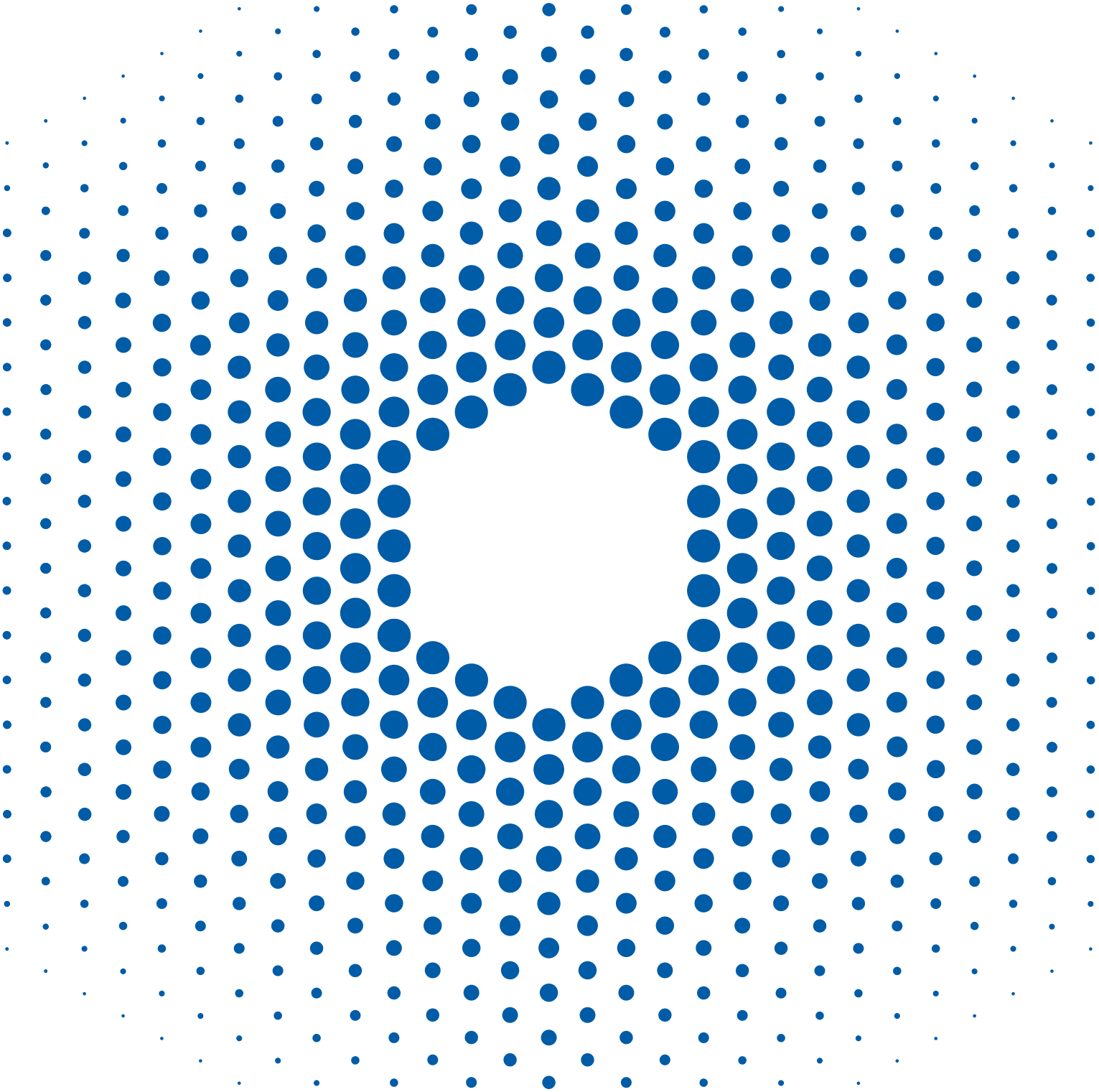

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Defocus Incorporated Multiple Segments (DIMS) spectacle lenses slow myopia progression: a 2-year randomised clinical trial

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► Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/bjophthalmol-2018-313739).

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Received 14 December 2018
Revised 1 April 2019
Accepted 10 May 2019

To cite: Lam CSY, Tang WC, Tse DY, *et al*. *Br J Ophthalmol* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/bjophthalmol-2018-313739

ABSTRACT

Aim To determine if 'Defocus Incorporated Multiple Segments' (DIMS) spectacle lenses slow childhood myopia progression.

Methods A 2-year double-masked randomised controlled trial was carried out in 183 Chinese children aged 8–13 years, with myopia between −1.00 and −5.00 D and astigmatism ≤1.50 D. Children were randomly assigned to wear DIMS (n=93) or single vision (SV) spectacle lenses (n=90). DIMS lens incorporated multiple segments with myopic defocus of +3.50 D. Refractive error (cycloplegic autorefraction) and axial length were measured at 6month intervals.

Results 160 children completed the study, n=79 in the DIMS group and n=81 in the SV group. Average (SE) myopic progressions over 2 years were −0.41±0.06 D in the DIMS group and −0.85±0.08 D in the SV group. Mean (SE) axial elongation was 0.21±0.02 mm and 0.55±0.02 mm in the DIMS and SV groups, respectively. Myopia progressed 52% more slowly for children in the DIMS group compared with those in the SV group (mean difference −0.44±0.09 D, 95% CI −0.73 to −0.37, p<0.0001). Likewise, children in the DIMS group had less axial elongation by 62% than those in the SV group (mean difference 0.34±0.04 mm, 95% CI 0.22 to 0.37, p<0.0001). 21.5% children who wore DIMS lenses had no myopia progression over 2 years, but only 7.4% for those who wore SV lenses.

Conclusions Daily wear of the DIMS lens significantly retarded myopia progression and axial elongation in myopic children. Our results demonstrated simultaneous clear vision with constant myopic defocus can slow myopia progression.

Trial registration number NCT02206217.

INTRODUCTION

The increasing prevalence of myopia is reaching an alarmingly high level globally.[1 2] In many parts of East and Southeast Asia, as many as 70%–80% of young adults are myopic,[1–3] and as many as 20% of children are highly myopic, with refractions worse than −6 D.[2] Highly myopic eyes have higher risk of developing blinding complications such as retinal degenerations[4 5] and glaucoma.[6] It is no doubt that epidemic of myopia debilitates both at individual level and public health level.[7 8] In fact, myopia is now identified as one of immediate concerns by the WHO's Global Initiative for the Elimination of Avoidable Blindness.[8]

Several clinical interventions are currently used for slowing the progression of myopia.[9 10] A meta-analysis in efficacy comparison of different interventions for myopia control reported that pharmacological treatment is relatively more effective than optical methods using contact lenses or spectacles.[9 10] High-dose (1%) atropine[11] eye-drops are highly effective, but the associated side effects, such as photophobia and blurry vision, are not well tolerated. Lower dose (0.01%–0.1%)[12–14] atropine yields similar treatment effects with less side effects. Ideally, an intervention for myopia control should be as minimally invasive as possible, making spectacle lenses the ideal alternative option.

Animal studies have provided solid evidence that imposed myopic defocus (MD) inhibits eye growth whereas hyperopic defocus promotes eye growth.[15] Studies using chicks,[16 17] guinea pigs,[18] marmoset[19] and rhesus monkey[20] have demonstrated that myopic eye growth could be inhibited or reversed by applying MD using dual-power or multifocal lenses. Indeed, MD is likely be the key mechanism that underlies a number of current myopia control strategies, such as orthokeratology[21] and multifocal soft contact lenses.[22–24]

Several years ago, we designed a concentric dual-power soft contact lens called 'Defocus Incorporated Soft Contact' (DISC) lens for myopia control which imposes MD on both the central and peripheral retinas.[23] The clinical trial has shown the DISC lens wear significantly slowed myopia progression in schoolchildren by 25% over 2 years compared with the single vision (SV) contact lenses and 60% for a subgroup of children who have worn the lenses for more than 8 hours/day.[23] We have now designed a spectacle lens based on the MD mechanism for myopia control, and named it as Defocus Incorporated Multiple Segments (DIMS) spectacle lens. This lens provides the same optical stimulus as the DISC lens without the disadvantages inherent with contact lens wear. This study aims to investigate if the DIMS lenses can slow myopia progression in schoolchildren.

