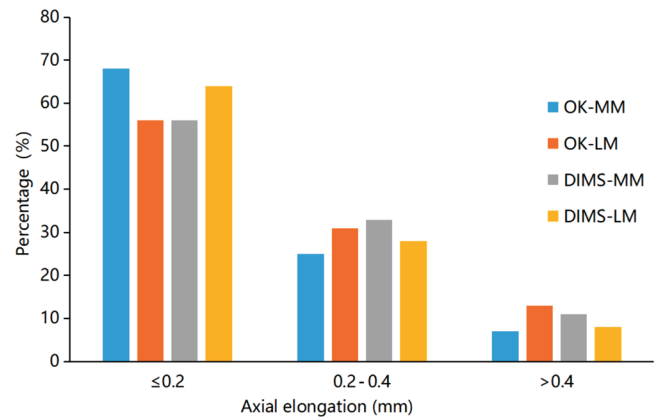


Figure 1 Percentage increase in AL over 1y AL: Axial length; OK: Orthokeratology; DIMS: Defocus incorporated multiple segments spectacles; MM: More myopic eye; LM: Less myopic eye.

Table 1 Comparison of baseline characteristics between the OK and DIMS groups

Characteristics	OK (n=96)	DIMS (n=106)	t	P
Age, y	10.97±1.91	11.05±2.06	0.280	0.780
Sex (male)	46 (47.9%)	58 (54.7%)	—	0.326
MM eyes				
SER, D	-3.63±1.26	-3.50±1.32	0.721	0.472
AL, mm	25.02±0.77	25.06±0.91	0.314	0.754
LM eyes				
SER, D	-2.34±1.27	-2.21±1.27	0.756	0.450
AL, mm	24.49±0.74	24.52±0.89	0.268	0.789
Interocular difference				
Anisotropic SER, D	-1.29±0.63	-1.29±0.53	-0.049	0.961
Anisotropic AL, mm	0.53±0.33	0.55±0.25	0.157	0.875

OK: Orthokeratology; DIMS: Defocus incorporated multiple segments spectacles; SD: Standard deviation; SER: Spherical equivalent refraction; AL: Axial length; MM: More myopic eyes; LM: Less myopic eyes.

age (OK-MM: $r = -0.324$, $P = 0.001$; OK-LM: $r = -0.435$, $P < 0.001$) and baseline AL (OK-MM: $r = -0.235$, $P = 0.021$; OK-LM: $r = -0.234$, $P = 0.022$), and positively correlated with baseline SER (OK-MM: $r = 0.292$, $P = 0.004$; OK-LM: $r = 0.220$, $P = 0.031$). In the DIMS groups, AL changes were negatively correlated with age (DIMS-MM: $r = -0.253$, $P = 0.009$; DIMS-LM: $r = -0.321$, $P = 0.001$). However, no significant correlation was found between AL change and baseline SER (DIMS-MM: $r = 0.009$, $P = 0.929$; DIMS-LM: $r = 0.000$, $P = 0.999$) or baseline AL (DIMS-MM: $r = 0.068$, $P = 0.491$; DIMS-LM: $r = 0.071$, $P = 0.468$).

DISCUSSION

Anisometropia is a visual condition characterized by unequal refractive power between the two eyes, primarily caused by variations in AL and corneal curvature. Studies have shown that the incidence and severity of anisometropia increase with age and myopia progression^[4-6]. Significant or prolonged

Table 2 Comparison of AL changes and anisotropic AL between the OK and DIMS groups at baseline and after 1y mean±SD, mm

Groups	n	AL change in MM	AL change in LM	P	Anisotropic AL at baseline	Anisotropic AL after 1y
Total						
OK	96	0.14±0.18	0.20±0.19	<0.001	0.53±0.33	0.46±0.33
DIMS	106	0.19±0.18	0.18±0.18	0.381	0.55±0.25	0.55±0.28
P		0.037	0.337		0.877	0.050
-0.50 to -3.00 D						
OK	36	0.19±0.14	0.24±0.14	0.020	0.40±0.22	0.37±0.25
DIMS	43	0.17±0.19	0.17±0.13	0.924	0.45±0.15	0.45±0.20
P		0.545	0.024		0.235	0.057
-3.25 to -6.00 D						
OK	60	0.10±0.19	0.18±0.21	<0.001	0.61±0.36	0.53±0.35
DIMS	63	0.20±0.18	0.18±0.20	0.183	0.59±0.28	0.61±0.31
P		0.003	0.940		0.812	0.154

-0.50 to -3.00 D and -3.25 to -6.00 D subgroups are classified based on the degree of myopia in the MM eye. AL: Axial length; OK: Orthokeratology; DIMS: Defocus incorporated multiple segments spectacles; SD: Standard deviation; MM: More myopic eye; LM: Less myopic eye.

