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ORIGINAL RESEARCH

Influence of Astigmatism Type on Myopia Progression Among Children Wearing Defocus Incorporated Multiple Segments (DIMS) Spectacle Lenses

Jenna M Hoogendoorn[1], Rakhee Shah[2], Laurentius J Van Rijn[3], Natalia Vlasak[4]

[1]Vrije Universiteit Amsterdam, Amsterdam, the Netherlands; [2]Optometry & Visual Sciences, City St George's, University of London, London, EC1V 0HB, UK; [3]Department of Ophthalmology, Amsterdam UMC and Department of Ophthalmology, OLVG Amsterdam, Amsterdam, the Netherlands; [4]HOYA Vision Care, Amsterdam, the Netherlands

Correspondence: Jenna M Hoogendoorn, Vrije Universiteit Amsterdam, De Boelelaan, Amsterdam, 1105 HV, the Netherlands,
Email jennahoogendoorn@gmail.com

Purpose: This study aimed to retrospectively analyse two datasets to investigate the correlation between progressive myopia and astigmatism focusing on the influence of the type of astigmatism on myopia progression in children undergoing myopia management with Defocus Incorporated Multiple Segments (DIMS) spectacle lenses.

Patients and Methods: Retrospective right eye data from two anonymised datasets were obtained for analysis: an Asian paediatric population, and a Caucasian paediatric population. Participants' refractive error at baseline was classified into one of four categories: spherical, with-the-rule (WTR), oblique or against-the-rule (ATR) astigmatism. Myopia progression was evaluated by the change in Spherical Equivalent Refraction (SER) and Axial Length (AL) between baseline and follow-up visits.

Results: Retrospective analyses were conducted on right eye data from 265 children (160 Asian & 105 Caucasian). Linear Mixed Models (LMM) analysis of the combined datasets ($n = 184$) demonstrated a statistically significant main effect of astigmatism type on longitudinal patterns on SER change ($p < 0.001$), interaction between time and astigmatism was not significant ($p = 0.07$). In contrast, the LMM resulted in no statistically significant main effect of the astigmatism types on AL change ($p = 0.06$). The interaction term between time and astigmatism type also did not reveal a statistically significant effect on AL change ($p = 0.21$). This indicates that the trajectory of myopia progression over time was comparable across all groups despite initial differences at baseline. Analyses revealed that WTR-astigmatism was associated with the least myopia progression and ATR-astigmatism was associated with the greatest progression in this study. The presence of astigmatism at baseline did not significantly affect myopia progression in children wearing DIMS spectacles.

Conclusion: The type of astigmatism affected myopia progression. Participants with WTR-astigmatism wearing DIMS spectacles showed less myopia progression compared to participants with oblique or ATR-astigmatism. Long-term investigations in participants with different types of astigmatism undergoing myopia management are required to better understand the relationship between progressive myopia and astigmatism type.

Keywords: astigmatism, myopia progression, myopia management, DIMS spectacles

Introduction

Myopia is an increasing problem worldwide. The current estimation is that in 2050 approximately 50% of the world population will be myopic.[1]

Myopia or near-sightedness primarily occurs due to excessive increase in the axial length (AL) in childhood resulting in blurred distance vision due to the light rays and image focussing in front of the retina. The prevalence of myopia has increased at an alarming rate[2] over recent decades with progression continuing into the late teenage years[3] likely due to

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changes in lifestyle – increased time on near activities and decreased time outdoors. A spherical equivalent refraction (SER) of more than −6.00 dioptres (D) and an axial length (AL) of more than 26 mm is considered as high myopia; SER from −3.25D to −6.00D as moderate myopia and SER of −0.50D to −3.00D as low myopia.[4] High myopia is associated with an increased risk of ocular complications.[5]

In astigmatism, the cornea or lens is curved more steeply in one direction, resulting in a stronger refraction in one meridian and weaker in the orthogonal meridian.[6,7] Hence, astigmatism occurs when parallel rays of light focus at focal lines perpendicular to one another rather than a single focal point resulting in blurred or distorted vision at all distances. Astigmatism can be sub-classified into three different types: With-the rule (WTR), Oblique and Against-the-rule (ATR), depending on the direction of the orthogonal meridian.

Myopia is a complex ocular condition with a multifactorial aetiology hence the specific onset and mechanism of myopia progression is not yet fully understood. However, evidence supports the defocus-theory which proposes that peripheral hyperopic defocus can cause axial elongation as the eye grows towards the plane of defocus.[8,9] The orientation of astigmatism creates non-uniform patterns of defocus on the retina, which also act as a signal for the eye growth during the emmetropisation process.[10]

