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Peripheral refraction and myopia progression after 36 months of orthokeratology wear in schoolchildren

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Background: Orthokeratology (Ortho-K) effectively slows axial elongation in myopic eyes, but its long-term effects on peripheral refraction (PR) and its relationship with myopia progression remains unclear.

Aim: This study aimed to determine the changes in PR and myopia progression over 36 months of Ortho-K wear in children.

Setting: This is a prospective cohort study.

Methods: Twenty-nine myopic children aged 8–9 years old were enrolled in this study. Ortho-K lenses were prescribed, and analyses were conducted at baseline, 12, and 36 months (M). Assessments included axial length (AL) and cycloplegic refraction at central and peripheral (30°N, 20°N, 10°N, 10°T, 20°T, and 30°T). Intraocular pressure (IOP), corneal thickness and endothelial morphology were monitored throughout the study. Data were analysed using repeated-measures ANOVA or the Friedman test, with Bonferroni correction; $p < 0.05$ was considered significant.

Results: Relative peripheral refraction (RPR) shifted from baseline hyperopic to myopic defocus at 12M at 30°N, 20°N, 20°T, and 30°T ($p < 0.01$). A further significant myopic shift was observed at 20°N after 12M, but no correlation with AL growth. Axial length decreased significantly in the first year (−0.16 ± 0.04 mm, $p = 0.003$), then elongated slowly thereafter (0.24 ± 0.08 mm in the next 24M, $p = 0.02$). Best corrected visual acuity remained stable, and no significant changes in ocular health parameters or complications were observed.

Conclusion: Wearing Ortho-K lenses for 36 months slowed down axial elongation and sustained peripheral myopic defocus without compromising ocular health. Regular IOP and corneal health monitoring are recommended to ensure stable ocular physiology during long-term Ortho-K wear.

Contribution: This study provides evidence on the effectiveness and ocular physiological responses of long-term wearing of Ortho-K lenses in children.

Keywords: orthokeratology; peripheral refraction; axial length; myopia progression; ocular health.

Introduction

Myopia is a growing public health concern worldwide, as higher degrees of myopia significantly increase the risk of sight-threatening complications, including myopic maculopathy, and its comorbidities, retinal detachment, glaucoma, and cataract, which collectively contribute to substantial socioeconomic burdens.[1] The rising prevalence is especially concerning in children, as early-onset myopia is associated with a higher risk of developing high myopia.[2,3]

Myopia progresses with excessive axial length (AL) elongation, where the eye grows disproportionately long relative to its optical power, causing light to focus in front of the retina. Myopic eyes typically exhibit relative peripheral hyperopia, where peripheral light focuses behind the retina, potentially stimulating further axial growth.[4,5] As such, peripheral refraction (PR) has become a key parameter in understanding myopia progression and evaluating interventions.

Orthokeratology (Ortho-K), involving overnight wear of reverse-geometry rigid contact lenses, effectively slows myopia progression by 40% – 60% compared to single-vision spectacles or soft

contact lenses.[6] It reshapes the cornea by flattening the centre and steepening the mid-periphery, resulting in the induction of relative peripheral myopia, shifting the peripheral focus in front of the retina.[7] This myopic defocus is believed to counteract relative peripheral hyperopia and reduce the stimulus for axial elongation, aligning with evidence from animal studies.[5]

Previous clinical studies have consistently shown that Ortho-K induces a relative myopic shift in PR across horizontal meridians, with the magnitude of the shift increasing towards the periphery.[8,9,10,11,12] These peripheral optical changes occur within the first few weeks of lens wear and remain generally stable during continued treatment, where current evidence is limited up to 18 months.[8,12] A recent systematic review by Queirós et al.[13] further summarised findings from studies with treatment durations of up to 1 year, reporting greater peripheral myopic blur with longer wear compared to shorter periods of less than 3 months.

Longitudinal data on PR, AL, and visual outcomes together can elucidate how Ortho-K lenses modulate ocular growth over time. Despite the clinical need for sustained intervention, given that myopia progression typically continues throughout adolescence, current evidence remains limited by a predominance of short-term studies,[8,9,10,11,12] offering a limited understanding of the persistence of peripheral optical changes and their relationship with long-term myopia control. Besides, ocular health monitoring (intraocular pressure, endothelial health, corneal thickness) remains important for long-term contact lens wear, although most studies report Ortho-K to be safe when managed properly.[14]

This prospective study was motivated by the need to address these knowledge gaps and provide evidence on the long-term effects of Ortho-K in myopic children. We aimed to evaluate PR and AL changes after 36 months of Ortho-K wear in schoolchildren and assess their ocular physiological responses. Understanding these long-term effects is crucial for optimising Ortho-K as a myopia control option and incorporating it into clinical practice.

