Influence of keratometric parameters in myopia progression in patients treated with lenses for myopia control

Influência dos parâmetros queratométricos na progressão da miopia em crianças tratadas com lentes para controle da miopia

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ABSTRACT

Objective: To investigate the predictive role of keratometric and biometric parameters on myopia progression in children undergoing optical myopia control.

Methods: This retrospective study included pediatric myopic patients treated with defocus-correcting spectacle or contact lenses at *Unidade Local de Saúde Almada-Seixal*. Biometric and keratometric measurements (axial length, K1, K2, and mean keratometry) were obtained using the ZEISS IOLMaster700 at baseline and after 12 months. Clinically significant progression was defined as an increase in spherical equivalent ≥ −0.50 D/year or axial length > 0.20 mm/year. Correlation and multivariable regression analyses were performed.

Results: Ninety-four eyes from 47 children (mean age 11.55 ± 2.66 years) were analyzed. Clinically significant progression occurred in 39.4% of eyes. Eyes in the Progression Group had significantly longer baseline axial length (25.16 ± 1.42 mm *versus* 24.52 ± 0.98 mm; $p < 0.05$) and flatter corneas, with lower mean keratometry values (43.44 ± 1.58 D *versus* 44.14 ± 1.35 D; $p < 0.05$). Mean keratometry showed a positive correlation with spherical variation, while axial length demonstrated a negative correlation. Both parameters remained independently associated with progression.

Conclusion: In addition to axial length, baseline keratometry was significantly associated with myopia progression under optical treatment. Flatter corneas were associated with increased myopia progression, supporting the inclusion of keratometric parameters in baseline evaluation of myopic children.

RESUMO

Objetivo: Investigar o papel preditivo dos parâmetros queratométricos e biométricos na progressão da miopia em crianças submetidas a tratamento óptico para controle da miopia.

Métodos: Estudo retrospectivo que incluiu pacientes pediátricos com miopia tratados com lentes oftálmicas ou de contato com desfocagem para controle da miopia na Unidade Local de Saúde Almada-Seixal. As medições biométricas e queratométricas (comprimento axial, K1, K2 e queratometria média) foram obtidas com o ZEISS IOLMaster 700 no início do tratamento e após 12 meses. Progressão clinicamente significativa foi definida como aumento do equivalente esférico ≥ −0,50 D/ano ou aumento do comprimento axial > 0,20 mm/ano. Foram realizadas análises de correlação e regressão multivariável.

Resultados: Foram analisados 94 olhos de 47 crianças (idade média de 11,55 ± 2,66 anos). Observou-se progressão clinicamente significativa em 39,4% dos olhos. Os olhos do grupo com progressão apresentaram comprimento axial inicial significativamente maior (25,16 ± 1,42 mm versus 24,52 ± 0,98 mm; $p < 0,05$) e córneas mais planas, com valores inferiores de queratometria média (43,44 ± 1,58 D versus 44,14 ± 1,35 D; $p < 0,05$). A queratometria média apresentou correlação positiva com a variação esférica, enquanto o comprimento axial apresentou correlação negativa. Ambos os parâmetros permaneceram independentemente associados a progressão.

Conclusão: Para além do comprimento axial, a queratometria inicial apresentou associação significativa com a progressão de miopia em crianças sob tratamento óptico. Córneas mais planas associaram-se a maior progressão da miopia, apoiando a inclusão de parâmetros queratométricos na avaliação inicial de crianças com miopia.

INTRODUCTION

Myopia has emerged as a major global public health issue, with rapidly increasing prevalence among children and adolescents. In 2020, approximately 37% of the European population was affected, and projections estimate this number will rise to 56% by 2050.[1,2] The prevalence is particularly high in urban areas of East Asia, where myopia rates can reach as high as 80% among older adolescents and young adults in major metropolitan areas.[3] This growing incidence has been largely attributed to environmental and behavioral factors, particularly prolonged near-work and reduced outdoor activity.[4]

Beyond its refractive implications, myopia represents a significant cause of irreversible visual impairment, being associated with increased risk of retinal detachment, choroidal neovascularization, glaucoma, cataract, and myopic macular degeneration.[5,6] Consequently, myopia control has become a central focus in ophthalmic research and clinical practice.

Evidence-based strategies to control myopia progression include optical and pharmacological approaches. Among the optical options, defocus-correcting spectacle and contact lenses have shown promising results in reducing myopia progression.[7-9] While the underlying mechanisms remain under investigation, these lenses are thought to modulate retinal defocus and influence ocular growth.