Progressive myopia is hereditary, and children of myopic parents tend to have longer eyeballs, increasing their risk of developing myopia.[11,12] Besides the heritable factors, multiple environmental factors affect myopia progression. Some examples of these environmental factors include outdoor light, residential environment and near-working activities.[8] Excessively short working distances, for instance, results in the eye accommodating for a prolonged period creating a defocus point behind the retina resulting in an elongation of the eyeball. Additionally, research shows that Asian countries have a higher myopia prevalence compared to European countries.[13] Living in an urban rather than rural environment is also associated with an increased risk of myopia.[14] African American, Hispanic and Asian children had a higher risk for astigmatism than other racial/ethnic groups.[15] Evidence suggests that exposure to outdoor light may be protective against myopia development.[16,17]

Myopia management research has focused on developing strategies such as pharmacological, optical and light-based treatments to slow down myopia progression. One example of spectacle lens interventions is the Defocus Incorporated Multiple Segments (DIMS) spectacle lenses, which have been shown to produce a significant reduction in myopia progression.[18,19] DIMS spectacles have the myopes distance spherical correction, incorporated into defocus-free central zone. This central clear zone is surrounded by a treatment zone with multiple segments having a relative positive power (+3.50D) arranged in a honeycomb pattern. The small plus lenses in the treatment zone are arranged on the surface of the DIMS spectacle lenses and are respectively smaller than the pupil, resulting in incoming light being refracted solely by the single-vision zone or by the multiple lenses simultaneously. Therefore, this design simultaneously introduces myopic defocus and provides clear vision for the wearer at all viewing distances.[20,21] This lens design enables the correction of the myopia whilst reducing myopia progression. Research shows significant reduction of myopia progression in children who use DIMS spectacle lenses or atropine or combination therapy compared to conventional single-vision lenses.[18,22,23]

The evidence regarding the correlation between myopic eye growth, myopia progression and astigmatism is scarce and controversial with some animal studies concluding that astigmatism may degrade the eye's ability to emmetropise, while some studies propose astigmatism may in fact help facilitate emmetropisation.[24–26] One human study highlighted that higher myopia was associated with higher magnitude of astigmatism[15] and other research studies indicated greater astigmatic progression being associated with myopia.[27–29] There is conflicting evidence on whether there is a link between the prevalence of myopia and the magnitude of astigmatism. This study investigates the association between myopia progression and astigmatism with a particular emphasis on the influence of the types of astigmatism (WTR, oblique, or ATR) on myopia progression in children wearing DIMS spectacles.

Materials and Methods

Participants

This study retrospectively analysed anonymised data from two separate independent paediatric datasets: one from an Asian population and one from a Caucasian population.

The Asian dataset comprised 160 children aged 8–13 years (*M* = 10.13; *SD* = 1.46), who completed the two-year randomized controlled DIMS spectacle lens trial.[18] Eligibility criteria included: cycloplegic SER between −1.00D and −5.00D and both anisometropia and astigmatism ≤1.50D. The AL ranged between 21.87 mm and 26.47 mm (*M* = 24.66; *SD* = 0.82). Participants were randomised to either the DIMS spectacle lens group (*n* = 79) or single vision (SV) lens group (*n* = 81). Data collection and eye examinations were conducted at the Centre of myopia research at The Hong Kong Polytechnic University in Hong Kong.

The Caucasian dataset consisted of 105 children aged 5–16 years (*M* = 10.22; *SD* = 2.25) who have completed the DIMS UK observational study.[19] Eligibility criteria included: cycloplegic SER of −0.50D to −8.50D, anisometropia ≤ 1.50D and astigmatism ≤ 2.50D. The AL ranged between 21.84 mm and 27.30 mm (*M* = 24.60; *SD* = 0.93). Data collection and eye examinations were conducted at multiple sites in the United Kingdom.

The intervention group of the Asian dataset and the Caucasian dataset were combined and analysis included 184 participants aged 5–16 years (*M* = 10.21; *SD* = 1.95). The baseline SER ranged from −7.43D to −0.50D (*M* = −3.04; *SD* = 1.37) and baseline AL from 21.84 mm to 27.30 mm (*M* = 24.64; *SD* = 0.88).

Classification

Previous analysis reported no significant interocular differences,[18,19] hence only the right eye data of children were included. Retrospective data for both datasets included age, gender and baseline astigmatism. Clinically significant astigmatism was defined as a cylinder power ≤−0.50D. Both datasets provided longitudinal measurements of AL and SER at baseline, 6-, 12-, 18- and 24-month follow-up periods. Myopia progression was quantified as a change in SER and AL relative to baseline. SER was calculated by adding the spherical component (S) with half of the cylinder component (C); SER = S + ½ C.[30]

Participants were classified into astigmatism types based on their baseline refractive measurements. With-the-rule astigmatism was defined as a steeper vertical meridian compared to the horizontal meridian requiring a concave cylinder correction at 180 ± 20° or a convex cylinder correction at 90 ± 20°.[31] Against-the-rule astigmatism was defined as a steeper horizontal meridian requiring convex cylindrical correction at 180 ± 20°or a concave cylindrical correction at 90 ± 20°. Oblique astigmatism was defined when the principal meridians were at any other angle.