MATERIALS AND METHODS

Study design

This study was a prospective, randomised and double-masked clinical trial conducted between August 2014 and July 2017. The subjects were randomly allocated to wear either DIMS spectacle lenses (treatment group) or SV spectacle lenses

(control group). Spherical equivalent refraction (SER) and axial length (AL) were measured at baseline and every 6 months over 2 years. The changes in SER and AL between two groups were compared over the study period. Data collection and eye examinations were carried out in the Centre for Myopia Research at the Hong Kong Polytechnic University. Written assent and informed consent were obtained from the children and their parents before participation.

Subjects

Phone screening and visual screening were performed to determine whether the child met the study criteria. One hundred and eighty-three schoolchildren were recruited between August 2014 and July 2015. Inclusion criteria were:

- Hong Kong Chinese.
- 8–13 years old.
- SER: −1.00 to −5.00 dioptres (D).
- Astigmatism and anisometropia of 1.50 D or less.
- Monocular best corrected visual acuity (VA) of 0.00 logMAR (6/6) or better.
- Acceptance of random group allocation and the masked study design.

Exclusion criteria were:

- Strabismus and binocular vision abnormalities.
- Ocular and systemic abnormalities.
- Prior experience of myopia control.

Randomisation

Simple randomisation was implemented by the unmasked investigator (UI) by putting subject file numbers (1–200) in a spreadsheet of Excel (Microsoft Office) and creating a column of random numbers for the group allocation. Eligible subjects were then assigned to either group by following a random software sequence generated from Excel.

Sample size calculation

To achieve a 90% power to detect a 0.50D difference (0.70D of SD)[23] in myopia progression between two groups with an alpha level of 0.01 (2-tailed); the minimum subject number required in each group was 59. Assuming a dropout rate of about 15%, at least 70 subjects were required in each group.

Intervention and control

The children in the treatment group wore the DIMS spectacle lenses while those in the control group wore ordinary SV spectacle lenses.

The DIMS lens is a custom-made plastic spectacle lens. It comprises a central optical zone (9 mm in diameter) for correcting distance refractive errors, and an annular multiple focal zone with multiple segments (33 mm in diameter) having a relative positive power (+3.50 D) (figure 1). The diameter of each segment is 1.03 mm. This design simultaneously introduces MD and provides clear vision for the wearer at all viewing distances. There are multiple foci from MD at a plane in front of the retina, which would be received as blur images on the retina.

The final distance prescription was determined by the UI using cycloplegic subjective refraction measured by the masked investigator (MI). The lenses were replaced with an updated prescription when the change of SER was more than 0.50 D.

Masking and wear compliance

We adopted the same study protocol in our previous randomised controlled trials using progressive addition lenses[25] and the DISC lenses.[23] The UI was responsible for group allocation, spectacle-dispensing work, measuring visual performance of lenses, record keeping, data entry and compliance checking. The MI was responsible for refraction and related eye data measurement. Both the children and their parents were masked to group allocation until data analysis was completed. The masking procedures fulfilled the Consolidated Standards of Reporting Trials requirements.[26] Prior to the data measurement by MI, the spectacles were removed from the children by the UI.

At spectacles delivery, the children were instructed to wear the spectacles in full-time mode, except during sleeping and taking shower. Wear compliance was monitored and checked by phone calls and questionnaires.

Outcome variables

Refraction and AL under cycloplegia were measured at baseline and at 6-month intervals for 2 years. The primary outcome was myopia progression, which was the difference between the mean cycloplegic SER at the baseline and subsequent 6-month visits for 24 months. The secondary outcome was the change of AL,

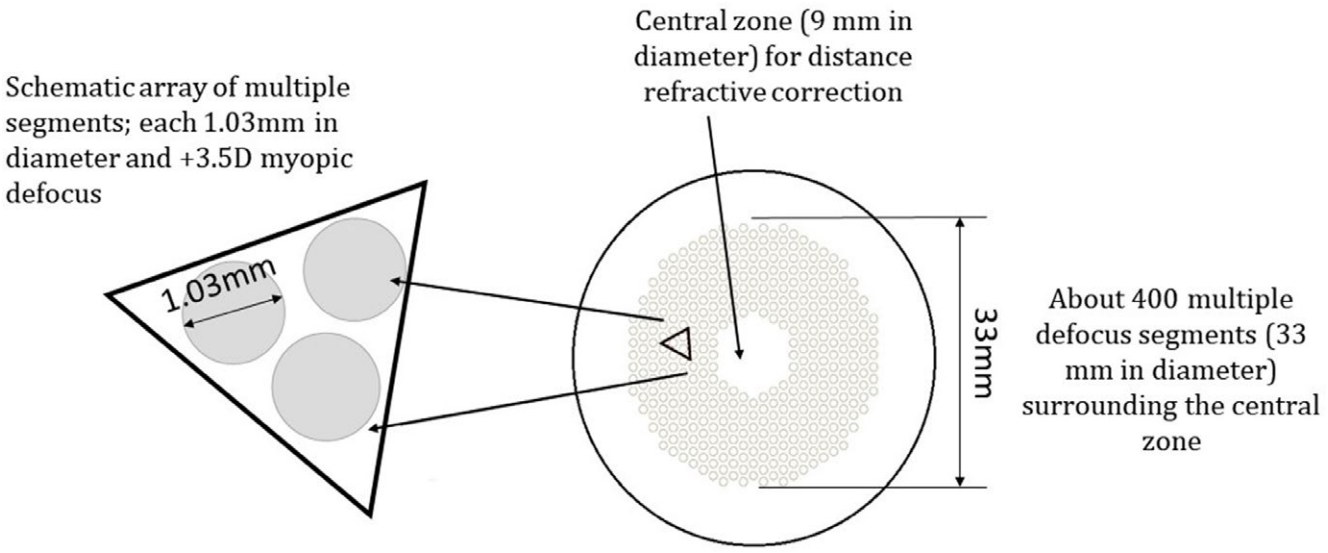

Figure 1 The design of the Defocus Incorporated Multiple Segments (DIMS) spectacle lens.

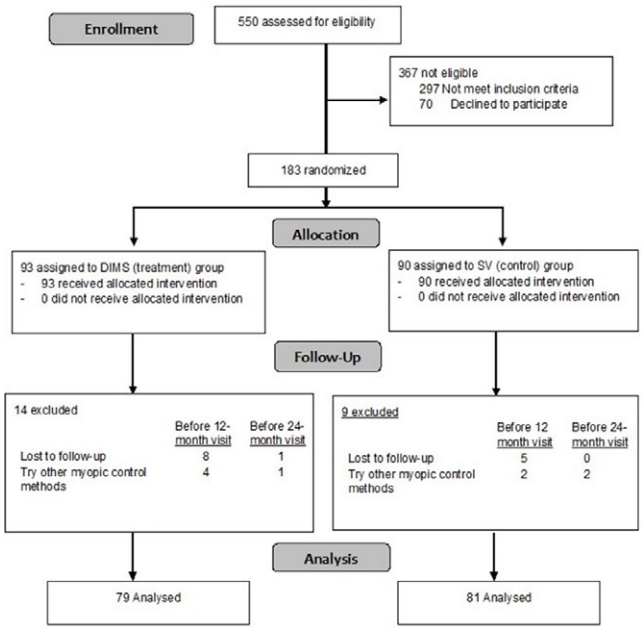

Figure 2 A flow diagram of the study design. DIMS, Defocus Incorporated Multiple Segments spectacle lens; SV, single vision spectacle lens.

which was the difference between the mean AL at the baseline and subsequent 6-month visits for 24 months.

One drop of Alcaine 0.5% followed by one to two drops of cyclopentolate HCL 1% were instilled to induce cycloplegia. Cycloplegia was confirmed by measuring the amplitude of accommodation using push-up method when accommodation was 2 D or less. Cycloplegic refraction was measured with an open-field autorefractor (Shin-Nippon NVision-K5001). AL was measured by partial coherence interferometry IOL Master (Carl Zeiss). Average of five measurements of autorefraction and AL for each eye were obtained for analysis.