Research methods and design

Study design

This prospective longitudinal study was conducted at the Optometry Clinic, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Kuala Lumpur Campus. It forms part of the myopia control study using Ortho-K lenses in Kuala Lumpur. A total of 29 myopic children who had completed the initial 12-month study were invited to participate in this 36-month follow-up. All measurements were taken at baseline 12 and 36 months. According to previous literature, a clinically meaningful effect in myopia control was considered to be an AL change of < 0.18 mm/year or a SER shift of < 0.50 D/year.[15] Sample size calculation was conducted using G*power software (version 3.1.9.4). A repeated-measures ANOVA (within-subject factors) with a significance level of 0.05 determined that a minimum of seven subjects would be needed to achieve 90% power to detect a 0.18 mm (standard deviation [s.d.] 0.26)[16] (equivalent to a change of 0.50 D in refraction)[15] difference in axial measurement. Taking into account a 20% dropout rate, the required sample size was adjusted to a minimum of nine subjects for this study.

This study included children aged 8–9 years old, with spherical equivalent refraction (SER) ranging from −0.75 D to −4.00 D, astigmatism less than −1.50 DC, and best corrected log of the minimal angle of resolution (logMAR) visual acuity (VA) of 0.0 or better in each eye at baseline. None of the participants had received prior myopia control treatment, and all were free from ocular or systemic abnormalities. Participants were instructed to wear the Ortho-K lenses for a minimum of 8 h during sleep. Participation was voluntary, and the lenses were provided at no cost.

Orthokeratology lens

Menicon Z Night Ortho-K lenses (Menicon Co., Ltd., Japan) made of Tisilfocon A material were used in this study. The lenses have an oxygen permeability (Dk) of 163×10^{-11} (cm^2/s) [mL O_2/mL · mmHg] and an overall diameter of 10.60 mm. Each lens employed a four-curve reverse-geometry design comprising a base curve (optical zone diameter: 6.0 mm), reverse curve, alignment curve, and peripheral curve, which together reshaped the cornea to achieve the intended refractive correction. Lens parameters (base optical zone radius [BOZR]: 7.20 mm – 10.10 mm) were individually designed based on each subject's corneal topography and refractive error, incorporating a Jessen factor of +0.50 D to ensure full correction and optimal lens centration during overnight wear.

Visual acuity

Distance VA was assessed using the Early Treatment Diabetic Retinopathy Study (ETDRS) chart, placed on an illuminated cabinet at a distance of 4 m. The VA score was determined by the smallest line of letters the subjects could accurately read, with each letter corresponding to a score of 0.02 logMAR.

Central and peripheral refraction

Before measurements, a topical anaesthetic (0.5% proxymetacaine hydrochloride, Alcaine, Alcon) was administered, followed by cycloplegia induced with two drops of 1% cyclopentolate hydrochloride (Cyclogel™, Alcon, Geneva, Switzerland) applied at 5-min intervals. Autorefraction in primary gaze and at peripheral eccentricities was measured using a WAM-5500 autorefractor (Grand Seiko Co., Ltd., Hiroshima, Japan) once the pupil diameter exceeded 5 mm. Subjects were instructed to stabilise their heads in a forward-facing position, while rotating their eyes to fixate on high-contrast letter targets (6/12 or 0.3 logMAR) mounted on a wall at a distance of 4 m. The targets were positioned at 10° intervals across the central ± 30° horizontal

eccentricities, covering both nasal and temporal visual fields (VF). The findings were documented as VF eccentricities, with the nasal VF corresponding to the temporal retina and the temporal VF corresponding to the nasal retina. For each eye, the contralateral eye was occluded during testing. Five consistent measurements were taken at each eccentricity, and the mean value was calculated. Refractive error data were recorded in terms of sphere (S), cylinder (C), and axis (θ). Both on-axis and PR were calculated as spherical equivalent refractive error, computed as spherical power plus half the cylindrical power. Relative peripheral refraction was computed as eccentric SER minus on-axis SER.