In addition to treatment modalities, identifying predictive biomarkers of myopia progression is crucial for early intervention. Although axial length (AL) has been traditionally regarded as the primary indicator of progression, corneal parameters such as mean keratometry and corneal curvature have also been explored as potential contributors.[10,11] However, most existing studies are cross-sectional, assessing associations at a single point in time rather than over the course of disease evolution.

This study aims to evaluate the influence of keratometric and biometric parameters on myopia progression in children and adolescents treated with defocus-correcting spectacles or contact lenses. By assessing longitudinal changes in these parameters, we sought to determine whether keratometry could serve as a clinically relevant biomarker alongside AL in predicting myopia progression.

METHODS

This was a retrospective study conducted using anonymized clinical data from patients previously treated at the *Unidade Local de Saúde Almada-Seixal*, Portugal. According to the regulations of the Ethics Committee of the *Unidade Local de Saúde Almada-Seixal*, formal ethical approval was not required for retrospective studies using anonymized data. The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent had been obtained from all patients (or their legal guardians) at the time of their original clinical treatment for the use of anonymized data in research and publication.

Study design and subjects

Retrospective study including myopic children older than 4 years-old and younger than 18-year-old treated in *Hospital Garcia de Orta* with defocus-correcting spectacles or contact lenses. The dataset corresponds to the period between March 2021 and August 2024. The inclusion criteria for the subjects were as follows: age greater than 4 years and less than 18 years; treatment with defocus-correcting spectacles or contact lenses for at least 12 months; ability of parents to provide informed consent. Exclusion criteria were previous or concomitant pharmacological treatment for myopia; other sight-threatening diseases; ocular or systemic diseases strongly associated with AL variations (e.g. Marfan syndrome); clinical and tomographic suspicion of corneal ectasia given by Belin/Ambrosio enhanced ectasia display-Deviation (BAD-D) value higher than 1.2; previous significant ocular trauma or previous ocular surgery.

Examination

Objective refraction was obtained by retinoscopy after full cycloplegia (three instillations of cyclopentolate 1%, five minutes apart). Autorefraction was performed with Canon RK-F2 autorefractor to confirm retinoscopy findings. The Zeiss IOLMaster 700 was used to measure biometric and keratometric parameters (AL, K1, K2 and Mean keratometry). Spherical equivalent (SE) was calculated as sphere plus half cylinder. Data were collected at baseline and at a 12-month appointment. Data from both eyes of each subject were included for statistical purposes.

Statistical analysis

Data variation was calculated between the 12-month and baseline evaluations. Clinically significant myopia progression was defined as an increase in sphere of ≥ -0.5 diopters/year or an increase in AL of > 0.2 mm/year. Patients' demographics were compared via Chi-squared test. Pearson correlation analysis was performed to evaluate correlations between spherical error and biometric data. Statistical

analyses were performed with SPSS software and $p < 0.05$ was considered to indicate statistical significance.

RESULTS

The final sample included 47 children (94 eyes) with mean age of 11.55 ± 2.66 years (5 to 17 years). Of these, 32 were treated with MiYOSMART® (HOYA) spectacle lenses, 10 with Stellest™ (Essilor®) spectacle lenses, and 5 with MiSight 1 day (CooperVision) contact lenses. A sphere increase of > -0.5 diopters/year was observed in 24 eyes (25.53%). Clinically significant myopia progression was observed in 37 eyes (39.36%). Demographic data and treatment options are presented in table 1. Regarding treatment choices, no statistically significant difference was found between groups.

Table 1. Baseline demographic characteristics of participants

Baseline characteristic	Progression Group	No Progression Group	Full sample	p-value
Gender				0.054
Female	12 (32.43)	30 (52.63)	42 (44.68)	
Male	25 (67.57)	27 (47.37)	52 (55.32)	
Treatment choice				0.157
Spectacle lenses	31 (83.78)	53 (92.98)	84 (89.36)	
Contact lenses	6 (16.22)	4 (7.02)	10 (10.64)	

* $p < 0.05$.
Results expressed as n (%).