Data Analysis

Statistical analyses were conducted using SPSS for Windows (version 28; IBM Corp., Armonk, NY, USA). Analyses were performed separately for each dataset and on the combined dataset. For the Asian analysis, a 2 × 2 factorial ANOVA was conducted with astigmatism presence and intervention as factors to assess the effect of the presence of astigmatism on SER and AL change at the 24-month follow-up period. For the Caucasian analysis, the effect of the presence of astigmatism on myopia progression was assessed using an independent *t*-test, with the SER and AL change at the 24-month follow-up period as the dependent variable. For the combined analysis, only participants within the intervention groups of both datasets were included. A 2 × 2 factorial ANOVA was conducted with astigmatism presence and dataset as factors to assess the effect of the presence of astigmatism on both SER and AL change at the 24-month follow-up period. Participants with clinically significant astigmatism were assigned to the astigmatic group, whereas those without were assigned to the spherical group. Two-tailed tests were employed to evaluate group differences, and p-values <0.05 were taken to be statistically significant.

To examine the influence of astigmatism type on myopia progression, a linear mixed models (LMM) conducted, using SER and AL changes across all follow-up periods as dependent variables. Baseline SER and AL measurements were included in the model as a continuous covariate to correct for the initial differences between the astigmatism types. The dataset was included as a fixed factor in the combined analysis to control for differences between the Asian and Caucasian. Additionally, type of astigmatism and follow-up period were included as fixed factors. The interaction term time*astigmatism type was used to examine whether the astigmatism types differed in myopia progression. The analysis of the Asian dataset included intervention as a fixed factor. The model also included the interaction term follow-up period*intervention and type of astigmatism*intervention to test the effects differed between the intervention and control participants. A random intercept for each participant was included to account for the repeated measures within the participants.

All models were estimated using maximum likelihood estimation and an AR(1) covariance structure for the repeated factor follow-up period. The LMM framework allowed for the inclusion of participants with incomplete follow-up data under the assumption that data were missing at random. No imputation of missing values was performed.

Bonferroni-adjusted post-hoc pairwise comparisons were used to examine mean differences between the different astigmatism groups.

Results

This study investigated right eye data of 265 children, age 5–16 years (M = 10.16; SD = 1.81). Baseline demographic data of all participants of the different analyses was shown in Table 1. Within the Asian dataset 43 participants (26.9%) were classified as spherical and 117 participants (73.1%) were astigmatic. Seventy-nine participants were prescribed DIMS spectacles (intervention group) and 81 participants were prescribed standard single vision spectacle lenses (control group). In the Caucasian dataset, 32 participants (30.5%) were classified as spherical and 73 participants (69.5%) were astigmatic. All Caucasian participants were prescribed DIMS spectacles. The combined dataset comprised 184 participants who wore DIMS spectacles; the intervention group of the Asian dataset (n = 79) combined with the Caucasian dataset (n = 105). Both datasets were further classified by astigmatism type displayed in Figure 1.

Analysis of the Asian Dataset

A 2 × 2 factorial ANOVA showed a significant main effect of the intervention on SER change at the 24-month follow-up period, $F(1, 156) = 8{,}61$, $p < 0.001$. Additionally, the main effect of astigmatism was approaching significance, $F(1, 156) = 1.16$, $p = 0.05$, indicating that participants with astigmatism showed different myopia progression compared to participants with spherical myopia. The interaction between the intervention and the presence of astigmatism was not significant $F(1, 156) = 0.17$, $p = 0.46$, suggesting that the effect of the intervention with DIMS spectacles was similar regardless of the presence of astigmatism.

Similarly, a 2 × 2 factorial ANOVA was conducted to examine the effect of the presence of astigmatism on AL change at the 24-month follow-up period. A significant main effect of the intervention on AL change at the 24-month follow-up period was also found, $F(1, 156) = 57.10$, $p < 0.001$. There was no significant main effect of astigmatism, $F(1, 156) =$

Table 1 A Table of Baseline Demographic Data of All Participants Included in the Analyses

Subjects	**Mean ± SD**		
	Asian Dataset (n = 160)	**Caucasian Dataset (n = 105)**	**Combined Datasets (n = 184)**
Age	10.13 ± 1.46	10.22 ± 2.25	10.21 ± 1.95
Gender			
Male, % (n)	56.3 (90)	44.8 (47)	50.5 (93)
Female, % (n)	43.8 (70)	55.2 (58)	49.5 (91)
Intervention			
SV, % (n)	50.6 (81)	0.0 (0)	0.0 (0)
DIMS, % (n)	49.4 (79)	100 (105)	100 (184)
Cycloplegic autorefraction in SER (D)	−2.87 ± 0.96	−3.09 ± 1.61	−3.04 ± 1.37
Axial length (mm)	24.66 ± 0.82	24.60 ± 0.93	24.64 ± 0.88

Note: Values are expressed as mean ± standard deviation (SD).
Abbreviation: SV, Single Vision; DIMS, Defocus Incorporated Multiple Segments; SER, Spherical Equivalent Refraction.