Other measurements at each follow-up

Other outcomes such as distance and near VA, near phoria and accommodation lag were measured when the children were wearing full correction of distance at each 6-month follow-up.

Visual performance with the experimental lenses was also assessed. Distance and near VA, accommodation, phoria and stereopsis were measured when the subjects collected their spectacles. Vision quality, comfort and frequency of visual symptoms with lens wear were graded by the subjects themselves through questionnaires (online supplementary methods). Data between the two groups were compared.

Statistical analysis

There were no statistically significant differences between data from two eyes, only data of right eyes were used for analyses. Unpaired t-tests were used to compare baseline characteristics between groups when normality assumptions were preserved. Otherwise, Mann-Whitney U test for continuous data and the χ^2 test for categorical data were used.

Myopia progression over 2 years was calculated as the difference between SER at the baseline and the 2-year visits. For the subjects completed the study, the changes in SER and AL between two groups were compared using unpaired t-tests. The efficacy of myopia control of DIMS lens (%) was determined by dividing the difference in myopia progression (or axial elongation) between two groups with the myopia progression (or axial elongation) in the SV group, then multiplied by 100%.

Data analysis also followed the intention-to-treated approach for the subjects lost to follow-up. Generalised estimating equations (GEE) were adopted for handling missing data. GEE, with one within-subject factor (time), one between-subject factor (group: DIMS or SV) and their interactions, was used to determine the treatment effect on two main outcomes adjusted for some covariates. These covariates included age, gender, baseline refractive error, near phoria, lag of accommodation, number of myopic parents, time spent on near works and outdoor activities. The significant covariates ($p<0.05$) were tested for their correlation with the changes of SER and AL independently using Pearson correlation analysis.

RESULTS

Subject profile

Figure 2 is a flow diagram illustrating the number of subjects recruited, enrolled and dropped out. One hundred and eighty-three eligible schoolchildren participated and were randomly allocated to the DIMS group (n=93) and the SV group (n=90). One hundred and sixty subjects successfully completed the study: 79 (85%) children in the treatment group and 81 (90%) in the control group. The dropout rate was slightly higher in the treatment group (15%) than the control group (10%) (online supplementary eTables 1 and 2). Fourteen out of 23 children dropped out early soon after the baseline data collection.

Both groups showed an overall good compliance and could wear the spectacles full time. The mean daily lens-wearing time in the DIMS group and SV group was 15.5±2.6 and 15.3±2.1 hours, respectively, and was not significantly different.

Baseline characteristics

There were no statistically significant differences between the DIMS and SV groups in the baseline characteristics ($p>0.05$) (table 1). The mean initial myopia in the DIMS and SV groups was −2.93±1.04 D and −2.70±0.98 D, respectively. The mean initial AL was 24.85±1.59 mm and 24.72±1.30 mm in the DIMS and SV groups, respectively.

Changes in the refraction and AL

Completed subjects

For subjects who completed the 2-year trial (table 2), the mean myopia progression (SE) over 2 years in the DIMS group (n=79) and the SV group (n=81) was −0.38±0.06 D and −0.93±0.06 D, respectively. The total increase in AL was 0.21±0.02 mm and 0.53±0.03 mm, respectively. Schoolchildren wearing DIMS lenses had myopia progression significantly reduced by 59% (mean difference −0.55±0.09 D, $p<0.0001$) and axial elongation decreased by 60% (mean difference 0.32±0.04 mm, $p<0.0001$) compared with those wearing SV lenses.

All enrolled subjects

Changes in SER

The mean myopia progression over 2 years in the DIMS group (n=93) and the SV group (n=90) was −0.38±0.06 D and −0.85±0.08 D, respectively. Children wearing DIMS lenses had significantly less myopia progression by 55% (mean difference −0.47±0.09 D, $p<0.0001$).

The tests of model effect (online supplementary eTable 3) indicated that group, time and age ($p<0.05$) had significant association with the magnitude of myopia progression. After model

Table 1 Baseline demographics data of all and the completed subjects

Baseline demographic data, mean (SD)	Mean (SD)			
	All		Completed	
	DIMS (n=93)	SV (n=90)	DIMS (n=79)	SV (n=81)
Age at enrolment (years)	10.19±1.46	10.01±1.44	10.20±1.47	10.00±1.45
Gender				
Male, % (n)	59.1 (55)	55.6 (50)	58.2 (46)	54.3 (44)
Female, % (n)	40.9 (38)	44.4 (40)	41.8 (33)	45.7 (37)
Cycloplegic autorefraction in SER (D)	−2.93±1.04	−2.70±0.98	−2.97±0.97	−2.76±0.96
Axial length (mm)	24.85±1.59	24.72±1.30	24.70±0.82	24.60±0.83
Corneal power at steep meridian (D)	44.46±1.67	44.39±1.69	44.5±1.61	44.5±1.65
Corneal power at flat meridian (D)	43.14±1.41	43.09±1.45	43.2±1.41	43.2±1.44
Near phoria, Δ	−1.96±3.93	−0.98±3.53	−2.16±4.07	−0.15±3.28
Accommodation lag (D)	0.97±0.49	1.06±0.40	0.98±0.42	1.04±0.35
Myopics parents, n				
0	3	6	2	5
1	22	23	18	20
2	68	61	59	56

Δ, prism dioptres; AL, axial length; D, dioptres;DIMS, Defocus Incorporated Multiple Segments spectacle lens; SER, spherical equivalent refraction; SV, single vision spectacle lens.

adjustment, the mean myopia progressions were −0.41±0.06 D in the DIMS group and −0.85±0.08 D in the SV group (online supplementary eTable 4). Children wearing DIMS lenses had significantly less myopia progression by 52% (mean difference −0.44±0.09 D, p<0.0001). Controlling for covariates did not greatly change the treatment effect compared with the unadjusted means. The DIMS lens had the greatest effect on slowing myopia progression in the first 6 months, after that, the magnitude slightly decreased at 12-month visit and was sustained to the 24-month visits (figure 3).

For Pearson correlation analysis, the changes in SER significantly correlated (r^2=0.22, p<0.001) with subject's age in the DIMS group (online supplementary eFigure 1). Myopia progression was slightly slower in older children who wore DIMS lenses. In SV group, no significant correlation was found (r^2=0.04, p>0.05).

Table 2 Changes in the cycloplegic spherical equivalent refraction and axial length (from baseline) in the DIMS and the SV groups

	DIMS (n=79)	SV (n=81)	Mean difference (SE)
Time/visit	SER changes in dioptres, mean (SE)		
6 months	−0.13±0.03	−0.37±0.04	−0.24±0.05*
12 months	−0.17±0.05	−0.55±0.04	−0.38±0.07*
18 months	−0.31±0.06	−0.72±0.05	−0.42±0.08*
24 months	−0.38±0.06	−0.93±0.06	−0.55±0.09*
Time/visit	Changes in AL (mm), mean (SE)		
6 months	0.03±0.01	0.20±0.01	0.16±0.02*
12 months	0.11±0.02	0.32±0.02	0.21±0.02*
18 months	0.15±0.02	0.43±0.02	0.27±0.03*
24 months	0.21±0.02	0.53±0.03	0.32±0.04*

*Statistically significant difference between two experimental groups (unpaired t-tests, p<0.0001).
Δ, prism dioptres;D, dioptres;DIMS, Defocus Incorporated Multiple Segments spectacle lens; SER, spherical equivalent refraction; SV, single vision spectacle lens.

Changes in AL

The total increase in AL over 2 years was 0.21±0.02 mm and 0.56±0.02 mm in the DIMS and SV groups, respectively. The DIMS lenses significantly slowed axial elongation by 63% (mean difference 0.35 (0.04) mm, p<0.0001) as compared with the SV lenses. Group, time and age were found to be associated with AL changes. Model-adjusted mean changes in AL±SE were 0.21±0.02 mm and 0.55±0.02 mm in the DIMS and SV groups, respectively. The DIMS lens showed a significant effect on slowing axial elongation by 62% (mean difference 0.34±0.03 mm, p<0.0001).

