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Correction of peripheral myopic defocus with HAL spectacle lenses

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ABSTRACT

Current methods to slow myopia progression based on the theory of peripheral defocus have shown their efficacy when used as spectacle, contact, and orthokeratology lenses. Spectacle lenses with highly aspherical microlenslets (Stellest®) were introduced into clinical practice in 2020, and their efficacy was rated highly in different studies.

AIM: To investigate peripheral defocus imposed by Stellest® spectacle lenses in myopic children.

MATERIAL AND METHODS: Peripheral refraction (PR) was evaluated in 42 children (84 eyes) with low-to-moderate myopia. Patients of Group 1 (42 eyes) were examined under cycloplegic conditions, without correction and with HAL spectacle lenses, in the primary position and different directions of gaze, 15° and 30° temporally (T) and nasally (N) from the fovea. Patients of Group 2 (42 eyes) were examined under mydriatic conditions, without correction and with HAL spectacle lenses, 5°, 10°, 15° nasally and temporally from the fovea, in the different directions of gaze. PR was measured using the Grand Seiko WAM-5500 open-field binocular autorefractor. To calculate peripheral defocus, central (axial) refraction was subtracted from the peripheral spherical equivalent taking into account the +/– sign.

RESULTS: HAL spectacle lenses reduced hyperopic defocus and imposed a myopic one in all tested areas of the near retinal periphery; the differences at N5 and N10 points were statistically significant (p <0.05). At N15 point ocular movements imposed myopic defocus of –0.26 D (p <0.05). There is also a trend towards a decrease in hyperopic defocus at T15 and N30 points.

CONCLUSION: The first study of peripheral refraction with HAL spectacle lenses (Stellest®) helped demonstrate that the lenses imposed myopic defocus on the retinal periphery, with the greatest defocus on the near nasal periphery.

Keywords: myopia; HAL lenses; Stellest; peripheral defocus; peripheral refraction.

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Коррекция периферического дефокуса миопических глаз очковыми линзами HALs

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АННОТАЦИЯ

Современные методы торможения прогрессирования близорукости, основанные на теории периферического дефокуса, показали свою эффективность в формате очков, контактных линз или ортокератологического воздействия. Очковые линзы с высокоасферическими микролинзами HALs (Stellest®) вошли в клиническую практику в 2020 году и получили высокую оценку эффективности в различных исследованиях.

Цель. Исследовать наведённый очками Stellest ® периферический дефокус миопических глаз у детей.

Материал и методы. Периферическую рефракцию (ПР) исследовали у 42 детей (84 глаза) с миопией слабой и средней степени. Пациентам в первой группе (42 глаза) цикл измерений проводился в условиях циклоплегии, без коррекции и в очках HALs, при взгляде прямо и с отклонением взора, в зонах 15° и 30° к виску и к носу от центра фовеа. Во второй группе (42 глаза) с узким зрачком измерения проводили без коррекции и в очках HALs, в зонах 5°, 10°, 15° к носу (N) и к виску (T) от центра фовеа с отклонением взора. ПР определяли с помощью бинокулярного авторефкератометра «открытого поля» WAM 5500 фирмы «Grand Seiko». Для вычисления периферического дефокуса из величины периферического сферэквивалента вычитали значение центральной (осевой) рефракции с учётом её знака.

Результаты. В очках с линзами HALs во всех исследованных зонах ближней периферии сетчатки устраняется гиперметропический и формируется миопический дефокус; в зонах N5 и N10 — достоверный (p <0,05). В зоне N15 при отклонении взора формируется миопический дефокус величиной -0,26 дптр (p <0,05). При этом прослеживается тенденция к уменьшению гиперметропического дефокуса в T15 и N30.

Заключение. Впервые проведённое исследование периферической рефракции в очках с линзами HALs (Stellest®) позволило подтвердить факт наведения этими линзами миопического дефокуса на периферию сетчатки, наиболее выраженного на ближней носовой периферии.

Ключевые слова: миопия; линзы HALs; Stellest; периферический дефокус; периферическая рефракция.

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INTRODUCTION

Current non–surgical methods to slow myopia progression are based on the theory of peripheral defocus. This theory suggests that the eye growth and refractive development are influenced by optical defocus imposed on the retinal periphery, with myopic defocus inhibiting anterior-posterior axis elongation and hyperopic defocus accelerating this process [1–5]. As shown in experimental studies, a peripheral defocus mechanism involves changing the rate of neuromodulator release and proteoglycan synthesis, changing expression of various protein growth factors, activity of metalloproteinases and their inhibitors, and the level of transmembrane proteins in the eye tissues resulting in transformation of the scleral matrix, thereby promoting or inhibiting elongation of the axial length and increase of refractive error [6]. This finding resulted in development of a strategic concept using optical methods to control myopia by imposing relative myopic defocus in the peripheral field of view. These methods, including spectacle, contact, and orthokeratological lenses, have demonstrated their effectiveness in slowing myopia progression compared to traditional monofocal lenses [7–14].

