Predictors of Myopia Progression with Myopia-Control Spectacle Lenses

Preditores da Progressão da Miopia em Crianças com Lentes de Controlo da Miopia

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ABSTRACT

INTRODUCTION: Myopia prevalence has increased sharply worldwide, becoming a major public health issue. As onset and progression occur mainly in childhood, early detection and intervention are essential to prevent high myopia and related complications. Spectacle designs such as DIMS, HALT, and CARE lenses slow axial elongation by modifying peripheral defocus. However, the influence of corneal astigmatism (CA) and axis orientation on treatment response remains poorly understood. This study aimed to evaluate the influence of keratometric and biometric parameters on myopia progression in children treated with myopia-control lenses.

METHODS: A retrospective observational study included 38 eyes from 19 children aged 5–18 years prescribed myopia-control lenses. Baseline and 6–12-month follow-up data were obtained. Biometric and keratometric parameters were obtained with ARGOS® Optical Biometer. Myopia progression was defined using the Age-Matched Myopia Control (AMMC) system, which adjusts for age- and sex-specific AL growth. Annualized changes were calculated to account for follow-up duration. Group comparisons used the Mann–Whitney U test, and logistic regression identified predictors of progression.

RESULTS: Progression occurred in 24 eyes (63.2%), while 14 (36.8%) remained stable. Progressors were younger (10.5 *vs* 12 years, p=0.037). Non-progressors showed higher baseline CA (1.53 *vs* 0.75 D, p=0.006) and vitreous chamber depth (17.52 *vs* 16.79 mm, p=0.046). No significant axis changes occurred (p=0.500). In multivariate analysis adjusted for age, lower baseline CA independently predicted myopia progression (p=0.024; OR = 0.22, 95% CI [0.06–0.82]).

CONCLUSION: Lower baseline corneal astigmatism was independently associated with greater myopia progression despite myopia-control lenses, while higher CA appeared protective, possibly by reducing peripheral hyperopic defocus. Incorporating keratometric parameters, particularly CA, into pediatric myopia assessment may enhance risk stratification and support individualized management strategies.

KEYWORDS: Child; Eyeglasses; Myopia; Refraction, Ocular; Visual Acuity.

RESUMO

INTRODUÇÃO: A prevalência de miopia tem aumentado de forma acentuada em todo o mundo, sendo que a deteção e a intervenção precoces são essenciais para prevenir as suas

complicações associadas. Lentes oftálmicas como as DIMS, HALT e CARE reduzem o alongamento axial ao modificar o desfoque periférico. No entanto, a influência do astigmatismo corneano (AC) na resposta ao tratamento permanece pouco compreendida. Este estudo avaliou a influência dos parâmetros queratométricos e biométricos na progressão da miopia em crianças tratadas com lentes de controlo da miopia.

MÉTODOS: Foi realizado um estudo observacional retrospetivo que incluiu 38 olhos de 19 crianças (5-18 anos), a quem foram prescritas lentes de controlo da miopia. Foram recolhidos dados basais e de seguimento (6–12 meses). Os parâmetros biométricos e queratométricos foram obtidos com o biómetro ótico ARGOS®. A progressão da miopia foi definida segundo o sistema *Age-Matched Myopia Control* (AMMC), que ajusta o crescimento do comprimento axial (AL) à idade e ao sexo. As variações foram anualizadas para considerar a duração do seguimento. Foi utilizado o teste de Mann–Whitney U para comparação entre grupos e análises de regressão logística.

RESULTADOS: A progressão ocorreu em 24 olhos (63,2%), enquanto 14 (36,8%) permaneceram estáveis. Os olhos com progressão pertenciam a crianças mais jovens (10,5 *vs* 12 anos, p=0,037). Os olhos sem progressão apresentaram valores mais elevados de AC basal (1,53 *vs* 0,75 D, p=0,006) e de profundidade da câmara vítrea (17,52 *vs* 16,79 mm, p=0,046). Não houve alterações na orientação do eixo (p=0,500). Na análise multivariada ajustada à idade, um AC basal inferior foi um preditor independente de progressão (p=0,024; OR = 0,22; IC 95% [0,06–0,82]).