Ocular biometry

Axial length was measured using applanation A-scan biometry (PacScan Plus, Sonomed Escalon, NY, United States), which automatically captured the mean of five measurements with a s.d. of <0.10 mm.

Corneal endothelial morphology and intraocular pressure

The measurements of endothelial cell density (ECD), hexagonality (HEX), coefficient of variation (COV), and central corneal thickness (CCT) were conducted using a non-contact specular microscope (SP-3000P, Topcon, Japan). The three best-captured images were then directly transferred to the computer using IMAGEnet™ 2000 digital imaging system software (Topcon Inc., Tokyo, Japan) for subsequent analysis. Intraocular pressure (IOP) was assessed using a non-contact tonometer (Topcon CT-80, Topcon Corporation, Tokyo, Japan), with the average value calculated from three consecutive readings.

Statistical analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS version 24), IBM, USA. All data were reported as mean ± s.d. Only data for the right eye were included in this study. Normality was assessed for all variables. For normally distributed data, parametric tests were used: one-way repeated-measures analysis of variance (RM-ANOVA) was performed to evaluate the differences in the baseline, 12 months, and 36 months data, with Mauchly's test of sphericity applied. If sphericity was violated ($p < 0.05$), the Huynh-Feldt correction was used; otherwise, the standard ANOVA *F*-test assuming sphericity was applied. Significant results ($p < 0.05$) were followed by Bonferroni-corrected pairwise comparisons. An independent *t*-test was used to compare the difference in subgroups (moderate vs. low myopia). For non-normally distributed data, non-parametric tests were used: the Friedman test assessed differences across each time point, followed by the Wilcoxon Signed Rank test with Bonferroni correction for pairwise comparisons; the Chi-square test was used to evaluate categorical data; and Mann-Whitney *U* tests compared the difference between subgroups. Correlations were assessed using Spearman's rho correlation. Statistical significance was defined as $p < 0.05$, while a Bonferroni-adjusted $p < 0.025$ was applied for multiple comparisons.

Ethical considerations

This study was approved by the Institutional Review Board at a public university in Malaysia and adhered to the Tenets of the Declaration of Helsinki. Before enrolment, subjects and their parents were thoroughly informed about the research project. Written informed consent was obtained from the parents.

Ethical clearance to conduct this study was obtained from the Universiti Kebangsaan Malaysia Research Ethics Committee (No. UKM PPI/111/8/JEP-2023-441).

Results

Subject demographics

A total of 29 subjects were included in the study. The baseline demographics were presented in Table 1. The mean age of subjects was 8.41 ± 0.50 years. The average baseline SER was −2.98 ± 1.06 D, and the baseline AL was 23.76 ± 0.74 mm.

Change in myopia progression

A comparison across the three visits revealed significant changes in AL ($F_{1.353, 37.882} = 5.081$, $p = 0.021$, $\eta^2_p = 0.15$) and SER ($F_{1.119, 31.332} = 224.186$, $p < 0.001$, $\eta^2_p = 0.89$) over time (Table 2). AL decreased by 0.16 ± 0.04 mm from baseline to 12 months ($p = 0.003$) but increased by 0.24 ± 0.08 mm from 12 to 36 months ($p = 0.02$), resulting in no significant net change from baseline to 36 months. Significant changes in SER were observed from −2.98 ± 1.06 D at baseline to −0.13 ± 0.16 D at 12 months ($p < 0.001$), with no significant change from 12 to 36 months (−0.20 ± 0.24 D, $p = 0.523$). A statistically significant inverse correlation was observed between changes in AL and SER ($r = -0.439$, $p = 0.017$).

Changes in peripheral refraction

The central and PR for each timeline was shown in Figure 1. While comparing data from the three visits, significant changes were observed in 30°N ($F_{1.277, 35.761} = 20.31$, $p < 0.001$, $\eta^2_p = 0.42$), 20°N ($F_{1.221, 34.178} = 73.395$, $p < 0.001$, $\eta^2_p = 0.72$), 10°N ($F_{1.111, 31.095} = 134.622$, $p < 0.001$, $\eta^2_p = 0.83$), 10°T ($F_{1.313, 36.759} = 149.496$, $p < 0.001$, $\eta^2_p = 0.85$), 20°T ($F_{1.412, 39.549} = 67.977$, $p < 0.001$, $\eta^2_p = 0.71$) and 30°T ($F_{1.262, 35.333} = 10.165$, $p = 0.002$, $\eta^2_p = 0.27$) over time (Table 2). Peripheral refraction became significantly more myopic in all eccentricities from baseline to 12 months ($p < 0.006$). From 12 to 36 months, only PR at 10°N and 20°N showed a significant myopic shift ($p < 0.001$). However, PR at either phase was not correlated with the change in AL during every follow-up period ($p > 0.05$).