For individual subjects

Seventeen (21.5%) out of 79 children wearing DIMS lenses had no myopia progression over 2 years (online supplementary eFigure 2), which was higher than the SV group (6 of 81, 7%). Likewise, 14% of the children wearing DIMS lenses had no axial elongation whereas all children in the SV group had axial elongation (online supplementary eFigure 3).

Visual performance with lens wear

There were no statistically significant differences between the two lens types in influencing VA and accommodation (unpaired t-test, p>0.05) (online supplementary eTable 5), except stereoacuity (p=0.04). However, the mean difference was only 5 s of arc, which is not clinically significant.

DISCUSSION

Children wearing the DIMS spectacle lenses had myopia progression significantly reduced by 52% and axial elongation by 62%

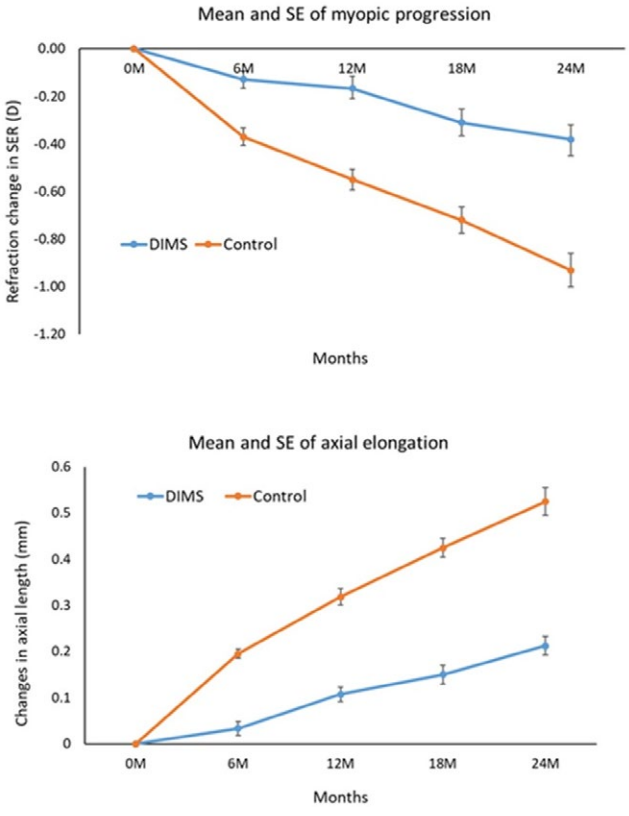

Figure 3 Model-adjusted mean and SE of myopia progression and axial length from baseline to 24 months. DIMS, Defocus Incorporated Multiple Segments; SER, spherical equivalent refraction.

over 2 years when compared with those wearing SV lenses. The greatest treatment effect was observed during the first 6 months of lens wear. It was due to the higher myopia progression in the SV group during this time, otherwise the treatment effect was quite consistent over the 2 years (figure 3, online supplementary eTable 4). The treatment effect with the DIMS lens was similar to that achieved with 6–8 hours daily wear of DISC lens, at around 50%–60%.[23] These findings are consistent with our previous animal studies[17 18] and the clinical trial of the DISC lens,[22] that the principle of employing MD does retard eye growth and myopia progression.

The DIMS lens design showed much better effect on slowing childhood myopia progression than existing progressive addition lenses (10%–35%),[25 27–31] spectacle lens with peripheral defocus[32] and contact lens[33] (34%) designed for reducing relative peripheral hyperopia (online supplementary eTable 6). The efficacy of myopia control is comparable to those of orthokeratology (60%),[10 21] prismatic bifocal spectacle lenses (about 50%)[34] and bifocal soft contact lenses (50%–60%)[10 23 35] and relatively less when compared with high and low-dose atropine (70+%).[11–14]

The DIMS lenses have slowed myopia progression, and have stopped myopia progression in some children (online supplementary eFigures 2 and 3). 21.5% of children in the DIMS group had no myopia progression over 2 years whereas only 7.4% in the control group. About 13% of children in the DIMS group still showed considerable progression in terms of refraction (>1 D). Such variations in retardation effect have been observed with prismatic bifocal spectacles, Cheng *et al*[34] showed that prismatic bifocals were more effective in the children with low accommodative lag. Also, they found that age, initial myopia and parental myopia were associated with the treatment effect. In contrast, in our study the magnitude of treatment effect was not dependent on lag of accommodation, initial myopia nor parental myopia.

Analysis of model effects indicated that age was the only associated factor that exhibited significant effect on myopia progression, and the effect of myopia control with DIMS lenses was greater in older children (aged 10–13) (online supplementary eFigure 1). About 80% of the DIMS wearers who had considerable myopia progression were younger children aged 8–9 years. We speculate that variations in treatment effect of the DIMS lenses may be due to different retinal profile or peripheral refraction among the children.[36] If there is a high amount of peripheral hyperopia, the amount of effective MD at the peripheral retina will be less, and thereby minimising the treatment effect.

In our previous study, wearing time was found to be a significant factor in determining the treatment effect of DISC lenses.[23] No such correlation was found in the present study. This is probably a result of the overall higher compliance, that the subjects were able to wear their assigned spectacle lenses constantly, with over 15 hours/day. The dropout rate in this study was much lower (13%) than that in our previous study using the DISC lenses (42%).[23]

The findings of visual performance (online supplementary eTable 5 and eFigure 4) showed that the DIMS lens could provide good vision at distance and near comparable to conventional SV spectacle lenses. Although some subjects initially noticed the slight blurriness at the mid-peripheral field, they fully adapted to the lenses in a few days. The symptoms (score below 2) such as ghost image, dizziness and headache seldom occurred during DIMS lens wear (online supplementary eFigure 5). No treatment-related adverse event was reported.

The current report includes only the first 2-year result, when the third year of the study is ongoing. Also, the current study is limited to Chinese children, further study will be needed to determine the treatment effect of the DIMS lenses in other ethnic populations. DIMS and SV lens could hardly be differentiated by their appearance unless the lens was tilted and the multiple segments may be observed from the reflection of a light source. Most children were not aware of the multiple segments features. A few children in the treatment group might recognise the multiple segments but they had no particular difficulties in using the lens as their previous spectacle lenses. Nevertheless, the study could not be totally masked for some subjects. Our study did not include children with over −5 D of myopia. The retardation effect on myopia progression in high myopes was yet to be determined. Further investigation is also required, in particular, to determine its optimal effectiveness in preventing myopia progression and incidence.

CONCLUSIONS

Daily wear of the DIMS lens significantly slowed myopia progression and axial elongation in myopic schoolchildren as compared with wearing SV spectacle lenses. They provided good vision while presenting simultaneous MD to the eyes. This intervention is simple to use and is the least invasive method compared with pharmacological or contact lens treatments. The DIMS spectacle lens offers an alternative treatment modality for myopia control.

Acknowledgements The authors thank the employees of HOYA who participated in the calculation, ordering and manufacturing of the lenses. HOYA provided the spectacles and lenses for the study. We are grateful for advice from Professor Ian Morgan and Dr Maureen Boost, statistical advice from Dr Paul Lee and Ms Yee Mui Kwok in liaison with the parents.

Contributors All the authors listed have been involved in the undertaking of the clinical trial with emphasis on various aspects, from the conception of the lens design, fabrication of the lens and registration of the clinical trial and preparation of clinical protocol to data collection and analysis, interpretation and conclusions. A few manuscripts are now in preparation by the author team.

Funding This was a collaborative research supported by HOYA, Tokyo, Japan (PolyU grant numbers H-ZG3B and 1-87LK). In addition to the financial support, the sponsor also provided manufacturing spectacle lenses and frames. It was a joint collaboration in the design of the DIMS lens.

Competing interests None. Patents titled 'Spectacle Lens' in China (CN104678572 B) and in USA (US10268050 B2) were issued on 27 April 2018 and 23 April 2019 respectively.

Patient consent for publication Not required.

Ethics approval All aspects of the study met the tenets of the Declaration of Helsinki and were approved by the Human Subjects Ethics Subcommittee of the Hong Kong Polytechnic University.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Data are available upon request.

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Myopia control effect of defocus incorporated multiple segments (DIMS) spectacle lens in Chinese children: results of a 3-year follow-up study

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► Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/bjophthalmol-2020-317664).