CONCLUSÃO: Um menor astigmatismo corneano basal associou-se, de forma independente, a uma maior progressão da miopia, mesmo com o uso de lentes de controlo da miopia. Por outro lado, valores mais elevados de AC parecem exercer um efeito protetor, possivelmente por reduzirem o desfoque periférico hipermetrópico. A inclusão de parâmetros queratométricos na avaliação da miopia pode melhorar a estratificação do risco e apoiar estratégias de gestão mais individualizadas.

PALAVRAS-CHAVE: Acuidade Visual; Criança; Miopia; Óculos; Refração Ocular.

INTRODUCTION

Myopia is a growing global public health concern, with prevalence increasing sharply in recent decades, not only in East Asia but also across Europe and North America.[1] Because onset and progression occur primarily during childhood, early detection and intervention are essential to prevent high myopia and its sight-threatening complications in adulthood, such as retinal detachment and myopic maculopathy, highlighting the importance of early intervention to slow progression.[2]

Several optical strategies have been developed for myopia control, including spectacle designs such as defocus incorporated multiple segments (DIMS), highly aspherical lenslet target (HALT) technology and cylindrical annular refractive elements (CARE) lenses. These lenses provide clear central vision while modulating peripheral defocus to reduce axial elongation.[3] Over the past years, they have demonstrated significant efficacy in randomized clinical trials, supporting their growing clinical adoption and expanding scientific evidence base.[4-7]

Myopic refractive error arises from a complex interaction between axial length (AL) and corneal refractive power.[8,9] These parameters may act as biomarkers for assessing the risk of myopia progression. While spherical equivalent (SE) and mean keratometry (Km) are well studied, the role of corneal astigmatism (CA) has been less explored, particularly in the context of myopia-control lenses.[10] Moreover, the potential influence of astigmatism axis orientation remains poorly understood.[11]

Emerging evidence also suggests that posterior segment parameters, especially vitreous chamber depth (VCD) and the axial length/corneal radius ratio (AL/CR), may be associated with myopia progression.[12-14] These findings reinforce the relevance of AL as a key biomarker in myopia monitoring and risk assessment.[15] When integrated with objective data from modern optical biometers, these parameters may offer a consistent and objective means of characterizing ocular growth dynamics and predicting the risk of myopia progression.

This study aimed to evaluate the influence of keratometric and biometric parameters on myopia progression in children treated with myopia-control lenses.

METHODS

A retrospective observational study was conducted including children aged 5–18 years followed at a pediatric ophthalmology clinic and prescribed myopia-control lenses (DIMS, HALT or CARE). Data were collected at baseline and after 6–12 months of lens wear. None of the children were previously exposed to any myopia-control intervention.

Demographic, refractive, and lens-type data were retrieved from clinical records. Biometric and keratometric measurements were obtained using the ARGOS® Optical Biometer, including:

- Refractive error parameters, in diopters (D): sphere, cylinder, and SE.

- Structural parameters: central corneal thickness (CCT, µm), anterior chamber depth (ACD, mm), corneal diameter (CD, mm), lens thickness (LT, mm) and AL (mm)
- Corneal parameters, in diopters (D): flat keratometry (K1), steep keratometry (K2) and Km.

Derived variables were calculated as follows:

- CA = K2 – K1
- VCD = AL – (CCT/1000 + ACD + LT)
- Corneal radius (CR, mm) = 337.5/Km
- AL/CR ratio = AL/CR

Children with ocular conditions other than myopia (such as strabismus or amblyopia) and those with prior exposure to any myopia-control treatment, including contact lenses, were excluded from the study.

Clinically significant myopia progression was primarily defined using an age- and sex-adjusted approach based on the Age-Matched Myopia Control (AMMC) system, which accounts for normative axial length growth and classifies eyes as progressing or stable according to individual axial elongation rates (validated by Graff *et al*).[16]

For contextual and comparative purposes, a conventional axial elongation cut-off of ≥0.20 mm/year was also considered in an exploratory analysis, in line with commonly adopted criteria in the literature.

Data analysis was performed with IBM SPSS Statistics 30. Continuous variables were expressed as median and interquartile range (IQR: Q1–Q3). Deltas, defined as the absolute changes (Δ) between baseline and follow-up were computed. To account for variations in follow-up duration, all Δ values were annualized according to the formula:

Δ annual = Δ / (follow-up time in days / 365.25).