Table 3 Correlation analysis between baseline characteristics and AL changes after 1y

Characteristics	OK-MM		OK-LM		DIMS-MM		DIMS-LM	
	r	P	r	P	r	P	r	P
Age	-0.324	0.001	-0.435	<0.001	-0.253	0.009	-0.321	0.001
SER	0.292	0.004	0.220	0.031	0.009	0.929	<0.001	0.999
AL	-0.235	0.021	-0.234	0.022	0.068	0.491	0.071	0.468

AL: Axial length; OK: Orthokeratology; DIMS: Defocus incorporated multiple segments spectacles; MM: More myopic eyes; LM: Less myopic eyes; SER: Spherical equivalent refraction.

interocular differences can disrupt binocular visual function, leading to vision-related complications such as diplopia, visual fatigue, difficulty adapting to corrective lenses, and inability to perform fine visual tasks^[7]. Given its crucial role in binocular vision development during childhood, anisometropia requires careful attention and management in affected children.

Currently, OK and multi-segment spectacle lenses are the most common and effective non-pharmacological interventions for slowing myopia progression and AL elongation, demonstrating superior efficacy compared with single-vision spectacles (SVS)^[15-16]. OK lenses are frequently employed for myopia correction and control due to their ability to retard myopic progression, balance binocular vision, and reduce anisometropic values^[13-16]. Furthermore, studies have shown that spectacle lenses incorporating positive power lenslets, such as DIMS and highly aspherical lenslets (HAL) significantly slow myopia and AL progression compared with SVS in myopic children^[19-22]. However, there is limited research on the application of multi-segment spectacle lenses for myopic anisometropia.

This study retrospectively analyzed AL changes in children with bilateral myopic anisometropia after 1y of wearing OK or DIMS lenses. The results revealed that OK lenses effectively reduced the degree of binocular anisometropia, while DIMS lenses exhibited similar effects on binocular myopia control. OK lenses demonstrated greater efficacy in eyes with higher

degrees of myopia, while DIMS lenses demonstrated superior myopia control in eyes with SER less than -3.00 D, the myopia control effect of DIMS-LM was superior to that of OK-LM eyes. These findings suggest that both OK and DIMS lenses are viable options for managing myopic anisometropia, with OK lenses preferable in cases of higher refractive error, while DIMS lenses are preferable for lower refractive errors. Additionally, correlation analysis revealed that AL elongation in the OK group was negatively correlated with baseline AL and positively correlated with baseline SER. However, no significant correlation was observed between AL elongation and baseline AL or SER in the DIMS group.

Chen *et al*^[14] investigated bilateral AL growth patterns in anisometropic children undergoing unilateral OK treatment, followed by bilateral treatment when the previously non-myopia eyes developed myopia. It was demonstrated that OK treatment effectively controlled AL growth in unilateral myopia. However, when the contralateral eye developed myopia and received OK treatment, AL growth in the previously myopic eye accelerated, although its control remained superior to that observed in spectacle wearers. During the bilateral treatment period, OK lenses exhibited a moderate and comparable effect on AL retardation in both eyes. However, this study found that the changes of AL in OK-MM eyes were significantly slower than that in OK-LM eyes. Chen *et al*'s^[14] study included monocular refractive

anisometropic myopia, while our study included binocular refractive anisometropic myopia. The wearing patterns of glasses were different, which resulted in different eye axis growth in both eyes for the two studies.