Changes in relative peripheral refraction

The RPR for each timeline was presented in Figure 2. Significant changes were detected at 30°N ($F_{1.11, 31.066} = 57.734$,

$p < 0.001$, $\eta^2_p = 0.67$), 20°N ($F_{1.121, 31.387} = 15.011$, $p < 0.001$, $\eta^2_p = 0.35$), 20°T ($F_{1.205, 33.741} = 15.183$, $p < 0.001$, $\eta^2_p = 0.35$), and 30°T ($F_{1.151, 32.218} = 36.203$, $p < 0.001$, $\eta^2_p = 0.56$) across the three visits (Table 2). At baseline, RPR was significantly hyperopic at greater eccentricities (20° and 30°) in both nasal and temporal VFs. By the 12-month follow-up, a significant myopic shift in RPR was observed at these same eccentricities. From 12 to 36 months, only RPR at 20°N showed a significant myopic shift ($p = 0.002$), but no correlation was found with AL changes ($p = 0.063$). In contrast, RPR changes at 30°N ($r = 0.423$, $p = 0.022$) and 10°T ($r = 0.388$, $p = 0.038$) between 12 and 36 months showed significant correlations with AL progression. No other RPR locations or time points demonstrated this relationship with AL changes ($p > 0.05$).

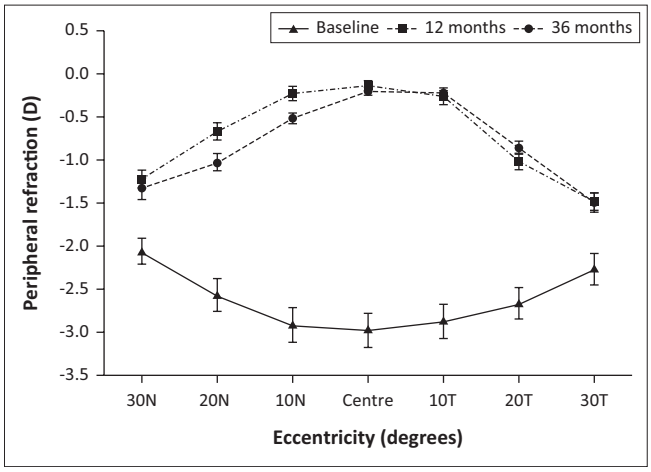
TABLE 1: Baseline demographic data of participants who completed 36 months of Ortho-K wear ($N = 29$).

Parameter	Eccentricity	Variable
Age (years)	-	8.41 ± 0.50
Gender		
Male	-	13
Female	-	16
Cycloplegic spherical equivalent (D)	-	-2.98 ± 1.06
Best corrected VA (logMAR)	-	-0.01 ± 0.06
Cornea curvature FK (D)	-	43.59 ± 1.30
Axial length (mm)	-	23.76 ± 0.74
Peripheral refraction (D)	N30	-2.06 ± 0.82
	N20	-2.57 ± 1.01
	N10	-2.92 ± 1.06
	T10	-2.88 ± 1.09
	T20	-2.67 ± 0.96
	T30	-2.27 ± 0.95
Intraocular pressure (mmHg)	-	14.90 ± 1.52
Central corneal thickness (μm)	-	526.93 ± 22.47
Endothelial cell density (cells/mm²)	-	3295.90 ± 224.76
Hexagonal cell percentage (%)	-	60.81 ± 10.45
Coefficient of variation (%)	-	37.72 ± 8.61

Note: Parameters are given as mean ± standard deviation.

Relationship between baseline spherical equivalent refraction and change in relative peripheral refraction

The baseline SER showed positive correlation with the change in RPR from baseline to 12 months ($p < 0.001$),



Note: Data are presented as mean with error bars representing the standard error (s.e.).