This adjustment allowed interindividual comparison of progression rates independent of follow-up length.

Group comparisons were made using the Mann–Whitney U test and binary logistic regression identified independent predictors of progression. Changes in astigmatism axis orientation between baseline and follow-up were assessed using the McNemar test for paired categorical data. A p-value < 0.05 was considered statistically significant.

All data remained anonymized. The study was conducted in accordance with the principles of the Declaration of Helsinki for the protection of human subjects in medical research. Due to the retrospective design of the study and the use of anonymized data, informed consent was waived.

RESULTS

A total of 38 eyes from 19 children were included. Progression was observed in 24 eyes (63.2%), while 14 eyes (36.8%) remained stable.

Progressors were significantly younger than non-progressors (median 10.5 *vs* 12 years, p=0.037). Of the 19 children included, 7 (36.8%) were female and 12 (63.2%) were male. The proportion of males did not differ significantly between progressors and non-progressors (p=0.301). Follow-up duration, lens type distribution, and baseline axial length percentiles did not differ between groups, as displayed in Table 1.

At baseline, several biometric parameters differed between males and females (Table 2). Female children had shorter axial length, shallower anterior chamber depth, steeper mean keratometry, and thicker central corneas than males. No statistically significant differences were observed in corneal astigmatism.

Regarding baseline and final biometric parameters (Table 3), refractive error (spherical power, cylinder power, and SE) showed no significant differences between groups at either time point. Non-progressors presented significantly higher CA both at baseline (1.53 *vs* 0.75 D, p=0.006) and at follow-up (1.69 *vs* 0.96 D, p=0.004). ACD was shallower in non-progressors both at baseline (3.82 *vs* 4.02 mm, p=0.015) and follow-up (3.79 *vs* 4.01 mm, p=0.010). VCD was also greater in non-progressors at baseline (17.52 *vs* 16.79 mm, p=0.046). No significant intergroup differences were observed for AL, K1, K2, Km, CD and LT.

All 14 non-progressors exhibited with-the-rule (WTR) astigmatism at baseline, whereas 20 of the 24 progressors (83.3%) also showed WTR orientation. No significant

Table 1. Baseline demographic and clinical characteristics of the study sample. p values refer to group comparisons between progressors and non-progressors using the Mann–Whitney U or Chi-square test as appropriate.

		Overall (n=38)	Progressors (N=24)	Non-progressors (N=14)	*p*
Sex, male n (%)		24 (63.2)	17 (70.8%)	7 (50%)	0.301
Age, years median [IQR]		11 [7; 12]	10.5 [7; 12]	12 [8.75; 12.5]	**0.037**
Follow-up time, days median [IQR]		185 [180; 249]	192 [180; 249]	183.5 [179.75; 218]	0.665
Myopia lenses n (%)	DIMS	27 (71.1)	17 (70.8)	10 (71.4)	0.443
	HALT	3 (7.9)	1 (4.2)	2 (14.3)	
	CARE	8 (21.1)	6 (25)	2 (14.3)	
AL percentiles n (%)	P98	22 (57.9)	15 (62.5)	7 (50)	0.105
	P95	5 (13.2)	5 (20.8)	0 (0)	
	P90	5 (13.2)	3 (12.5)	2 (14.3)	
	≤ P75	6 (15.8)	1 (4.2)	5 (35.7)	

Table 2. Baseline biometric and keratometric parameters according to sex. Data are expressed as median [IQR]. Comparisons were performed using the Mann–Whitney U test.