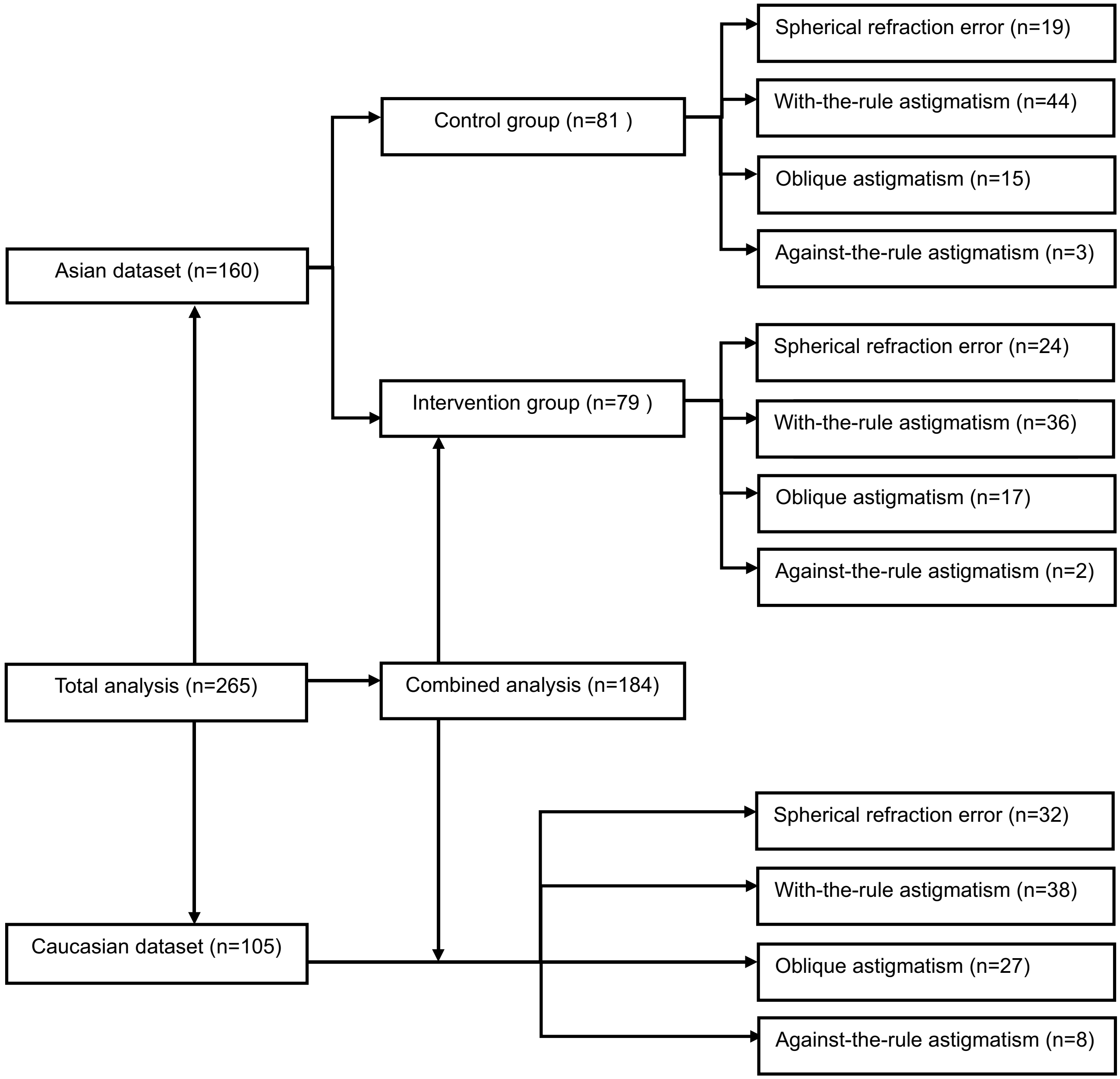

Figure 1 A flowchart presenting the different groups and subgroups. Both Asian and Caucasian children were subclassified into four categories based on their refractive error.

1.53, $p = 0.22$. The interaction between the intervention and the presence of astigmatism was not significant, $F(1, 156) = 0.24$, $p = 0.62$, indicating that the effect of the intervention with DIMS spectacles did not differ between participants with spherical myopia and with astigmatism.

LMM analysis revealed no statistically significant main effect of the astigmatism type on both SER ($F(3, 163.86) = 1.85$, $p = 0.14$) and AL ($F(3, 165.71) = 1.57$, $p = 0.20$) progression across follow-up visits. Baseline measurements show no influence on the progression for both SER change ($p = 0.20$) and AL change ($p = 0.07$). Additionally, the astigmatism type*time interaction was not statistically significant for either the SER ($F(9, 299.60) = 0.92$, $p = 0.93$) or AL ($F(9, 469.40) = 0.79$, $p = 0.62$) change, indicating no evidence that astigmatism type influenced progression trajectories over time. The time*intervention interaction was also not statistically significant for both the SER ($F(3, 299.60) = 0.18$, $p = 0.91$) and AL ($F(3, 469.40) = 1.13$, $p = 0.34$) change, suggesting intervention effects on myopia progression.