FIGURE 1: Peripheral refraction in the horizontal visual field.

TABLE 2: Ocular parameters over 36 months wearing Ortho-K lenses ($N = 29$).

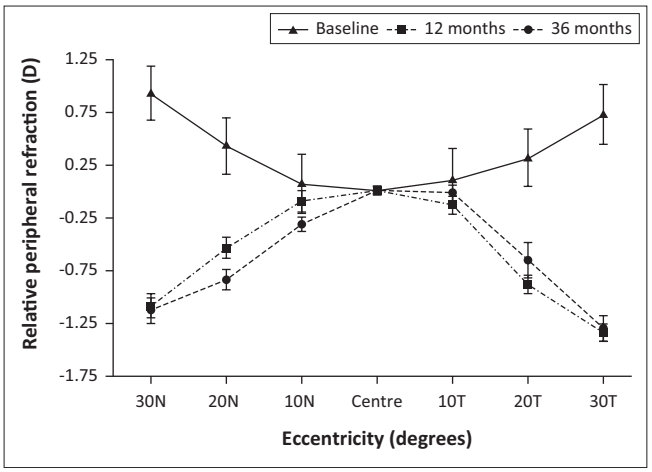
Parameter	Baseline	12 months	36 months	*p*-value
SER (D)	-2.98 ± 1.06†	-0.13 ± 0.16	-0.20 ± 0.24§	0.001
BCVA (logMAR)	-0.01 ± 0.06	-0.02 ± 0.07	0.00 ± 0.04	0.253
FK (D)	43.59 ± 1.30†	40.76 ± 1.59	40.39 ± 1.21§	< 0.001
AL (mm)	23.76 ± 0.74†	23.60 ± 0.57	23.84 ± 0.71§	0.021
IOP (mmHg)	14.90 ± 1.52	14.76 ± 1.38	14.97 ± 1.52	0.290
CCT (μm)	526.93 ± 22.47	522.21 ± 22.02	523.52 ± 21.64	0.080
ECD (cells/mm²)	3295.90 ± 224.76	3268.63 ± 229.57	3271.76 ± 223.92	0.325
HEX (%)	60.81 ± 10.45	60.48 ± 10.59	59.48 ± 11.95	0.420
COV (%)	37.72 ± 8.61	37.83 ± 8.62	39.43 ± 9.97	0.069
Peripheral refraction				
PR-30N	-2.06 ± 0.82	-1.22 ± 0.59	-1.33 ± 0.67	< 0.001
PR-20N	-2.57 ± 1.01	-0.67 ± 0.52	-1.03 ± 0.50	< 0.001
PR-10N	-2.92 ± 1.06	-0.23 ± 0.44	-0.52 ± 0.32	< 0.001
PR-10T	-2.88 ± 1.09	-0.27 ± 0.47	-0.22 ± 0.33	< 0.001¶
PR-20T	-2.67 ± 0.96	-1.02 ± 0.50	-0.86 ± 0.45	< 0.001
PR-30T	-2.27 ± 0.95	-1.48 ± 0.55	-1.50 ± 0.61	0.002
Relative peripheral refraction				
RPR-30N	0.92 ± 1.35†	-1.09 ± 0.59	-1.14 ± 0.64§	< 0.001
RPR-20N	0.42 ± 1.48†	-0.54 ± 0.54‡	-1.84 ± 0.52§	< 0.001
RPR-10N	0.06 ± 1.51	-0.10 ± 0.53	-0.32 ± 0.37	0.273
RPR-10T	0.10 ± 1.61	-0.14 ± 0.48	-0.02 ± 0.39	0.402¶
RPR-20T	0.31 ± 1.45†	-0.89 ± 0.51	-0.66 ± 0.48§	< 0.001
RPR-30T	0.72 ± 1.52†	-1.35 ± 0.56	-1.30 ± 0.64§	< 0.001

Note: All data are presented as mean ± standard deviation.

SER, spherical equivalent refraction; BCVA, best corrected visual acuity; FK, flat keratometry; AL, axial length; IOP, intraocular pressure; CCT, central corneal thickness; ECD, endothelial cell density; HEX, hexagonal cell percentage; COV, coefficient of variation; PR, peripheral refraction; RPR, relative peripheral refraction; N, nasal visual field; T, temporal visual field.