The overall mean baseline AL was 24.77 ± 1.21 mm. The mean baseline AL in the Progression Group was higher than in the no Progression Group (25.16 ± 1.42 mm *versus* 24.52 ± 0.98 mm; $p < 0.05$). The mean baseline keratometry (Mean keratometry) was lower in the Progression Group when compared to no Progression Group (43.44 ± 1.58 *versus* 44.14 ± 1.35; $p < 0.05$). Collected data was analyzed and ectasia suspicion was ruled out for all cases. Full sample's descriptive analysis of biometric and keratometric parameters is presented in table 2. Group descriptive analysis of baseline biometric and keratometric parameters is presented in table 3.

Table 2. Full sample descriptive analysis of biometric and keratometric parameters

	M	SD	Minimum	Maximum
Age, years	11.55	2.66	5.00	17.00
K1, D	43.27	1.43	39.38	45.80
K2, D	44.46	1.61	41.05	49.31
Km, D	43.87	1.48	40.22	47.38
Ast, D	1.18	0.71	0.25	3.86
AL, mm	24.77	1.21	22.87	28.34
Δ AL, mm	0.14	0.26	-0.92	1.58
Δ Sph, D	-0.16	0.71	-3.00	1.50

M: mean; SD: standard deviation; Km: mean keratometry (baseline); Ast: astigmatism (baseline); AL: axial length (baseline); Δ AL: axial length variation; Δ Sph: spherical variation.

Table 3. Group descriptive analysis of baseline biometric and keratometric parameters

	Group	n	Mean	SD	p-value
Age	0	57	11.58	0.35	0.908
	1	37	11.51	0.44	
Km	0	57	44.14	1.35	0.024*
	1	37	43.44	1.58	
AL	0	57	24.52	0.98	0.011*
	1	37	25.16	1.42	
Ast	0	57	1.15	0.74	0.317
	1	37	1.24	0.66	

*$p < 0.05$.
Group 0: No Progression Group; Group 1: Progression Group; SD: standard deviation; AL: axial length; Ast: astigmatism.

A significant positive correlation was found between mean keratometry and spherical variation ($r = 0.343$; $p < 0.001$). A significant negative correlation was found between AL and spherical variation ($r = -0.252$; $p < 0.05$) and between baseline mean keratometry and baseline AL ($r = -0.665$; $p < 0.001$). Table 4 presents correlation analyses between spherical variation, biometric and keratometric data. A multivariable regression confirmed an independent association between baseline AL and myopia progression.

Table 4. Correlation analyses between spherical variation, axial length variation and biometric and keratometric parameters

	Pearson's r	p-value
Δ Sph - Km	0.343*	< 0.001
Δ Sph - Ast	0.031	0.766
Δ Sph - AL	-0.252†	0.014
Δ AL - Km	-0.111	0.286
Δ AL - Ast	0.068	0.515
Δ AL - AL	-0.043	0.678
Km - Ast	0.256†	0.013
Km - AL	-0.665*	< 0.001
Ast - AL	0.131	0.209

* $p < 0.05$; † $p < 0.001$; ‡ $p < 0.01$.
Δ Sph: sphere variation; Δ AL: axial length variation; Km: mean keratometry (baseline); Ast: astigmatism (baseline); AL: axial length (baseline).

DISCUSSION

Myopia is a complex visual condition that occurs when the optical power of the eye is too strong for its AL, causing light rays to focus in front of the retina. This imbalance may result from excessive axial elongation (axial myopia) – the most common mechanism – or from increased curvature of the cornea or crystalline lens, leading to what is termed refractive myopia.[12,13] Rather than being a simple refractive error, myopia is now recognized as a multifactorial disorder involving structural, biomechanical, and environmental determinants.[3,4]

Its global prevalence has risen dramatically over recent decades and continues to accelerate: by 2050, nearly half of the world's population is projected to be myopic.[8] This trend is driven by a combination of genetic

susceptibility and environmental influences, such as reduced outdoor exposure and increased near-work activity.[1,3] Beyond its optical implications, myopia is associated with a higher lifetime risk of sight-threatening complications, including retinal detachment, myopic maculopathy, choroidal neovascularization, glaucoma, and cataract.[5,14] The socioeconomic burden of these sequelae is considerable, particularly as onset occurs at increasingly younger ages and progression tends to be faster during childhood.[15] Consequently, understanding the biological mechanisms and structural contributors to myopia progression has become a critical step toward preventing long-term visual morbidity.