Variable		Males (N=24)	Females (N=14)	*p*
AL, mm – median [IQR]	Baseline	25.62 [24.29, 26.22]	24.62 [23.61, 25.17]	**0.032***
	Final	25.66 [24.36, 26.19]	24.64 [23.71, 25.27]	**0.047***
CA, D – median [IQR]	Baseline	0.91 [0.65, 1.59]	0.89 [0.63, 1.56]	0.917
	Final	1.06 [0.75, 1.75]	1.02 [0.52, 1.54]	0.643
Km, D – median [IQR]	Baseline	43.11 [41.94, 44.73]	44.49 [43.32, 45.26]	**0.032***
	Final	43.10 [42.02, 44.74]	44.52 [43.21, 45.25]	**0.032***
CCT, µm – median [IQR]	Baseline	530 [512, 554]	577 [533, 597]	**0.006***
	Final	534 [511, 553]	575 [534, 606]	**0.005***
ACD, mm – median [IQR]	Baseline	4.07 [3.88, 4.29]	3.80 [3.69, 4.00]	**<0.001***
	Final	4.04 [3.87, 4.14]	3.79 [3.77, 3.97]	**0.004***
LT, mm – median [IQR]	Baseline	3.44 [3.43, 3.55]	3.54 [3.41, 3.62]	0.244
	Final	3.47 [3.35, 3.66]	3.52 [3.38, 3.59]	0.823
AL/CR ratio – median [IQR]	Baseline	3.24 [3.18, 3.30]	3.20 [3.16, 3.26]	0.315
	Final	3.23 [3.19, 3.30]	3.22 [3.14, 3.27]	0.427
VCD, mm – median [IQR]	Baseline	17.72 [16.21, 18.21]	16.64 [15.83, 17.26]	0.106
	Final	17.81 [16.10, 18.24]	16.85 [15.92, 17.28]	0.113

Table 3. Baseline and final biometric and keratometric parameters in progressors and non-progressors. *p* values compare groups at each time point (Mann–Whitney U test).

Variable		Progressors (N=24)	Non-progressors (N=14)	*p*
Spherical power, D – median [IQR]	Baseline	-3.00 [-4.00, -2.25]	-3.75 [-5.31, -1.50]	0.649
	Final	-3.00 [-4.00, -2.25]	-3.75 [-5.31, -1.50]	0.649
Cylinder power, D – median [IQR]	Baseline	-0.25 [-0.69, 0]	-1.25 [-4.00, 0]	0.067
	Final	-0.25 [-0.69, 0]	-1.25 [-4.00, 0]	0.067
SE, D – median [IQR]	Baseline	-3.00 [-4.41, -2.25]	-5.00 [-6.06, -1.50]	0.203
	Final	-3.00 [-4.41, -2.25]	-5.00 [-6.06, -1.50]	0.405
AL, mm – median [IQR]	Baseline	24.98 [23.29, 25.77]	25.54 [24.77, 26.22]	0.096
	Final	25.02 [23.56, 25.89]	25.57 [24.67, 26.17]	0.169
CA, D – median [IQR]	Baseline	0.75 [0.64, 0.98]	1.53 [0.86, 2.78]	**0.006***
	Final	0.96 [0.54, 1.16]	1.69 [0.85, 2.78]	**0.004***
K1, D – median [IQR]	Baseline	43.17 [42.59, 45.04]	42.73 [40.85, 43.66]	0.105
	Final	43.17 [42.52, 45.04]	42.62 [40.96, 43.68]	0.072
K2, D – median [IQR]	Baseline	44.09 [43.34, 46.12]	43.86 [43.23, 46.35]	0.672
	Final	44.05 [43.41, 46.03]	43.76 [43.15, 46.35]	0.809
Km, D – median [IQR]	Baseline	43.58 [42.96, 45.53]	43.25 [41.60, 44.91]	0.232
	Final	43.46 [42.98, 45.60]	43.14 [41.82, 44.91]	0.198
CCT, µm – median [IQR]	Baseline	546 [528, 587]	540 [510, 560]	0.238
	Final	545 [517, 594]	544 [512, 568]	0.422
ACD, mm – median [IQR]	Baseline	4.02 [3.85, 4.29]	3.82 [3.78, 4.03]	**0.015***
	Final	4.01 [3.87, 4.12]	3.79 [3.76, 4.03]	**0.010***
LT, mm – median [IQR]	Baseline	3.44 [3.32, 3.56]	3.52 [3.41, 3.63]	0.168
	Final	3.48 [3.30, 3.66]	3.54 [3.40, 3.61]	0.785
VCD, mm – median [IQR]	Baseline	16.79 [15.48, 17.78]	17.52 [16.85, 18.28]	**0.046***
	Final	16.90 [15.86, 17.93]	17.55 [16.89, 18.25]	0.069
CD, mm – median [IQR]	Baseline	13.11 [12.88, 13.68]	13.20 [12.65,13.57]	0.868
	Final	13.28 [13.04, 13.75]	13.28 [13.00, 13.78]	0.797
AL/CR ratio – median [IQR]	Baseline	3.22 [3.16, 3.27]	3.25 [3.17, 3.39]	0.364
	Final	3.22 [3.19, 3.29]	3.24 [3.14, 3.38]	0.999

changes in astigmatism axis classification were observed throughout the follow-up period (p=0.500).