At 24 months, the WTR-astigmatism group exhibited the least SER progression in the control group ($M = -0.86$; $SD = 0.62$) and intervention group ($M = -0.23$; $SD = 0.40$) whereas participants with ATR-astigmatism demonstrated the greatest SER progression in the control group ($M = -1.31$; $SD = 0.32$) and intervention group ($M = -0.44$; $SD = 0.98$). Post-hoc Bonferroni-adjusted comparisons only confirmed statistically significant differences in SER change between the WTR and ATR-astigmatism group ($p = 0.02$), and the ATR and oblique group ($p = 0.03$). The WTR-astigmatism group and spherical group approached significance ($p = 0.05$). No statistically significant group differences were detected for AL progression, although the result approached significance (WTR-ATR; $p = 0.05$).

Analysis of the Caucasian Dataset

The independent *t*-test showed no significant difference in SER progression at 24 months between the astigmatic ($M = -0.58$; $SD = 0.54$) and spherical groups ($M = -0.55$; $SD = 0.61$), $t(103) = 0.26$, $p = 0.79$, $d = 0.05$. Similarly, AL progression did not differ significantly at 24 months ($M = 0.29$; $SD = 0.27$ vs. $M = 0.31$; $SD = 0.30$ respectively), $t(103) = 0.28$, $p = 0.79$, $d = 0.07$. For both analyses, Levene's test confirmed equality of variances ($p = 0.28$ and $p = 0.34$; SER and AL change respectively).

The LMM revealed no statistically significant main effect of astigmatism type on SER change $F(3, 115.56) = 0.70$, $p = 0.56$. Nevertheless, the LMM revealed no statistically significant main effect of astigmatism type on AL change $F(3, 111.08) = 0.48$, $p = 0.70$. Baseline measurements showed no statistically significant influence on AL ($p = 0.05$) and SER change ($p = 0.26$). Analyses of the interaction term astigmatism type*follow-up period showed no significant outcome (SER; $p = 0.16$, AL; $p = 0.86$). However, visual inspection of the descriptive data indicated that the WTR-astigmatism group ($M = 0.26$; $SD = 0.30$) exhibited the least change in AL elongation whereas the ATR-astigmatism group ($M = 0.36$; $SD = 0.27$) showed the greatest progression, compared to the spherical ($M = 0.31$; $SD = 0.30$) and oblique ($M = 0.31$; $SD = 0.24$) groups. The analysis of the SER progression was inconclusive.

Combined Dataset Analysis

To examine the influence of astigmatism on myopia progression in children wearing DIMS spectacle lenses, the Asian control group participants fitted with single-vision lenses (n = 81) were excluded.

To investigate the influence of the presence of astigmatism on myopia progression, a factorial ANOVA including the presence of astigmatism and the effect of the dataset at the 24-month follow-up period, was conducted. A comparison of the mean change in SER and AL across multiple follow-up periods for the spherical and astigmatic groups is shown in Table 2. The analysis of the SER change at the 24-month follow-up period revealed no significant difference between the datasets ($p = 0.14$) suggesting no influence of ethnicity. Additionally, the ANOVA revealed no significant effect of the presence of astigmatism on SER change at the 24-month follow-up period $F(1, 180) = 1{,}80$, $p = 0.18$.

Table 2 A Table Comparing the Mean Change in SER and AL for the Spherical and Astigmatic Groups of the Combined Data Set Across Multiple Follow-Up Periods

Follow-up		n	Mean SER (D)		Mean SER Change (D)		*p*
			Spherical	Astigmatism	Spherical	Astigmatism	
SER (D)	Baseline	184	−2.64 ± 1.17	−3.17 ± 1.40			0.02*
	6 month	183	−2.86 ± 1.22	−3.35 ± 1.47	−0.22 ± 0.26	−0.18 ± 0.30	0.39
	12 month	182	−2.96 ± 1.34	−3.41 ± 1.45	−0.32 ± 0.41	−0.24 ± 0.47	0.27
	18 month	178	−3.13 ± 1.35	−3.55 ± 1.46	−0.48 ± 0.51	−0.37 ± 0.51	0.20
	24 month	184	−3.20 ± 1.44	−3.63 ± 1.45	−0.56 ± 0.59	−0.46 ± 0.54	0.35

(*Continued*)

Table 2 (Continued).