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Received 4 August 2020
Revised 8 February 2021
Accepted 20 February 2021

To cite: Lam CSY, Tang WC, Lee PH, *et al*. *Br J Ophthalmol* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/bjophthalmol-2020-317664

ABSTRACT

Aims To determine myopia progression in children who continued to wear the defocus incorporated multiple segments (DIMS) lenses or switched from single vision (SV) to DIMS lenses for a 1-year period following a 2-year myopia control trial.

Methods 128 children participated in this study. The children who had worn DIMS lenses continued to wear DIMS lenses (DIMS group), and children who had worn SV lenses switched to wear DIMS lenses (Control-to-DIMS group). Cycloplegic spherical equivalent refraction (SER) and axial length (AL) were measured at 6-month interval. Historical controls were age matched to the DIMS group at 24 months and used for comparing the third-year changes.

Results Over 3 years, SER and AL changes in the DIMS group (n=65) were −0.52±0.69D and 0.31±0.26 mm; these changes were not statistically significant over time (repeated measures analysis of variance, p>0.05). SER (−0.04±0. 38D) and AL (0.08±0.12 mm) changes in the Control-to-DIMS group (n=55) in the third year were less compared with the first (mean difference=0.45 ± 0.30D, 0.21±0.11 mm, p<0.001) and second (0.34±0.30D, 0.12±0.10 mm, p<0.001) years. Changes in SER and AL in both groups over that period were significantly less than in the historical control group (DIMS vs historical control: mean difference=−0.18±0.42D, p=0.012; 0.08±0.15 mm, p=0.001; Control-to-DIMS versus historical control: adjusted mean differences=−0.30±0.42D, p<0.001; 0.12±0.16 mm, p<0.001).

Conclusions Myopia control effect was sustained in the third year in children who had used the DIMS spectacles in the previous 2 years and was also shown in the children switching from SV to DIMS lenses.

INTRODUCTION

The prevalence of myopia is growing alarmingly worldwide, especially in East Asian populations.[1–3] High myopia is associated with an increased risk of sight-threatening eye disease[4–6] creating a long-term burden on economies and public healthcare.[7 8] There is no doubt that myopia is a significant public health issue and a global concern.[8] Effective interventions for myopia management and reduction would alleviate this problem.

Currently, a variety of modalities are used for myopia control in children.[9–11] High-dose (1%) atropine eye-drops seem the most effective in myopia control, but the associated side effects, such as photophobia and blurred near vision, hinder its wide clinical application.[12] In recent years, some studies have reported that low-dose (0.01%) atropine treatment has yielded positive results with minimal side effects and low myopic rebound.[13–15] Optical treatments, including orthokeratology,[16–18] executive top bifocal spectacles[19] and multifocal soft contact lenses incorporating myopic defocus[20–24] have also shown promising results in slowing myopia progression. However, each method has limitations.[11]

The defocus incorporated multiple segments (DIMS) spectacle lens is designed to control myopia in children, based on the principle of myopic defocus and simultaneous vision. It is a dual-focus spectacle lens consisting of a central optical zone for correcting distance refractive error, and a batch of tiny circular segments with a relative positive power of 3.50D equally distributed throughout the mid-peripheral area in a honeycomb pattern.[25] Thus, the DIMS lens imposes myopic defocus while providing clear vision for the wearer simultaneously at all viewing distances. A 2-year double-masked randomised controlled trial (RCT) (ClinicalTrials.gov: NCT02206217) showed that DIMS lens wear slowed childhood adjusted myopia progression significantly by 52% and axial elongation by 62% compared with regular single vision (SV) spectacle lenses wear over 2 years.[25]

Our aims here are to determine (1) if myopia retardation (as measured by changes in spherical equivalent refraction (SER) and AL) continues in the third year of DIMS wear and (2) if myopia retardation is exhibited in the first year of DIMS wear by the original SV control group; both groups will be compared with a new historical control group.

MATERIALS AND METHODS

Study participants

Ethnic Chinese children who had completed the 2-year RCT[25] (NCT02206217, between August 2014 and July 2017) were invited to participate in this third-year follow-up study. Written assent and informed consent were obtained from the children and their parents respectively before participation.

Children who had worn DIMS lenses in the RCT continued to wear DIMS lenses in the third year (DIMS group). The children in the original control group were offered the DIMS treatment

and this gave us the opportunity to evaluate if the DIMS lenses could provide myopia control in the Control-to-DIMS group similar to that observed in the original DIMS group.

Study procedures and data collection

The primary and secondary outcomes were the changes in SER and axial length (AL). The procedures of data measurement followed those in the trial of DIMS lenses.[25] SER and AL were measured at 6-month intervals. SER was measured by cycloplegic autorefraction using an open-field autorefractor (Shin-Nippon NVision-K5001, Ajinomoto Trading Inc.). AL was measured by partial coherence interferometry using an IOL Master (Carl Zeiss Meditec). Cycloplegia was induced by instillation of one drop of alcaine 0.5%, followed by one to two drops of cyclopentolate HCL 1%. The measurements were taken 30 min after the instillation of eye drops, and cycloplegia was considered achieved when the amplitude of accommodation was less than 2.00D as measured using an RAF rule. An average of five autorefractions and AL measurements for each eye was used for data analysis.

The historical control group

Since the children originally in the control group switched to wear DIMS lenses in the third year, they could not be used as the 'control' to assess effectiveness on myopia control. Therefore, we obtained a historical control group by reviewing clinical records from the Optometry Clinic, PolyU for 2017–2019. The criteria for selection were based on the inclusion and exclusion criteria in the original RCT. Subjects were healthy myopic ethnic Chinese children who attended eye examinations in the clinic with at least 12-month follow-up data. They had not received any myopia interventions and were matched for age (between 10 and 15 years) and SER ranges (−1.00 to −5.50D) with the DIMS subjects at the end of the 2-year RCT. Annual myopia progression and AL changes in this group of children were calculated and compared with the third-year changes in the DIMS and Control-to-DIMS groups.

Statistical analysis

All statistical analyses were performed using SPSS V.20.0. Baseline characteristics and the changes in SER and AL are presented as mean±SD. The right eye data only were used for analysis as there was no statistically significant difference between the left and the right eye data.

Following Kolmogorov-Smirnov tests for distribution, unpaired t-tests, Mann-Whitney U tests or repeated measures analysis of variance (ANOVA) tests were used as appropriate. Pearson's correlation coefficient analyses were used to determine relationships between continuous variables and χ^2 tests for categorical data.

For both the DIMS group and Control-to-DIMS group, myopia progression and changes in AL in years 1, 2 and 3 were calculated and compared by repeated measures ANOVA and post hoc pairwise comparisons using Bonferroni corrections were performed for determining where the differences laid. Myopia progression and change in AL were calculated for the historical control group, for which we had one (12 months) set of data, and were compared with the third-year changes of two experimental groups by multiple linear regression approach with adjusting confounding covariates, such as age, sex, SER and AL.

RESULTS

Subject profile and baseline data

Figure 1 shows the number of subjects recruited and those lost to follow-up over 3 years. One hundred and sixty Chinese children completed the 2-year RCT and 128 of these agreed to participate in the third-year study. We compared the data between the subjects who joined and those who declined to join the third-year study for both the DIMS and Control-to-DIMS groups. No significant differences were found in terms of their age, gender, baseline myopia or AL, myopia progression or axial elongation in the previous 2-year trial ($p>0.05$) (online supplemental eTable 1).

At the end of the third year, 120 children (DIMS, n=65; Control-to-DIMS, n=55) completed the data collection. The mean age at enrolment (mean±SD) was 10.15±1.52 years and 10.24±1.42 years in the DIMS and the Control-to-DIMS groups, respectively. The baseline SER of the DIMS group and the Control-to-DIMS were −2.98±0.96D and −2.73±0.99D, respectively. The baseline AL of the DIMS and the Control-to-DIMS were 24.68±0.82 mm and 24.57±0.88 mm. There were no statistically significant differences between the two groups with respect to age at enrolment, gender proportion, baseline myopia or baseline AL ($p>0.05$).