Regarding annualized changes (Table 4), progressors exhibited significantly greater axial elongation compared to non-progressors (0.25 *vs* ~0 mm/year, p<0.001). Similarly, VCD growth was greater among progressors (0.24 *vs* 0.01 mm/year, p<0.001), and the AL/CR ratio showed a larger annual increase (0.030 *vs* –0.015/year, p< 0.001). Annualized changes in SE, CA and anterior segment structural parameters were not statistically significant.

Univariate logistic regression analyses were performed to identify potencial independent of myopia progression (Table 5). Variables with p<0.20 in univariate analyses were entered into the following model. In the final multivariate logistic regression model adjusted for age (Table 6), lower baseline CA was independently associated with higher odds of myopia progression (B = –1.53, p=0.024; OR = 0.22, 95% CI [0.06–0.82]). Age was not a significant predictor (p=0.18). The model demonstrated good fit (Nagelkerke R^2 = 0.38).

DISCUSSION

This study underscores the importance of a comprehensive evaluation of children with myopia that extends beyond AL alone. In clinical practice, biometric and ker-

Table 4. Annualized variation (Δ/year) in refractive, biometric, and keratometric parameters between progressors and non-progressors. *p* values from Mann–Whitney U test.

Variable	Progressors (N=24)	Non-progressors (N=14)	*p*
SE variation (ΔSE), D/year	0.00 [0,0]	0.00 [0,0]	0.480
Axial elongation (ΔAL), mm/year	0.255 [0.123, 0.255]	-0.056 [-0.180, 0.054]	<0.001
CA variation (ΔCA), D/year	0.061 [-0.230, 0.371]	0.034 [-0.066, 0.423]	0.506
CCT variation (ΔCCT), µm/year	1.631 [-10.154, 15.661]	0.564 [-3.470, 10.38]	0.964
ACD variation (ΔACD), mm/year	0.017 [-0.075, 0.067]	-0.046 [-0.107, 0.005]	0.226
LT variation (ΔLT), mm/year	-0.010 [-0.776, 0.154]	0.0204 [-0.197, 0.071]	0.785
AL/CR ratio variation (ΔAL/CR)	0.030 [0.002, 0.055]	-0.0150 [-0.036, 0.021]	**<0.001**
VCD growth (ΔVCD), mm/year	0.243 [0.145, 0.366]	0.010 [-0.100, 0.138]	**<0.001**

Table 5. Univariate binary logistic regression analysis for potential predictors of myopia progression. Results expressed as regression coefficients (B), standard error (SE), Wald statistics, *p* values, odds ratio (Exp [B]), and 95 % confidence intervals (CI).