Although myopia begins as a refractive mismatch, it often evolves into a structural and progressive disorder involving pathological remodeling of ocular tissues. Progressive axial elongation leads to stretching and thinning of the sclera, choroid, and retina, resulting in irreversible morphological alterations.[14,16] The posterior pole of the eye, in particular, undergoes mechanical stress that may predispose to complications such as posterior staphyloma, lacquer cracks, and myopic maculopathy.[17] This continuous structural change differentiates pathologic or progressive myopia from simple myopia and underscores its classification as a disease entity rather than merely a refractive condition.[12,13]

The process of axial elongation appears to be regulated by complex feedback mechanisms involving the retina, retinal pigment epithelium, choroid, and sclera. Experimental models have shown that retinal defocus can trigger molecular pathways that alter scleral extracellular matrix remodeling and influence ocular growth rate.[18,19] These findings provide a biological rationale for the use of interventions that modulate peripheral defocus, aiming to counteract the stimuli that promote excessive axial elongation. Understanding these mechanisms is crucial for developing predictive markers of progression and identifying patients at highest risk for long-term structural damage.

Given the increasing prevalence and early onset of myopia, several evidence-based interventions have been developed to limit its progression. Current strategies include optical, pharmacological, and behavioral approaches, each targeting different aspects of ocular growth regulation.[7] Among optical methods, peripheral defocus-modifying lenses – such as Defocus Incorporated Multiple Segments (DIMS) and highly aspherical lenslets (HAL) spectacle designs – have demonstrated efficacy in slowing myopia progression by approximately 50 to 60% compared with single-vision corrections.[8,9] Similarly, orthokeratology lenses, that work by temporarily reshaping the cornea, also induce peripheral myopic defocus that modulates axial elongation.[20]

Pharmacological approaches, particularly low-dose atropine (0.01 to 0.05%), have also shown consistent benefit in reducing progression rates and axial growth.[21,22] However, due to potential side effects and the need for long-term compliance, optical treatments remain the mainstay in many clinical settings. The underlying mechanism common to these therapies relies on altering the retinal defocus profile, reducing hyperopic defocus on the peripheral retina and thus attenuating the stimuli that promote ocular elongation.[18]

In our study, all participants were treated with spectacle or contact lenses specifically designed for myopia control, based on the principle of peripheral defocus correction. Spectacle lenses included MiYOSMART® and Stellest™ designs, both incorporating aspherical or multiple-segment lenslets to create peripheral myopic defocus. The contact lens group consisted of patients fitted with MiSight 1 *day* (CooperVision), a dual-focus daily disposable lens approved for pediatric myopia management. Consistent with previously published data, we observed no statistically significant difference in myopia progression between the two treatment modalities, suggesting that both designs provide comparable efficacy when appropriately fitted and monitored.[9,8,23,24]

The role of ocular biometric parameters in myopia development and progression has been the focus of extensive research. Among these, AL is widely recognized as the most robust and consistent biomarker of myopia progression, reflecting the structural elongation of the globe.[15,16] However, other anterior segment parameters – particularly keratometric values (K1, K2, mean keratometry) and corneal astigmatism – have also been investigated as potential contributors or modulators of refractive status.[10,11]

While the association between steeper corneas and higher myopic refractive errors is well established, this relationship is largely attributed to refractive myopia, in which corneal power plays a dominant optical role.[25] However, most of the existing literature exploring correlations between myopia and corneal parameters is based on cross-sectional analyses, capturing static associations rather than assessing longitudinal changes linked to disease progression. This approach overlooks the potential to identify corneal and biometric configurations that may predispose to faster axial elongation or act as early markers

of progression risk. Furthermore, few studies have evaluated these associations in children undergoing optical treatments for myopia control.

Given this background, our study sought to explore whether baseline keratometric and biometric parameters could serve as predictors of myopia progression in children and adolescents treated with defocus-correcting lenses.

In the present study, both axial AL and mean keratometry demonstrated significant associations with myopia progression over the 12-month follow-up. Children in the Progression Group presented longer baseline AL and flatter corneas compared with those who remained stable, and these parameters were independently correlated with spherical variation. The multivariable regression analysis demonstrated an independent association between both AL and mean keratometry and myopia, suggesting that flatter corneas and greater ocular length at baseline may predispose to faster myopic progression, even under optical treatment.

It should be noted that the progression and No Progression Groups were not fully balanced at baseline, with differences in refractive status and AL, including the presence of eyes with ALs compatible with high myopia. Although this baseline imbalance should be considered when interpreting the results, it is also consistent with previous evidence showing that greater AL and higher degrees of myopia are associated with an increased likelihood of future progression.