Orthokeratological lenses, multifocal contact lenses, perifocal (Perifocal-M), and defocus incorporated multiple segments (DIMS) spectacle lenses, and lenses with highly aspherical microlenslets (HAL) were designed to impose peripheral myopic defocus on the retina [15–28]. The similar effect was reported with excimer laser treatment of myopia [29–31].

As an optical method of controlling myopia, spectacle lenses have recently attracted a lot of research interest around the world, as they are the most convenient to use in children and offer high compliance. Their wide adoption is expected to reverse the growing myopia pandemic [32, 33].

Since 2015 the Helmholtz National Medical Research Center of Eye Diseases has been diligently investigating peripheral refraction (PR) with Perifocal-M spectacle lenses imposing peripheral myopic defocus. Comprehensive examination of perifocal lenses [34–38] using the proprietary methods [39, 40] demonstrated imposed peripheral myopic defocus (or reduced hyperopic defocus) in myopic eyes with Perifocal-M spectacle lenses both in the primary position (limited head rotation study) and different directions of gaze. The latter is of significant value as, compared to contact lenses, PR with spectacles ocular movements differs from that in the primary position because light rays pass through different areas of the lens with different refractive power.

A new design with highly aspherical microlenslets (Stellest®) was introduced in 2020. Effectiveness of HAL lenses with (Stellest®) in slowing myopia progression has been demonstrated in both foreign and Russian publications [41–44]. There are single reports of PR change over time in uncorrected children while wearing HAL spectacles [17]. A slight decrease in hyperopic defocus was found 15° and 30° of the horizontal meridian in the nasal and temporal regions following 6 and 12 months of full-time spectacle use. However, compared to Perifocal-M spectacles, peripheral defocus with Stellest® spectacle lenses have not been studied, and the nature of PR imposed by these lenses remains unresolved.

AIM: To study peripheral defocus in myopic children without correction and with HAL lenses, at 5° to 30°of nasal and temporal retinal periphery, and in different directions of gaze.

MATERIALS AND METHODS

PR was measured in 42 children (84 eyes) with low-to-moderate myopia. The patients were divided into two groups: Group 1 (42 eyes) was examined under cycloplegic conditions, without correction and with HAL spectacle lenses, in the primary position and different directions of gaze, 15° and 30° temporally and nasally from the fovea center; Group 2 (42 eyes) was examined under mydriatic conditions, without correction and with HALs spectacle lenses, 5°, 10°, 15° nasally and temporally from the fovea center, in the different directions of gaze. Peripheral refraction was determined using the Grand Seiko WAM-5500 open-field binocular autorefractor. The target placed 50 cm from the eyes was marked to fix the gaze in 5°, 10°, 15°, and 30° nasal and temporal positions relative to the center. The distance in centimeters was calculated according to the Bradis tables based on the known length of one leg (50 cm) and the specified angle of deviation. First, refraction was determined in the primary position, then sequentially at each fixation target. In the nasal and temporal directions of gaze, refraction was measured in the nasal and temporal retinal periphery, respectively. Spherical equivalent refraction was calculated in each position. To calculate peripheral defocus, central (axial) refraction was subtracted from the peripheral spherical equivalent taking into account the +/– sign.

RESULTS

Table 1 shows the results of peripheral refraction measurement at 15° and 30° of the horizontal meridian under cycloplegic conditions. Uncorrected PR was determined only with limited ocular movement, since numerous studies have convincingly shown that uncorrected PRs in intact eyes in the primary position (with a head rotation) and different directions of gaze are identical within the 30° periphery [45, 46].

This is impossible with spectacles because the rays pass through different areas of the lens with different refractive power. Of note, the measurement of PR with HAL spectacle lenses is challenging due to multiple microlenses resulting in high cylinder values when refraction is determined through microlenses and, on the contrary, in hyperopic defocus at the points where the measuring beam passed through the monofocal part of the lens. Repeated diligent measurements,

Table 1. Peripheral defocus with and without Stellest spectacle lenses, in cycloplegic conditions, in the different directions of gaze and primary position (with a head rotation)

Group 1 (n 42)	T30°	T15°	N15°	N30°
Cycloplegic, without spectacles (D)	0,7±1,42	0,19±0,74	0,19±0,72*	1,86±1,34
Cycloplegic, with spectacles, in the different directions of gaze (D)	0,58±1,4	0,01±1,0	-0,26±1,22*	1,1±2,46
With spectacles, in the primary position (D)	0,69±1,4	0,27±0,6	0,25±1,9	1,78±1,7

Note: T, measurements at a point relative to the temple from the center of the fovea; N, measurements at a point relative to the nose from the center of the fovea.

* The differences in the parameters are statistically significant (p <0.05).

followed by calculation of the spherical equivalent in each area tested, finally yielded the average values of peripheral defocus (Table 1).