Variable	B	SE	Wald	*P* value	Exp(B)	95% CI for Exp(B)
Age (years)	-0.270	0.131	4.25	0.039	0.76	0.59 – 0.99
Sex (ref= female)	–0.887	0.698	1.615	0.204	0.41	0.10 – 1.62
Lens type (ref = DIMS)				0.448		
CARE vs DIMS	1.22	1.29	0.90	0.342	3.40	0.272-42.44
HALT vs DIMS	1.79	1.47	1.48	0.224	6.00	0.34 – 107.42
Axial length percentile (ref=P75)				0.338		
P75 *vs* p90	-1.061	0.969	1.200	0.273	0.346	0.052-2.31
P75 *vs* p95	-0.368	1.090	0.114	0.736	0.692	0.082-5.863
P75 *vs* p98	1.242	1.178	1.111	0.292	3.462	0.344 – 34.843
Spherical power baseline (D)	0.181	0.185	0.95	0.329	1.20	0.83 – 1.72
Cylinder power baseline (D)	0.974	0.438	4.94	**0.026**	2.65	1.12 – 6.25
Spherical equivalent baseline (D)	0.264	0.162	2.65	0.104	1.30	0.95 – 1.79
Axial length baseline (mm)	-0.588	0.335	3.09	0.079	0.56	0.29 – 1.07
K1 (D)	0.439	0.228	3.71	0.054	1.55	0.99 – 2.42
K2 (D)	0.093	0.205	0.21	0.649	1.10	0.74 – 1.64
Mean keratometry (Km, D)	0.285	0.221	1.66	0.197	1.33	0.86 – 2.05
CA baseline (D)	-1.559	0.618	6.37	**0.012**	0.21	0.06 – 0.71
CCT baseline (µm)	0.013	0.011	1.474	0.225	1.01	0.992 – 1.035
ACD baseline (mm)	4.366	1.959	4.97	**0.026**	78.7	1.69 – 3661.4
Lens thickness (LT, mm)	-3.136	2.528	1.54	0.215	0.04	0.00 – 6.16
Corneal diameter (CD, mm)	0.013	0.011	1.47	0.225	1.01	0.99 – 1.04
Vitreous chamber depth (VCD, mm)	-0.602	0.321	3.53	0.060	0.55	0.29 – 1.03
AL/CR baseline	-4.834	3.732	1.68	0.195	0.01	0.00 – 11.95

Table 6. Multivariate logistic regression model adjusted for age, including variables with $p<0.20$ in univariate analysis. Results expressed as regression coefficients (B), standard error (SE), Wald statistics, p values, odds ratio (Exp [B]), and 95 % confidence intervals (CI).

Variable	B	SE	Wald	*p* value	Exp(B)	95% CI for Exp(B)
Age (years)	-0.208	0.156	1.76	0.184	0.81	0.60–1.10
Corneal astigmatism (CA, D)	-1.528	0.676	5.11	**0.024***	0.22	0.06–0.82
Constant	4.455	1.879	5.62	**0.018***	86.04	—

atometric parameters should be systematically considered when assessing progression risk and monitoring response to myopia-control interventions.

Lower baseline CA emerged as an independent predictor of myopia progression in children wearing myopia-control lenses, even after adjusting for age. This suggests that eyes with lower corneal toricity may be more susceptible to axial elongation despite optical intervention.

These findings align with growing evidence that ocular geometry and peripheral optics influence the retinal cues regulating eye growth.[17] From a biomechanical perspective, greater corneal toricity may induce relative peripheral myopic defocus along the steep meridian, acting as a natural brake on posterior elongation. Conversely, lower toricity produces a more rotationally symmetric refractive surface, which may enhance uniform peripheral hyperopic defocus that, in myopic eyes, can sustain the axial elongation stimulus. This interpretation is consistent with the optical model proposed by Queirós *et al* (2016), which suggests that peripheral astigmatism can modulate the retinal image shell and the ocular growth signal.[17] Thus, the protective effect observed in children with higher corneal astigmatism may reflect reduced optical symmetry and less persistent hyperopic defocus at the retinal periphery. However, few studies have directly examined this relationship in children wearing myopia-control spectacle designs, making the present study one of the first to explore this association.

Since total astigmatism reflects both corneal and internal components, our analysis focused on the corneal contribution. The absence of significant CA changes during follow-up suggests that myopia-control lenses do not induce corneal remodeling, consistent with Wang et al (2025), who reported stable corneal power in over 70% of children wearing DIMS lenses.[10,18] These findings support the view that corneal geometry remains largely unaffected during treatment, emphasizing the relevance of baseline corneal characteristics in modulating treatment response.

Clinically, these results suggest that baseline corneal astigmatism could serve as an accessible and objective biomarker for predicting treatment response in children undergoing myopia-control therapy. Those with lower astigmatism may be more susceptible to progression even under evidence-based optical interventions, indicating the need for closer monitoring and potentially combined approaches, such as pharmacologic therapy, to achieve optimal control of axial elongation.