Changes in SER and AL

Figure 2A and table 1 present the mean and cumulative changes in mean SER and AL from baseline to 36 months in both groups. Figure 2B shows the trend in changes in SER and AL changes in the third year.

The DIMS group

The mean changes in SER and AL in the DIMS group (n=65) were −0.52± 0.69D and 0.31± 0.26 mm over 3 years (table 1). The myopia progression and axial elongation did not change significantly

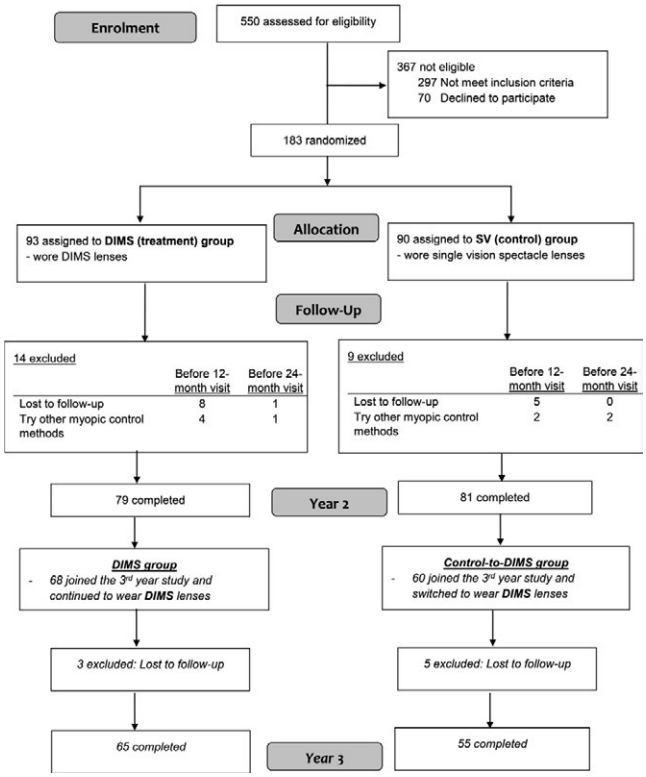

Figure 1 Subject numbers over 3 years. DIMS, defocus incorporated multiple segments; SV, single vision.

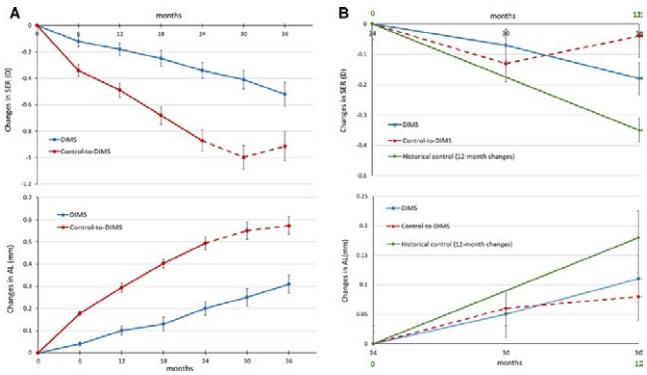

Figure 2 (A) Changes in spherical equivalent refraction (SER) and axial length (AL) from baseline to 36 months. The red dotted line represents the period (24–36 months) during which the previous single vision control group wore defocus incorporated multiple segments (DIMS) lenses. (B) The third-year changes in SER and AL in the DIMS and Control-to-DIMS groups. The green line shows the 12-month changes in SER and AL in the historical control group.

over time (repeated measures ANOVA, p>0.05). The mean annual changes in SER and AL in the DIMS group were −0.18± 0.25D and 0.10± 0.09 mm over 3 years.

The Control-to-DIMS group

In the Control-to-DIMS group (n=55), myopia progression and axial elongation were significantly different between the 3 years (repeated measures ANOVA, p<0.001). Post hoc analyses indicated that their myopia progression and axial elongation in the third year were significantly decreased compared with the first (mean difference=0.45±0.30D, 0.21±0.11 mm, p<0.001) and second years (mean difference=0.34±0.30D, 0.12± 0.10 mm, p<0.001) (figure 2A).

Table 1 Mean and cumulative changes in the cycloplegic SER and AL from baseline to 36 months in the DIMS group and Control-to-DIMS group

	Mean±SD			
	DIMS (n=65)	Control-to-DIMS (n=55)	DIMS (n=65)	Control-to-DIMS (n=55)
Time (months)	SER (D)		Changes in SER (D)	
0	−2.98±0.96	−2.73±0.99	–	–
6	−3.10±0.97	−3.07±1.02	−0.12±0.30	−0.34±0.33
12	−3.16±0.97	−3.22±1.08	−0.18±0.37	−0.49±0.40
18	−3.23±0.96	−3.41±1.09	−0.25±0.50	−0.68±0.52
24	−3.32±1.00	−3.61±1.15	−0.34±0.52	−0.87±0.59
30	−3.39±1.01	−3.73±1.23	−0.41±0.58	−1.00±0.67
36	−3.50±1.08	−3.65±1.34	−0.52±0.69	−0.92±0.81
Time (months)	AL (mm)		Changes in AL (mm)	
0	24.68±0.82	24.57±0.88	–	–
6	24.72±0.81	24.75±0.89	0.04±0.10	0.18±0.09
12	24.78±0.81	24.86±0.91	0.10±0.14	0.29±0.14
18	24.81±0.81	24.97±0.93	0.13±0.18	0.40±0.18
24	24.88±0.80	25.06±0.96	0.20±0.21	0.49±0.24
30	24.93±0.79	25.12±0.99	0.25±0.24	0.55±0.27
36	24.99±0.80	25.14±1.01	0.31±0.26	0.57±0.33

The grey blocks indicate the period of wearing DIMS lenses in the Control-to-DIMS group.
AL, axial length; Control-to-DIMS, subjects wore single vision spectacle lens during the 2-year randomised controlled trial and switched to wear DIMS lens; D, dioptres; DIMS, defocus incorporated multiple segments; SER, spherical equivalent refraction.

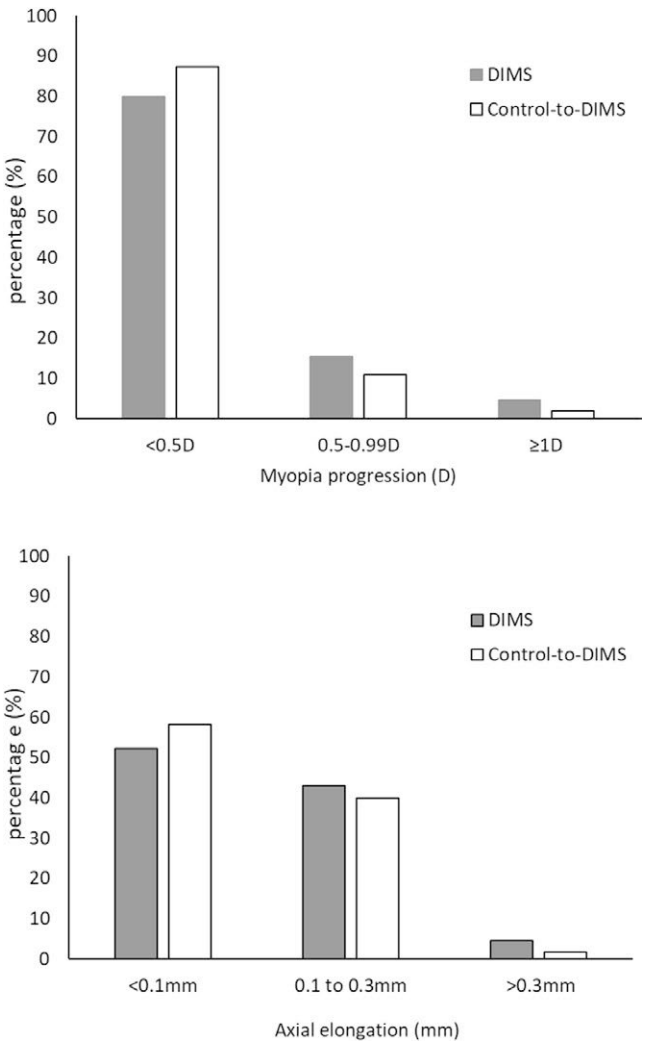

Figure 3 Distributions of myopia progression and axial elongation in the third year. DIMS, defocus incorporated multiple segments.