†, Significant difference between baseline and 12 months; ‡, Significant difference between 12 months and 36 months; §, Significant difference between baseline and 36 months; ¶, Statistical analysis performed using Friedman test, while other parameters using RM-ANOVA.

but not from 12 to 36 months ($p > 0.05$) (summarised in Table 3). The subjects were further divided into low myopia (SER < −3.00 D, $n = 14$) and moderate myopia (SER ≥ −3.00 D, $n = 15$) groups based on baseline SER. Independent *t*-tests showed that the moderate myopia group (−2.04 ± 0.50 D) had significantly more hyperopic baseline RPR than the low myopia group (−3.86 ± 0.55 D) across all eccentricities ($p < 0.001$). No significant differences in RPR were found at 12 and 36 months ($p > 0.05$). Significant between-group differences were observed in all RPR changes from baseline to 12 months, but not during the 12-to-36-month follow-up (Table 4).



Note: Data are presented as mean with error bars representing the standard error (s.e.).

FIGURE 2: Relative peripheral refraction in the horizontal visual field.

TABLE 4: Comparisons of groups based on baseline spherical equivalent refraction.

Variables	Low myopia ($n = 14$)	Moderate myopia ($n = 15$)	*t*	*p*-value
Baseline				
RPR-30N	-0.13 ± 1.02	1.90 ± 0.73	-6.195	< 0.001
RPR-20N	-0.64 ± 1.19	1.40 ± 0.94	-5.148	< 0.001
RPR-10N	-1.03 ± 1.21	1.08 ± 0.93	-5.294	< 0.001
RPR-10T	-1.05 ± 1.25	1.18 ± 1.08	-5.147	< 0.001
RPR-20T	-0.80 ± 1.07	1.34 ± 0.95	-5.816	< 0.001
RPR-30T	-0.50 ± 1.11	1.85 ± 0.79	-6.625	< 0.001
12 months				
RPR-30N	-1.16 ± 0.44†	-1.02 ± 0.71†	-0.666	0.511
RPR-20N	-0.50 ± 0.51†	-0.58 ± 0.58†	0.394	0.697
RPR-10N	-0.23 ± 0.34†	0.03 ± 0.65†	-1.391	0.178
RPR-10T	-0.08 ± 0.49†	-0.21 ± 0.47†	-0.300§	0.764‡
RPR-20T	-1.03 ± 0.60†	-0.76 ± 0.39†	-1.477	0.151
RPR-30T	-1.34 ± 0.52†	-1.36 ± 0.62†	0.084	0.934
36 months				
RPR-30N	-1.14 ± 0.49	-1.13 ± 0.78	-0.050	0.960
RPR-20N	-0.85 ± 0.47	-0.82 ± 0.57	-0.164	0.871
RPR-10N	-0.31 ± 0.39	-0.33 ± 0.36	0.162	0.873
RPR-10T	-0.06 ± 0.37	0.02 ± 0.43	-0.542	0.592
RPR-20T	-0.70 ± 0.54	-0.62 ± 0.43	-0.426	0.673
RPR-30T	-1.19 ± 0.76	-1.41 ± 0.51	0.902	0.375

Note: All data are presented as mean ± standard deviation.

SER, spherical equivalent refraction; RPR, relative peripheral refraction; N, nasal visual field; T, temporal visual field.

†, Significant difference between baseline and 12 months; ‡, Statistical analysis performed using the Mann–Whitney *U* test, while other parameters using an independent *t*-test; §, *z*.

TABLE 3: Correlation between baseline spherical equivalent refraction and change in relative peripheral refraction at different time points.

Eccentricities (degree)	Baseline to 12 months		12–36 months	
	r	*p*-value	*r*	*p*-value
30N	0.77	< 0.001†	0.19	0.335
20N	0.70	< 0.001†	-0.02	0.912
10N	0.55	0.002†	0.31	0.098
10T	0.73	< 0.001†	-0.08	0.693
20T	0.66	< 0.001†	0.09	0.658
30T	0.70	< 0.001†	0.11	0.561

SER, spherical equivalent refraction; RPR, relative peripheral refraction; N, nasal visual field; T, temporal visual field.

†, Significant when using Spearman's rho correlation.