			Mean AL (mm)		Mean AL change (mm)		*p*
			Spherical	Astigmatism	Spherical	Astigmatism	
AL (mm)	Baseline	184	24.54 ± 0.85	24.68 ± 0.90			0.52
	6 month	183	24.60 ± 0.83	24.74 ± 0.89	0.05 ± 0.17	0.06 ± 0.10	0.31
	12 month	182	24.69 ± 0.86	24.83 ± 0.89	0.14 ± 0.20	0.14 ± 0.18	1.00
	18 month	178	24.76 ± 0.86	24.84 ± 0.84	0.21 ± 0.24	0.20 ± 0.23	0.66
	24 month	184	24.84 ± 0.85	24.93 ± 0.87	0.28 ± 0.28	0.25 ± 0.25	0.41

Notes: Values are expressed as mean ± standard deviation (SD). *p*-values reflect a comparison of baseline measurements and myopia progression between the spherical and astigmatism group. $^{*}p < 0.05$.
Abbreviations: SER, Spherical Equivalent Refraction; AL, Axial Length.

Table 3 Baseline Measurements of the Spherical and Astigmatism Subtypes

Type of Astigmatism	n	Mean	
		SER (D)	AL (mm)
Spherical	75	−2.57 ± 1.08	24.55 ± 0.90
WTR	118	−3.22 ± 1.24	24.75 ± 0.82
Oblique	59	−2.98 ± 1.38	24.56 ± 0.93
ATR	13	−2.71 ± 1.45	24.49 ± 0.79

Notes: Values are expressed as mean ± standard deviation (SD).
Abbreviations: SER, Spherical Equivalent Refraction; AL, Axial Length; WTR, With-the-rule astigmatism; ATR, Against-the-rule astigmatism.

When comparing the astigmatic and spherical group participants, neither the presence of astigmatism ($F(1, 180) = 1.11$, $p = 0.30$) nor ethnicity ($F(1, 180) = 3.06$, $p = 0.08$) showed statistically significant differences in AL change at the 24-month follow-up period.

Baseline measurements of the spherical group and astigmatism subtypes are shown in Table 3. LMM analyses were conducted to investigate the effect of astigmatism type, on myopia progression measured by SER and AL change, as shown in Tables 4 and 5.

Descriptive analyses indicated that WTR participants experienced the least SER and AL progression, while ATR participants exhibited the most (Figure 2).

Post-hoc Bonferroni adjusted comparisons revealed statistically significant differences in SER progression between the WTR-astigmatism and spherical groups and between the WTR and oblique astigmatism groups ($p = 0.01$ for both), but not between the WTR and ATR groups ($p = 0.07$). For AL progression, the WTR-astigmatism group differed significantly from both the oblique and ATR-astigmatism groups ($p = 0.01$), but not from the spherical group ($p = 0.20$). Other pairwise comparisons were not statistically significant ($p \geq 0.05$).

Discussion

This retrospective study investigated the relationship between progressive myopia and astigmatism focussing on how different astigmatism types may influence myopia progression in a paediatric population undergoing myopia management with DIMS spectacles. While previous research has examined whether the presence of astigmatism affects myopia progression, relatively few studies have explored the role of astigmatism type on myopia progression. Our findings demonstrate that the presence of astigmatism does not significantly influence myopia progression. However, the type of

Table 4 LMM Analysis Results of the Combined Datasets of the Effect of Astigmatism Types on SER Change

Effect	Numerator df	df	*F*	*p*
Intercept	1	185.20	23.06	<0.001*
Type of astigmatism	3	185.28	7.70	<0.001*
Follow-up	3	351.27	5.01	0.00*
Astigmatism type*follow-up	9	351.66	1.81	0.07
Baseline SER	1	185.19	4.96	0.03*
Dataset	1	185.20	4.89	0.03*
Astigmatism type*dataset	3	185.28	1.74	0.16

Notes: n = 184. AR(1) covariance structure with maximum likelihood estimation. $^*p < 0.05$.
Abbreviation: SER, Spherical Equivalent Refraction.

Table 5 LMM Analysis Results of the Combined Datasets of the Effect of Astigmatism Types on AL Change

Effect	Numerator df	df	*F*	*p*
Intercept	1	193.36	3.31	0.07
Type of astigmatism	3	193.54	2.50	0.06
Follow-up	3	534.78	0.99	0.40
Astigmatism type*follow-up	9	534.91	1.35	0.21
Baseline AL (mm)	1	193.36	3.18	0.08
Dataset	1	193.36	2.24	0.14
Type of astigmatism*dataset	3	193.54	2.23	0.09

Note: n = 184. AR(1) covariance structure with maximum likelihood estimation.
Abbreviation: AL, Axial Length.

astigmatism does appear to influence progression rates. Although all astigmatism types followed broadly similar progression trajectories over time, children with with-the-rule (WTR) astigmatism demonstrated the least myopia progression, while those with against-the-rule (ATR) astigmatism showed the greatest progression.