DIMS compared with Control-to-DIMS in SER and AL changes

There were no statistically significant differences in myopia progression and axial elongation in the third year between the Control-to-DIMS group and the DIMS group ((p>0.05) (figure 2B).

The myopia of 80% of the subjects in the DIMS group progressed by less than 0.5D in the third year, compared with 87% in the Control-to-DIMS group. Only 5% and 2% in the DIMS and Control-to-DIMS groups, respectively, had myopia progression more than 1D. 52% and 58% in the DIMS and Control-to-DIMS groups had axial elongation less than 0.1 mm (figure 3).

DIMS compared with the historical control group in SER and AL changes

The historical control group (n=76, 39 males and 37 females) had a mean age of 12.19±0.71 years, baseline SER and AL were −2.93± 1.33D and 24.77± 0.91 mm. Baseline characteristics of the historical control group did not differ statistically significantly from those of DIMS groups at 24 months (p>0.05) (online supplemental eTable 2).

The 12-month changes in SER and AL in the historical control group were −0.35± 0.40D and 0.18± 0.14 mm. The myopia progression in the DIMS group in the third year was significantly less than in the historical control group (mean difference=−0.18±0.42D, p=0.012). Axial elongation in the DIMS group was also less than in the historical control group (mean differences=0.08±0.15 mm, p=0.001).

Control-to-DIMS compared with the historical control group in SER and AL changes

There were no significant differences between the baseline data of the historical control group and the 24-month data in the Control-to-DIMS group, in terms of age, sex or AL, however, SER was significantly less in the historical control group than in the Control-to-DIMS group (p=0.003), the historical control group having been matched to the DIMS group (online supplemental eTable 3).

The children in the Control-to-DIMS group switched to wear DIMS spectacles in the third year. After adjusting for baseline SER, their myopia progression over that period was significantly slower than in the historical control group (mean differences=−0.30±0.42D, p<0.001). A similar result was found in the AL changes after controlling the cofounding factor (mean differences=0.12±0.16 mm, p<0.001).

DISCUSSION

Myopia progression and axial elongation were less in the subjects wearing DIMS lenses throughout the 3 years, first compared with the initial control group (which subsequently became the Control-to-DIMS group), and then in the last 12 months compared with the historical control group. In the DIMS group, myopia progression and axial elongation in the third year were similar to those in the first and second years (figure 2A—blue line).

Overall myopia progression

The mean changes in SER and AL in the DIMS treatment group over the 3-year period were −0.52±0.69D and 0.31±0.26 mm. These findings are comparable with the corresponding findings in the 3-year trial with dual power contact lenses by Chamberlain *et al*[24] (-0.51±0.64D and 0.30±0.27 mm) and the 3-year trial with multifocal soft contact lenses by Walline *et al*[26] (-0.60D, range −0.72 to −0.47D and 0.39 mm, range 0.32–0.46 mm). Our progression findings were nearly 50% less than reported by Cheng *et al*[19] in a 3-year trial with bifocal and prismatic bifocal spectacle lenses which included subjects with fast myopia progression (−1.25±0.10D for the bifocal treatment group, and −1.01±0.13D for the prismatic bifocal treatment group).

Myopia retardation in DIMS and Control-to-DIMS groups

The mean changes in SER and AL in the DIMS group were −0.18±0.37D and 0.10±0.14 mm in the first year and, −0.17±0.31D and 0.10±0.11 mm in the second year. In the first 2 years, myopia progression and axial elongation in the DIMS group were retarded by 0.53D and 0.29 mm compared with the original control group.

The mean annual SER and AL changes in the historical control group aged from 10 to 15 years were −0.35D and 0.18 mm; when compared with the DIMS group's third year changes in SER and AL, myopia progression and axial elongation in the DIMS group were retarded by 0.18D and 0.08 mm, respectively (figure 2B). The overall 3 years control effect in the DIMS group would be myopia retardation by 0.71D and AL decrease by 0.37 mm.

Cheng *et al*[19] reported that in a selected group of fast progressing myopic children wearing executive top bifocal spectacles with and without prisms, lowered myopia progression by 0.81D and 1.05D compared with SV spectacle lenses wearing children. Chamberlain *et al*[24] showed that a dual power soft contact lens significantly slowed myopia progression by 0.73D in children of various ethnicity aged 8–12 years. Walline *et al* reported in their BLINK clinical trial that children wearing high add power (+2.50D) multifocal contact lenses had 0.46D less myopia progression over 3 years.[26] The reduction of myopia progression by the wearing of DIMS lenses is comparable to the findings from these studies using bifocals, dual focus and multifocal soft contact lenses.

The subjects in the Control-to-DIMS group showed significant reductions in myopia progression and axial elongation after switching from SV to DIMS lenses wear (figure 2B). Their changes in SER and AL in the third year were comparable to the first-year changes in the DIMS group, even though these subjects were 2 years older. In comparison to the historical control group, their myopia progression and axial elongation in the third year, after adjustment were reduced by 86% and 61%, respectively.

In the third year, more than 80% of the Control-to-DIMS children had myopia progression less than 0.5D, and approximately 70% showed progression less than 0.25D. All these findings suggested that the myopia control effect was achieved even though the subjects started to wear DIMS lenses at an older age.

Limitations

A limitation of this study was that the cohort used in the analyses comprised the DIMS plus the Control-to-DIMS groups of children so that the study was no longer randomised. This follow-up study, however, did benefit from the comparison of the third-year myopia progression findings in the DIMS group with the Control-to-DIMS group. While there were no statistically significant differences between the DIMS group and the historical control group at the start of the third year, there was a statistically significant difference in SER between the historical control group and the Control-to-DIMS group at baseline. This was because the historical control group was matched with the DIMS group at 24 months for age and SER and as the Control-to-DIMS group had no treatment in the first 2 years it could be expected to have more myopic SER. Although adjustment was made in the comparison, this approach does not eliminate the effect that can result from known or unknown factors, such as different examiners, the number of myopic parents and time spent on near and outdoor activities, and potentially could lead to selection bias for estimating the treatment efficacy of the DIMS lens.

CONCLUSIONS

The DIMS spectacle lens slowed myopia progression and axial elongation in children throughout the 3 years of study and the myopia control effect was also demonstrated in the Control-to-DIMS group. These findings provided further evidence that DIMS lenses slowed myopia progression and axial elongation in children. The optimal age at which treatment should commence is still to be determined and further monitoring is required to ascertain the treatment effect over a longer period. We also plan to follow up on those children who discontinued wearing the DIMS lenses to determine if rebound occurs.

Acknowledgements HOYA provided the frames and lenses for the study. We are grateful for advice from Professor Marion Edwards. We would like to thank the

employees of Hoya for assisting the ordering and manufacturing of the lenses and Ms Yee Mui Kwok for liaison with the parents.

Contributors Writing—Original Draft: CSYL, WCT; Writing—Review and Editing: CSYL, WCT, PHL; Conceptualisation: CHT, CSYL, HQ; Project administration: CSYL, CHT, KH; Investigation: WCT, HYZ; Methodology: CSYL, CHT, WCT; Visualisation: CSYL, CHT, WCT. All the authors listed have been involved in the undertaking of the clinical trial and follow up study including the conception of the lens design, fabrication of the lens, registration of the clinical trial, preparation of clinical protocol, data collection and analysis, interpretation of the findings and conclusions. A number of manuscripts are now in preparation by the author team.

Funding This was a collaborative research project supported by HOYA, Tokyo, Japan (PolyU grant numbers ZG5N), other PolyU grants: ZVN1, ZVN2, ZE1A, 8-8475, and by an RGC Research Impact Fund: R5032-18. The sponsor also provided specially manufactured spectacle lenses and frames.

Competing interests This collaborative research was supported by HOYA Corporation, Tokyo, Japan. Patents titled 'Spectacle Lens' in China (CN104678572 B) and USA (US10268050 B2) were issued on 27 April 2018 and 23 April 2019 respectively.

Patient consent for publication Not required.