Sex-related differences in ocular biometry are well established in the literature.[3,8] In our cohort, similar baseline differences were observed, namely in AL, CCT, ACD, and Km. However, sex was not associated with myopia progression. Importantly, corneal astigmatism did not differ between males and females, and its association with myopia progression remained significant, supporting an effect independent of sex-related biometric differences. These findings suggest that, within the context of myopia-control spectacle lenses, baseline corneal astigmatism may represent a distinct structural modifier of treatment response rather than a surrogate marker of sex-related biometric variation.

Moreover, this study reinforces the value of the AMMC classification system in evaluating progression.[16] By normalizing axial elongation according to sex- and age-specific growth curves, the AMMC approach accounts for physiological variability in ocular development. The observed differences in annual axial elongation, VCD growth, and AL/CR ratio between progressors and non-progressors confirm that this framework effectively discriminates true myopic progression from age-related growth. In this context, the absence of significant changes in spherical equivalent despite detectable axial elongation is consistent with the ability of AMMC-based analysis to identify subclinical progression before refractive changes become apparent.

Accordingly, the higher proportion of eyes classified as progressors in this study reflects the use of an age- and sex-adjusted definition of progression rather than a reduced treatment effect. Notably, when an exploratory analysis using the commonly adopted axial elongation cut-off of ≥0.20 mm/year was applied, the proportion of eyes meeting progression criteria in our cohort (44.7%) was comparable to that reported in the literature, where myopia-control spectacle lenses are known to slow axial elongation but do not fully prevent progression in all treated eyes (analysis not shown).[19-21] These findings illustrate how different definitions of progression capture distinct stages of myopic change and highlight the added sensitivity of the AMMC approach for detecting earlier structural progression.

Consistent with prior literature, posterior segment parameters, particularly VCD and AL/CR ratio, were confirmed as robust markers of ocular elongation.[14,15] Although these measures are collinear with AL, they offer complementary insight: the AL/CR ratio integrates the influence of corneal curvature, while VCD specifically quantifies posterior segment expansion, the anatomical hallmark of axial myopia. Together, these parameters may provide a more comprehensive evaluation of disease dynamics and treatment efficacy in future clinical trials.

Although axis orientation did not reach statistical significance, all non-progressors consistently exhibited WTR astigmatism, whereas non-WTR patterns were observed

only among progressors, suggesting a possible clinical trend that warrants further investigation. The limited number of non-WTR cases may have precluded statistical confirmation.

This study has limitations: the sample size was relatively small and derived from a single clinical center, which may reduce statistical power and generalizability. The follow-up period (6–12 months) may not capture long-term trends, particularly the translation of early axial elongation into refractive change, and cycloplegic refraction was not uniformly performed, potentially introducing minor refractive measurement bias. Moreover, the retrospective design limits causal inference.

Despite these limitations, our findings provide novel insight into the structural determinants of myopia progression under myopia-control lenses. Corneal astigmatism, often overlooked in routine myopia assessment, may represent a simple, reproducible, and clinically meaningful biomarker for progression risk stratification.[12] Integrating keratometric and posterior segment parameters could enhance personalized treatment planning and early identification of high-risk eyes. Future longitudinal studies with larger cohorts and multimodal imaging are warranted to confirm these findings and to elucidate the role of astigmatism orientation and posterior segment growth patterns.

CONCLUSION

In summary, higher corneal astigmatism appears to exert a protective effect against myopia progression in children treated with myopia-control spectacle lenses. Incorporating keratometric assessment, particularly corneal astigmatism, into routine pediatric myopia evaluations may improve early prediction of treatment response and guide individualized therapeutic strategies.

CONTRIBUTORSHIP STATEMENT / DECLARAÇÃO DE CONTRIBUIÇÃO

PCT and CCF: conceived the study, collected and analyzed the data, and contributed to writing and revising the manuscript.

MG, JAA, and JCP: contributed to data interpretation, manuscript writing, and critical review.

All authors reviewed and approved the final version of the manuscript for publication.

PCT e CCF: conceberam o estudo, recolheram e analisaram os dados e contribuíram para a redação e revisão do manuscrito.

MG, JAA e JCP: contribuíram para a interpretação dos dados, redação do manuscrito e revisão crítica.

Todos os autores revisaram e aprovaram a versão final do manuscrito para publicação.

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