Most of the existing literature addresses the relationship between the presence of astigmatism and myopia progression without distinguishing between the astigmatism subtypes.[15,27,32–34] The limited literature specifically examining astigmatism type and myopia progression made result interpretation challenging and hindered consensus on the relationship between astigmatism type and myopia progression. Previous studies reported higher prevalence of WTR-astigmatism in younger children,[35–40] a finding supported by the present work in which WTR-astigmatism was the predominant type in both the Caucasian and Asian cohorts. Additionally, the observed difference in myopia progression between ethnic groups aligns with existing literature.[36]

The absence of a significant association between baseline astigmatism and progression in our study is consistent with the findings of Chan et al (2018), who reported no meaningful effect of clinically significant astigmatism on the axial elongation.[35] Interestingly, children with purely spherical myopia progressed more rapidly than those with astigmatism in both spherical equivalent refraction (SER) and axial length (AL) despite also presenting with lower baseline myopia. Although this was not statistically substantiated, this may suggest that spherical myopes, despite initially being less myopic, exhibit faster progression compared to their astigmatic peers. However, contradictory evidence exists. Heidary

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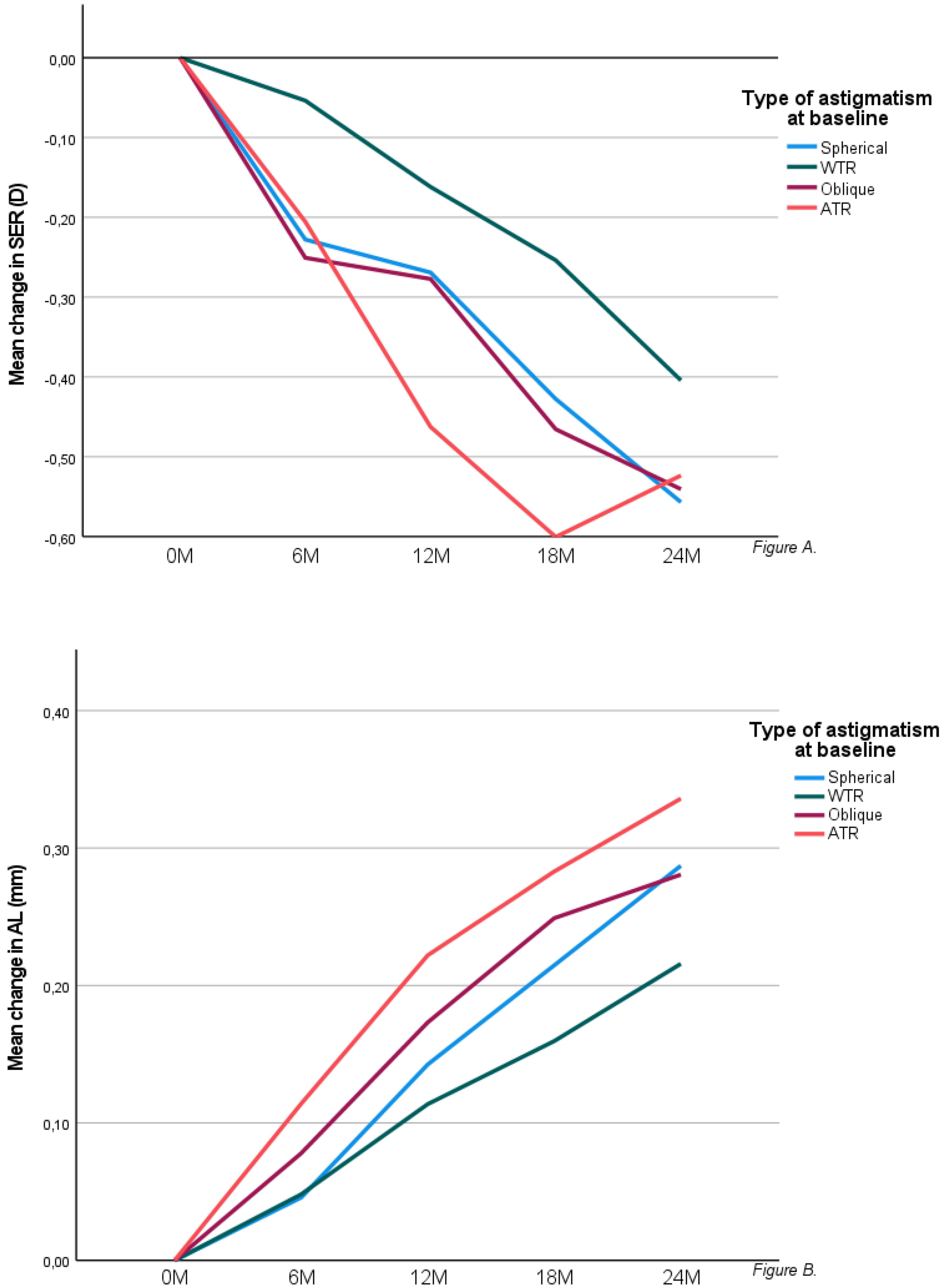

Figure 2 Mean change in SER and AL over 24 months for Asian and Caucasian children classified into four categories based on their refractive error.

et al (2005) reported that high myopia is not a risk factor for astigmatism,[41] whereas Gong et al (2024) reported that children with longer AL exhibited greater cylindrical power progression over time.[27] The higher baseline myopia and longer AL observed in the astigmatic cohort in the present study may reflect the tendency for highly myopic eyes to develop stronger hyperopic field curvature and associated astigmatism.[33] This may explain both the higher myopic refractive error and longer axial lengths in the astigmatic group.