Change in corneal endothelial morphology and intraocular pressure

Change in corneal endothelial morphology and IOP are presented in Table 2. Over 36 months of Ortho-K wear, all ocular health parameters remained stable, with no significant changes observed in ECD, HEX, COV, CCT, and IOP ($p > 0.05$). There were also no significant changes in BCVA ($p = 0.253$), indicating good visual quality was maintained (logMAR 0.00 equivalent to 6/6) throughout 36 months of Ortho-K wear.

Discussion

This study provides insights into the longitudinal effects of Ortho-K on PR and axial growth in myopic children over 3 years. Our findings demonstrate that Ortho-K treatment well controls myopia while reshaping the eye's refractive profile without compromising ocular health.

The significant SER reduction with a notable 0.16 ± 0.04 mm decrease in AL was observed at 12 months, which is consistent with prior studies.[16,17,18] This reduction is possibly attributed to central corneal thinning caused by epithelial tissue redistribution upon reaching full correction, along with choroidal thickening resulting from a reduction in myogenic stimulus to eye growth.[16,19,20] From 12 to 36 months, AL increased gradually by 0.24 ± 0.08 mm (annualised rate of 0.12 mm/year), reflecting post-adaptation ocular growth. Previous long-term studies report stable myopia progression with Ortho-K wear (0.16 mm/year – 0.26 mm/year),[21,22,23,24] although Santodomingo-Rubido et al.[25] observed more pronounced treatment effects: initial rates of 0.22 mm and 0.20 mm in the first 2 years, slowing to just 0.49mm over the next 5 years (approximately 0.098 mm/year). Our findings align with this favourable outcome, demonstrating well-controlled myopia progression that also mirrors physiological emmetropic growth (0.12 mm/year – 0.17 mm/year in ages 8–11).[26] The near-emmetropic growth pattern highlights Ortho-K's ability to maintain long-term control of axial elongation.

Baseline SER was significantly correlated with RPR changes from baseline to 12 months, consistent with the principle that initial central refractive error influences peripheral myopic shifts as the Ortho-K lenses reshape the cornea.[7,11,27]

Subgroup analysis revealed that moderate myopes (SER ≥ −3.00 D) exhibited more hyperopic baseline RPR than low myopes (SER < −3.00 D) across all eccentricities,[28] leading to significantly larger myopic RPR shifts during the first 12 months. By 12 months of Ortho-K wear, RPR stabilised across both groups, suggesting that Ortho-K treatment leads to a uniform peripheral refractive profile regardless of initial myopia severity.[29]

Significant myopic shifts in RPR at higher eccentricities (20° – 30° nasal and temporal) were observed from baseline to 12 and 36 months ($p < 0.001$) consistent with prior studies.[8,11,12] The further myopic shift at 20°N from 12 to 36 months is novel and may be attributed to the orbit's pyramidal anatomy, which favours temporal over nasal expansion,[4] or asymmetric corneal reshaping influenced by temporal decentration of the lens.[30,31] During the follow-up visit, we observed that a majority of subjects exhibited slight temporal lens decentration, which could result from underlying anatomical factors such as corneal toricity and eyelid tension.[31,32,33] This decentration was thought to bring the pupil closer to the treatment zone's edge, steepen the mid-peripheral nasal cornea, and thereby amplify myopic defocus in nasal RPR.[30] Several studies have demonstrated that lens decentration may contribute to reduced AL elongation.[34,35,36] Despite this, 20°N RPR changes in our study showed no correlation with AL progression, suggesting that this location may not directly influence eye growth.

In contrast, RPR changes at 30°N ($r = 0.423$, $p = 0.022$) and 10°T ($r = 0.388$, $p = 0.038$) from 12 to 36 months correlated significantly with AL progression ($p < 0.05$), suggesting that longitudinal PR dynamics at these locations are particularly influential in the myopia progression of slow-progressing myopes. Similar correlations were reported by Chen et al.,[9] who found that changes in RPR at 30°N and 30°T after 3 months of Ortho-K wear correlated with AL elongation ($r = 0.565$ and 0.526, respectively, $p < 0.05$). The stronger correlation on the nasal RPR potentially reflects nasal-temporal asymmetry in peripheral defocus. Our findings extend this to a longer timeframe (12–36 months), highlighting the sustained role of peripheral myopic defocus at 30°N in modulating AL growth. The 10°T correlation is less commonly reported, possibly reflecting unique retinal or corneal responses in our cohort. More data are needed to confirm these findings.