The lower keratometric values observed in the Progression Group should also be interpreted in light of the strong inverse relationship between corneal curvature and AL. Since eyes with longer ALs tend to present flatter corneas, part of the observed association between keratometry and progression may reflect baseline biometric differences rather than an independent effect of corneal curvature.

These findings reinforce the established understanding that axial elongation is the principal driver of myopia progression,[15,16] but also indicate that corneal curvature may bring additional information about individual susceptibility. Clinically, this suggests that keratometric assessment should not be overlooked in baseline evaluations of children at risk of progression. Flatter corneas may be associated with a structural configuration more prone to axial elongation, either due to inherent biomechanical properties of the cornea and sclera or as part of a broader pattern of ocular remodeling. Identifying such profiles could help refine risk stratification and guide more personalized monitoring and treatment strategies.

The relationship between ocular growth and refractive development is governed by a complex interaction between genetically programmed mechanisms and visually guided feedback processes. During normal eye growth, the cornea and crystalline lens follow intrinsic developmental trajectories largely determined by genetic and biochemical factors, maintaining proportional scaling and optical balance.[26,27] In contrast, axial elongation of the posterior segment is more strongly influenced by retinal and choroidal signaling pathways that respond to visual stimuli and defocus cues.[28] When the emmetropization process is disrupted—whether by environmental or optical factors—retinal feedback mechanisms promote scleral remodeling and increased axial growth to restore image focus on the retina.[18]

Our findings suggest that flatter corneas may identify eyes with a higher propensity for continued axial elongation, possibly reflecting an imbalance between anterior segment development and posterior segment expansion. From a biomechanical perspective, a flatter cornea could indicate a more compliant ocular shell or altered corneoscleral rigidity, both of which may facilitate elongation under defocus-driven stimuli.[29,30] This interpretation aligns with the hypothesis that corneal geometry and biomechanics are not merely passive optical contributors but active indicators of global ocular growth dynamics.

From a clinical perspective, our findings highlight the potential value of integrating keratometric parameters with AL in the evaluation and monitoring of myopic children. Although AL remains the most reliable indicator of progression, baseline corneal curvature may provide complementary information regarding the structural susceptibility to ocular elongation. Incorporating keratometric analysis into routine myopia assessment could therefore enhance the early identification of patients at greater risk for progression, facilitating timely and individualized intervention strategies.

Future prospective studies and randomized clinical trials are needed to determine whether keratometric parameters have true predictive value and whether specific corneal profiles are associated with differential responses to myopia-control interventions.

LIMITATIONS

The present study has several limitations that warrant acknowledgment. Its retrospective design, relatively small sample size, and one-year follow-up period may limit the generalizability of the findings. Additionally, subtle changes in keratometry may have been below

the detection threshold of the instrumentation used. Baseline differences in AL and refractive status between groups may have influenced progression rates. In addition, the inclusion of eyes with very long ALs, compatible with high myopia, may have introduced heterogeneity into the sample. Therefore, the observed associations should be interpreted with caution. Longitudinal, multicentric trials with standardized measurement protocols are needed to confirm these associations and explore the causal dynamics between corneal biomechanics and axial elongation.

CONCLUSION

Our study suggests an association between baseline keratometric parameters, axial length, and myopia progression in children undergoing optical myopia control. Consistent with prior evidence, a positive correlation between higher axial length and increased myopia progression was found, even in patients undergoing lens treatment. Furthermore, our findings suggest that flatter corneas may be associated with an increased risk of myopia progression, supporting the consideration of keratometric parameters alongside axial length during clinical evaluation. These results challenge the previously established paradigm that myopia progression is solely dependent on axial length, suggesting that keratometry could play a crucial role in deciding the timing and aggressiveness of myopia treatment.

DISCLOSURES

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The authors used ChatGPT 5 to assist with language refinement. All content was checked and approved by the authors.

Authors' contribution

IM: Conceptualization, Data curation, Formal analysis, Writing – original draft, Visualization, Writing – review & editing, Project administration. MV: Investigation, Data curation. GT: Investigation, Data curation. AMC: Methodology, Writing – review & editing, Resources. AS: Methodology, Writing – review & editing, Resources. JHM: Formal analysis, Visualization. TL: Conceptualization, Methodology, Writing – review & editing, Supervision. NC: Methodology, Supervision, Resources. AVE: Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, Resources, Validation.

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