The combined dataset analysis in the present study demonstrated that, despite a non-significant outcome, children with astigmatism presented longer axial lengths at baseline compared to their non-astigmatic peers, while children with purely spherical myopia exhibited faster progression over time. The results of the present study partially contrasts the findings reported of Domsa et al (2024) who reported greater progression among children with astigmatism compared to children with purely axial myopia.[32] The differing conclusions between the present work and Domsa et al (2024) likely reflect methodological differences between the two studies (ie. sample size and demographics, study duration, baseline refractive characteristics and eligibility criteria for progression).[32] While our results confirmed that greater astigmatism is associated with higher baseline myopia, in agreement with previous studies,[33,38] we found that children with spherical myopia demonstrated faster progression rates.

Overall, our results indicate that different astigmatism types vary in the degree of overall myopia progression relative to baseline SER and AL but follow a similar progression pattern over time. WTR-astigmatism was associated with the least myopia progression and ATR-astigmatism with the greatest. Importantly, DIMS spectacles reduced overall myopia progression, consistent with previous studies,[19,20] but did not exert differential effects across specific astigmatism types, suggesting a uniform treatment effect irrespective of subtype.

Strengths and Limitations

A key strength of the present study is its focus on the role of astigmatism type on myopia progression, an area that has received limited attention compared to research on the relationship between myopia progression and cylindric power.[39,42,43]

Several limitations should be acknowledged. Firstly, the unequal sample sizes across the four astigmatism groups reduced statistical power, limiting the ability to detect subtle differences. Additionally, the greatest variability occurred in the ATR- and WTR-astigmatism groups, which also showed the strongest effects. This combination of high variability and unequal group sizes may explain why statistically significant differences were detected primarily between ATR- and WTR-astigmatism but not among other subgroup comparisons. Secondly, children with moderate and high levels of astigmatic individuals were excluded, which may have reduced the sensitivity of our analysis and thus our ability to detect meaningful differences. Previous studies reported that highly astigmatic patients demonstrated faster refractive progression rates[37] and that astigmatism severity correlates with myopia progression rates.[38,39] By restricting the sample to low astigmatism cases, the present work may have overlooked meaningful differences. Although the overall presence of astigmatism did not significantly affect myopia progression, astigmatism type analyses revealed distinct differences in progression rates. While all types followed comparable longitudinal trajectories, the significant interaction between astigmatism subtype and overall progression highlights the importance of further examining astigmatism type-specific effects.

Future studies should include participants with varying degrees of astigmatism, particularly high astigmatism, and incorporate longer follow-up periods to more comprehensively assess astigmatism type-specific influences on myopia progression under myopia management interventions.

Conclusion

The combined analysis revealed that the presence of astigmatism at baseline did not significantly affect myopia progression, measured by SER and AL change, in children wearing DIMS spectacles. Furthermore, analysis of astigmatism types revealed distinct differences: WTR astigmatism was associated with the least progression, while the small sample of those with ATR astigmatism was associated with the greatest. After correcting for initial differences at baseline, analyses suggest that the apparent differences in myopia progression between the astigmatism types were partly explained by baseline differences. However, visual inspection shows that all types of astigmatism exhibited a broadly similar trajectory over time. These findings highlight the importance of considering astigmatism subtype, rather than astigmatism presence alone, when assessing myopia progression in children undergoing optical interventions.

Ethics

Informed consent was obtained from all participants and their parents or legal guardians prior to data collection in the study conducted by Lam et al., for the Asian dataset.[18,20] The Lam et al. study was approved by the Institutional Review Board/or Ethics Committee: Departmental Research Committee, The Hong Kong Polytechnic University, HK (Reference number: HSEARS20140630003, 30.07.1014); Informed consent was obtained from all participants and their parents or legal guardians prior to data collection in the study conducted McCullough et al. for the European dataset.[19] The McCullough et al. study was approved by Aston University Research Ethics Committee, UK (reference number 1659, 25.06.2020); Faculty Research Ethics Panel (FREP), Anglia Ruskin University, UK (reference number 20/21/002, 14.12.2020); Ulster University Research Ethics Committee, UK (reference number REC/20/0058, 11.08.2020).

This study was conducted as a retrospective analysis of fully anonymised and de-identified data. All direct and indirect patient identifiers were removed prior to data access by the present research team, such that re-identification of any individual was not reasonably possible. As the dataset contained no personal data, this study did not constitute human subjects research and formal ethical approval was not required.

This study was conducted in accordance with the tenets of the Declaration of Helsinki and adhered to all applicable institutional and national data governance standards.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

NV is an employee of HOYA Vision Care. RS was an employee of HOYA Vision Care when the present work was undertaken. The authors report no other conflicts of interest in this work.

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