The underlying ocular shape also influences peripheral optics. In untreated emmetropic eyes, the retina typically has an oblate configuration, yielding peripheral myopic defocus, whereas myopic eyes tend to exhibit a less oblate (more prolate) shape, resulting in hyperopic PR.[4,37] Under normal conditions, RPR is a surrogate for posterior eye shape.[38] During Ortho-K treatment, direct imaging of ocular shape is often impractical in typical optometric settings; thus, repeated PR serves as a convenient and accessible proxy. Recent MRI-based studies demonstrated that Ortho-K gradually makes the eye more oblate: children wearing Ortho-K for 12 months showed a greater increase in peripheral eye length (PEL) than AL, with PEL significantly correlated with PR changes, indicating PR may partly reflect posterior eye shape remodelling.[11] Additionally, Low et al.[39] found a negative correlation between AL and relative PEL across all eccentricities, suggesting that Ortho-K may alter the eye to an increasingly oblate globe with peripheral myopic defocus. While peripheral defocus is largely attributed to anterior corneal changes, these findings imply that posterior ocular shape also adapts in response to Ortho-K.

With the changes in PR observed in our study, Ortho-K is hypothesised to induce long-term changes in ocular shape, potentially influencing posterior eye geometry while maintaining the same intraocular volume. These alterations necessitate careful monitoring of IOP to ensure ocular health. IOP plays a vital role in monitoring the structural integrity of the eye, and fluctuations in IOP can pose risks to optic nerve health.[40] Over the 3 years, our study observed no significant fluctuations in IOP, consistent with earlier findings,[41] and reinforcing the safety profile of Ortho-K lens wear.

Regarding corneal endothelial morphology, our findings align with prior research indicating no significant changes in ECD, HEX, or COV. A 2-year study in children found no differences in these parameters between Ortho-K and spectacle wearers, suggesting minimal impact from high oxygen-permeable (high-Dk) lenses.[42] This is corroborated by a systematic review of 170 publications, which found no long-term endothelial damage with high-Dk Ortho-K lenses, with complications limited to manageable issues such as corneal staining.[14] Central corneal thickness exhibited the expected early thinning because of epithelial redistribution, but stabilised thereafter. A study on corneal biomechanics confirmed that these changes do not compromise corneal integrity, as they are reversible and stabilise over time.[43,44]

Limitations of the study

While this study provides longitudinal Ortho-K data, several limitations must be acknowledged. A control group was not included, which limits the interpretation of treatment efficacy in comparison to the natural progression of myopia and to outcomes achieved with other correction modalities. However, the within-subjects design offers long-term evidence of treatment-related changes. Future studies incorporating control cohorts could strengthen comparative interpretation. In addition, PR was measured only along the horizontal meridian. While this approach is supported by existing literature, as horizontal PR shows more consistent refractive patterns and a stronger association with myopia progression,[45,46] future research may benefit from incorporating multi-meridian measurements to provide a more comprehensive peripheral profile.

Conclusion

Wearing Menicon Z Night Ortho-K lenses for 36 months slowed axial elongation and induced sustained myopic defocus without compromising ocular health. These findings support the continued use of Ortho-K as a safe and effective modality for long-term myopia management. While the changes in RPR may primarily be attributed to central refractive correction, the resulting peripheral myopic defocus in specific retinal regions likely plays a key role in controlling myopia progression.

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Competing interests

The author reported that they received funding from Menicon Co. Ltd. (Japan), which may be affected by the research reported in the enclosed publication. The author has disclosed those interests fully and has implemented an approved plan for managing any potential conflicts arising from their involvement. The terms of these funding arrangements have been reviewed and approved by the affiliated university in accordance with its policy on objectivity in research.

CRediT authorship contribution

Yi Lin Ong: Conceptualisation, Data curation, Formal analysis, Methodology, Visualisation, Writing – original draft. Bariah Mohd-Ali: Conceptualisation, Funding acquisition, Project administration, Supervision, Writing – review & editing. Yu Chen Low: Data curation, Investigation, Methodology, Supervision. Mizhanim Mohamad Shahimin: Formal analysis, Writing – review & editing. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication, and take responsibility for the integrity of its findings.

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Data availability

The datasets generated and analysed during this study are available from the corresponding author, Bariah Mohd-Ali, upon reasonable request and with appropriate institutional approvals.

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