A study^[23] evaluating AL elongation in monocular myopic children treated with OK lenses or HALs found that, at the 12-month follow-up, AL elongation was significantly slower in myopic eyes treated with OK lenses (0.17 ± 0.20 mm) than in non-myopic eyes (0.41 ± 0.26 mm). However, no significant difference in AL elongation was observed in the HAL group between myopic (0.10 ± 0.15 mm) and non-myopic eyes (0.12 ± 0.12 mm). These findings suggested that while OK lenses effectively suppressed AL elongation in the myopic eye and minimized anisometropia, they may also accelerate myopia onset and progression in the untreated contralateral eye. In contrast, HALs demonstrated a similar effect in the myopic eye compared with monocular OK lenses, while offering superior efficacy in slowing AL elongation in the initially non-myopic eye. While this result aligns with the present study, the previous study focused on monocular anisometropia and it is not grouped according to myopia diopter, whereas the present study examined bilateral myopia.

Lu *et al*^[24] prospectively studied 496 myopic patients with SER between -0.50 D and -5.00 D, who received DIMS lenses (180 cases), OK lenses (180 cases), or SVS (180 cases). Participants were categorized into low myopia (-0.50 to -1.50 D), moderate myopia (-1.50 to -3.00 D), and high myopia (-3.00 to -5.00 D) subgroups. The study reported that AL elongation was significantly slower in the OK lens group (0.20 ± 0.18 mm) than in the DIMS lens (0.30 ± 0.22 mm) and SVS (0.38 ± 0.19 mm) groups. While OK and DIMS lenses exhibited similar AL changes in low myopia, both interventions showed superior efficacy in controlling myopia compared with SVS. However, in moderate myopia and high myopia, OK lenses were more effective in slowing AL elongation than DIMS lenses and SVS, with no significant differences observed between DIMS and SVS in high myopia. These findings generally corroborate the present study, although, in the present study, DIMS lenses were found to be more effective than OK lenses in lower myopia.

In the present study, the correlation between AL changes and baseline characteristics, including age, SER, and AL were investigated. The results revealed that AL changes in the OK and DIMS groups were significantly associated with age, with a more pronounced myopia control effect observed in older children. This result aligns with the study by Lam *et al*^[18], which reported a positive correlation between SER changes and age in children wearing DIMS lenses. However, Bao *et al*^[25] found no such correlation in children wearing HALs. Furthermore, Su *et al*^[26] investigated the 1-year myopia control

efficacy of novel Lenslet-ARray-integrated (LARI) spectacle lenses, which incorporated positive power lenslets (PLARI) and negative power lenslets (NLARI) myopic children. It was found that faster myopia progression was associated with younger age in SVS and PLARI groups, but not in NLARI groups. These inconsistencies across studies may be attributed to variations in lens design, sample size, grouping methods, baseline age of participants, and compliance with lens wearing. The prevailing hypothesis for myopia control with OK and DIMS lenses centers on the enhancement of myopic defocus signals at the peripheral retina^[27-29]. Studies have shown that the hyperopic peripheral defocus increases with the degree of central myopia^[30-32]. In cases of higher myopia, the greater intensity of defocus created by OK lenses on the cornea may provide a stronger myopic defocus signal at the peripheral retina, potentially improving AL elongation control. However, the myopia control effect of DIMS lens is not directly proportional to the degree of myopia, because the magnitude of lenslets in DIMS lenses is fixed at $+3.50$ D. The dose-dependent effect of lens-induced myopia in animal studies was related to peripheral defocus^[33-34]. In this study, DIMS lenses demonstrated better control of AL elongation than OK lenses in LM eyes, which may indicate that the efficacy of myopia control is dose-dependent with myopic defocus to some extent^[35]. Consequently, it may be essential to tailor the future DIMS lenses with different peripheral power of defocus, which should be based on the level of individual myopia to optimize treatment efficacy.

Despite the valuable insights provided by this retrospective study, it has limitations, including the lack of binocular visual function assessment, warranting further investigation in future clinical studies. Additionally, long-term clinical outcomes of OK and DIMS lenses in patients with myopic anisometropia should be investigated in larger cohorts.

In this study, OK lenses demonstrated greater efficacy than DIMS lenses in controlling AL elongation in higher myopia. However, DIMS lenses exhibited comparable binocular myopia control, thus being one of the options for managing lower myopia in children with myopic anisometropia.

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