As shown in the table, uncorrected PD was hyperopic in all tested areas and increased from the middle to the far periphery. At N15 point, ocular movements with spectacle correction imposed myopic defocus of –0.26 D (p <0.05). There is also a clear trend towards a decrease in hyperopic defocus at T15 and N30 points. The measurement in the primary position did not reveal the similar changes. This may be associated with challenges when measuring PR with a head rotation, interferences due to the spectacle frame, and resulting errors. Therefore, further measurements were conducted only with ocular movement.

The results of PR evaluation under mydriatic conditions in the near retinal periphery (5° and 10° from the fixation point) are shown in Table 2. Uncorrected defocus was also hyperopic at all points but lower. For instance, at 5° nasal and temporal points, low hyperopic defocus was close to zero and significantly lower than at 15° point in Group 1 (0.06±0.4 at T5 and 0.07±0.3 at N5 vs. 0.19±0.74 at T15 and 0.19±0.72 at N15, respectively). This finding supports the described trend towards an increase in hyperopic defocus to the periphery. PD at 10° was close to that at 15° in Group 1, with average PD at N10 non-significantly lower, and PD at T10 non-significantly higher. Comparing the PD at symmetrical 15° peripheral points gave interesting results. Group 1 and 2 were evaluated under cycloplegic and non-cycloplegic conditions, respectively. Since the targets were at 50 cm from the eye, the fixation was inevitably accompanied by accommodation. The latter is known to change the shape and refractive power of the lens, which also affects peripheral refraction. Any accommodation strain thickens the lens inducing negative spherical aberration which results in hyperopic defocus in the periphery. Comparison of PD at 15° under cycloplegic and non-cycloplegic conditions partially supports this consideration. At T15 point under mydriatic conditions (Group 2), hyperopic defocus was twice higher than under cycloplegic conditions (Group 1: 0.19±0.74). There were no significant differences in the corresponding nasal periphery. The PD measurements in Groups 1 and 2 being performed in different patients certainly limit the data interpretation. Inter-eye comparison of PD under cycloplegic and non-cycloplegic conditions warrants further investigations.

HAL spectacle lenses reduced hyperopic defocus and imposed a myopic one in all tested areas of the near retinal periphery; the changes at N5 and N10 points reached statistical significance (Table 2).

The obtained data showed that individual corrected and uncorrected PD values varied significantly. Individual defocus values obtained with Stellest® spectacle lenses were analyzed both in the primary position and different directions of gaze. With ocular movement, myopic defocus was most common (38 of 42 eyes) in the near nasal periphery. In the near temporal periphery, myopic defocus was observed in half of the examined eyes (21). Myopic defocus at 30° nasal and temporal points with Stellest® spectacle lenses was reported in 25% of eyes (in 9 and 11 eyes, respectively).

In the primary position, myopic defocus imposed by Stellest® spectacle lenses was most common in the near nasal periphery of the retina (in 27 of 42 eyes). In the near and far temporal periphery, it was observed in 13 and 11 eyes, respectively; at N30 point it was reported in 4 eyes.

Table 2. Peripheral defocus under mydriatic conditions in the near area only with ocular movement

Group 2 (n 42)	T15°	T10°	T5°	N5°	N10°	N15°
Uncorrected (D)	0,37±0,8	0,23±0,5	0,06±0,4	0,07±0,3*	0,12±0,6*	0,11±0,7
Corrected (D)	0,04±0,6	–0,01±0,7	–0,03±0,5	–0,19±0,5*	–0,23±0,4*	–0,08±0,7

Note: T, measurements at a point relative to the temple from the center of the fovea; N, measurements at a point relative to the nose from the center of the fovea.

*The differences in the parameters are statistically significant (p <0.05).

Table 3. Peripheral defocus with Stellest® spectacle lenses and ocular movement, *n*=42 eyes. Myopic defocus at different peripheral points (T30: 11 eyes; T15: 21 eyes; N15: 38 eyes; N30: 9 eyes)

Retinal area	T30	T15	N15	N30
Number of eyes with myopic defocus	11	21	38	9

Note: T, measurements at a point relative to the temple from the center of the fovea; N, measurements at a point relative to the nose from the center of the fovea.

Table 4. Peripheral defocus with Stellest® spectacle lenses in the primary position, *n*=42 eyes. Myopic defocus at different peripheral points (T30: 11 eyes; T15: 13 eyes; N15: 27 eyes; N30: 4 eyes)

Retinal area	T30	T15	N15	N30
Number of eyes with myopic defocus	11	13	27	4

Note: T, measurements at a point relative to the temple from the center of the fovea; N, measurements at a point relative to the nose from the center of the fovea.

CONCLUSION

The first study of peripheral refraction with HAL spectacle lenses (Stellest®) helped demonstrate that the lenses imposed myopic defocus on the retinal periphery, with the greatest defocus on the near nasal periphery.

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