Ethics approval The study obtained the human ethical approval from the Departmental Research Committee of the School of Optometry, The Hong Kong Polytechnic University. The reference number is HSEAR20140630003-03. All aspects of the study met the tenets of the Declaration of Helsinki and were approved by the Human Subjects Ethics Subcommittee of the Hong Kong Polytechnic University (PolyU).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. The primary and secondary outcomes and the baseline demography of the participants in the 2-year RCT and the third year study can be made available. Please contact CSYL at carly.lam@polyu.edu.hk.

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Supplementary content

Title: Myopia Control Effect of Defocus Incorporated Multiple Segments (DIMS) spectacle lens in Chinese children – results of a 3-year follow up study

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Supplementary Results

eTable 1. Demographic data between the subjects who had joined and the subjects who had not joined the third year.

eTable 2. Comparison between the baseline data for the historical control group and the data at 24-month in the DIMS group

eTable 3. Comparison between the baseline data in the historical control group and the data at 24-month in the Control-to-DIMS group.

eTable 1. Demographic data between the subjects who had joined and the subjects who had not joined the third-year study

DIMS group	**joined study (n=65)**	**not joined study (n= 14)**	**p-value (t-test /chi-square test)**
Age at enrolment (years)	10.15 ± 1.52	10.43 ± 1.22	0.521
Sex Male, % (n) Female, % (n)	 57% (37) 43% (28)	 64% (9) 36% (5)	0.612
Baseline SER (D)	-2.98 ± 0.96	-2.93 ± 1.05	0.863
Baseline AL (mm)	24.68 ± 0.82	24.81 ± 0.84	0.594
Myopia progression (D) in previous 2 years	-0.34 ± 0.52	-0.55 ± 0.54	0.177
Axial elongation (mm) in previous 2 years	0.20 ± 0.21	0.27 ± 0.23	0.270
Control to DIMS group	**joined study (n=55)**	**not joined study (n= 26)**	**p-value (t-test /chi-square test)**
Age at enrolment (years)	10.15 ± 1.42	9.83 ± 1.35	0.089
Sex Male, % (n) Female, % (n)	 47% (26) 53% (28)	 62% (16) 38% (10)	0.261
Baseline SER (D)	-2.73 ± 0.99	-2.86 ± 0.91	0.573

Lam CSY, *et al*. *Br J Ophthalmol* 2021;0:1–5. doi: 10.1136/bjophthalmol-2020-317664

Baseline AL (mm)	24.57 ± 0.88	24.73 ± 0.73	0.423
Myopia progression (D) in previous 2 years	-0.87 ± 0.59	-1.01 ± 0.62	0.330
Axial elongation (mm) in previous 2 years	0.49 ± 0.24	0.59 ± 0.23	0.080

eTable 2. Comparison between the baseline data for the historical control group and the data at 24-month in the DIMS group

	DIMS (n=65)	**Historical control group (n= 76)**	**p-value (t-test /chi-square test)**
Age	12.14 ± 1.52	12.19 ± 0.71	0.856
Sex Male, % (n) Female, % (n)	 57% (37) 43% (28)	 51% (39) 49% (37)	 0.506
Baseline SER (D)	-3.32 ± 1.00	- 2.93 ± 1.33	0.054
Baseline AL (mm)	24.88 ± 0.88	24.77 ± 0.91	0.469

eTable 3. Comparison between the baseline data in the historical control group and the data at 24-month in the Control-to-DIMS group

	Control-to-DIMS (n=55)	**Historical control group (n= 76)**	**p-value (t-test /chi-square test)**
Age	12.24 ± 1.47	12.19 ± 0.71	0.793
Sex Male, % (n) Female, % (n)	 47% (26) 53% (28)	 51% (39) 49% (37)	 0.722
Baseline SER (D)	-3.61 ± 1.15	-2.93 ± 1.33	0.003*
Baseline AL (mm)	25.06 ± 0.96	24.77 ± 0.91	0.081

*p value <0.05

View Abstract

CONTROL ID: 3711156

SUBMISSION ROLE: Abstract Submission

AUTHORS

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Commercial Relationships Disclosure: Carly Lam: Commercial Relationship(s);Code F (Financial Support):Hoya Corporation, Essilor, Johnson & Johnson;Code P (Patent):co-own patents with Hoya Corporation | Wing Chun Tang: Commercial Relationship: Code N (No Commercial Relationship) | Han Yu Zhang: Commercial Relationship: Code N (No Commercial Relationship) | Dennis Tse: Commercial Relationship: Code N (No Commercial Relationship) | Chi-ho To: Commercial Relationship(s);Code F (Financial Support):Hoya Corporation, Essilor, Johnson & Johnson vision care;Code P (Patent):co-own patents with Hoya Corporation

Study Group: (none)

ABSTRACT

TITLE: Myopia control in children wearing DIMS spectacle lens: 6 years results

ABSTRACT BODY:

Purpose: To evaluate the changes in refraction and axial length for a period of 6 years in children who completed the two-year clinical trial of Defocus Incorporated Multiple Segment (DIMS) lenses.

Methods: Myopic children who had completed the 2-year randomized clinical trial of DIMS lens were included in this follow-up study. Their cycloplegic refraction and axial length (AL) were measured up to 6 years. Children who changed to other myopia control methods were excluded. Participants were divided into 4 groups - Group 1: wore DIMS spectacles for a total of 6 years (include first two years in RCT); Group 2 wore DIMS spectacles in the first 3.5 years and changed to wear SV spectacles afterward; Group 3: wore SV spectacles in the first 2 years of RCT and switched to wear DIMS spectacles afterward; Group 4: wore SV spectacles in the first 2 years of RCT and switched to wear DIMS spectacles in the 3rd year and then switched to wear SV spectacles lens till end of the 6th year. Changes in spherical equivalent refraction (SER) and AL over the 6 years were analyzed and compared.

Results: 90 children completed the data collection at for a period of 6 years. The children in Group 1 (n=36) wore DIMS lenses throughout the study had -0.92 ± 1.15D of myopia progression and 0.60 ± 0.49mm of axial elongation. The mean annual changes were 0.15D and 0.10mm. Group 2 (n=14) stopped DIMS lens wear after the first 3.5 year and showed more myopia progression (mean differences: 0.2D) and axial elongation (0.07mm) than those in Group 1 between year 3.5 to year 6. Children in both Group 3 (n=22) and Group 4 (n=18) who wore the SV spectacles in the first two years and then switched to wear DIMS lens. Their rate of myopia progression and axial elongation decreased after switching to DIMS lens wear. Children in Group 4 exhibited faster myopic progression when they stopped the DIMS lens wear from year 3.5 to year 6.

Conclusions: DIMS lens maintained the effect on slowing myopia progression and axial growth in myopic children over a period of 6 years. When children stopped DIMS lens wear and wore single vision lenses, their myopia progression was faster than the children who continued with DIMS lens wear.

(No Image Selected)

Layman Abstract (optional): Provide a 50-200 word description of your work that non-scientists can understand. Describe the big picture and the implications of your findings, not the study itself and the associated details.: DIMS spectacle lens is found to be effective in slowing myopia control in a 2-years randomized clinical trial. When these children continued to wear the DIMS lens for a period of 6 years, the myopia control effect was sustained that both myopia progression and the axial length changes were similar to the findings in the 2 years RCT.

DETAILS

PRESENTATION TYPE: #1 Paper, #2 Poster

CURRENT REVIEWING CODE: 3410 Myopia: Epidemiology - CL

CURRENT SECTION: Clinical/Epidemiologic Research

Clinical Trial Registration (Abstract): Yes - http://www.clinicaltrials.gov

Other Registry Site (Abstract): (none)

Registration Number (Abstract): NCT02206217

Date Trial was Registered (MM/DD/YYYY) (Abstract): 08/01/2014

Date Trial Began (MM/DD/YYYY) (Abstract): 08/01/2014

Grant Support (Abstract): Yes

Support Detail (Abstract): This was supported by RUQT, 848K, ZVN1 and a collaborative research project supported by HOYA Corporation, Tokyo, Japan (PolyU grant numbers ZG5N and ZGAB). The sponsor also provided specially manufactured spectacle lenses, and frames.

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