Peripheral defocus of myopic eyes corrected with Perifocal-M glasses, monofocal glasses, and soft contact lenses

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The ***purpose*** *of the work was to study peripheral refraction in myopic patients without correction, in soft contact lenses (SCL), in monofocal glasses, and in Perifocal-M glasses.* ***Material and methods.*** *A total of 97 patients (184 eyes) aged 9–18 years with various degrees of myopia were examined. The peripheral refraction was measured using a Grand Seiko WR-5100K binocular open-field autorefractometer without correction, in glasses, and in the SCL. For the deviation of gaze, a nozzle was designed, which was attached to the device stand at a distance of 50 cm from the patient's eyes. On the nozzle, there were 4 marks for fixing the gaze in the position of 15° and 30° to the nose (N) and to the temple (T) from the central position.* ***Results.*** *In patients with myopia of various degrees without correction and with correction by monofocal glasses, hyperopic defocus formed in all zones on average. In eyes that were corrected with SCL and were mildly myopic in all zones, hyperopic defocus was detected. In moderate myopia, myopic defocus was detected in the zones T30° and N30°. With a high degree of myopia, myopic defocus was detected on the periphery in all zones except T15°, reaching -2.23 ± 1.35 D in the T30° zone and -1.56 ± 0.82 D in the N30° zone. In Perifocal-M glasses, myopic defocus formed in mildly myopic eyes: in the T15° zone its value was -0.95 ± 0.12 D, -0.24 ± 0.05 D in the N15° zone, and -1.14 ± 0.13 D in the T30° zone. Hyperopic defocus was observed only in the zone at N30°, and its value was minimal compared to other types of correction which was 0.13 ± 0.05 D. In moderate myopia, myopic defocus was observed only in the zone N15° at -0.28 ± 0.04 D. In all other zones, hyperopic defocus remained, but its magnitude was minimal compared to monofocal glasses: 0.6 ± 0.1 D at T30°, 0.05 ± 0.04 D at T15°, and 0.74 ± 0.11 D at N30°.* ***Conclusion.*** *In relation to peripheral defocus, perifocal glasses have an advantage in correcting myopia of a low and, in part, moderate degree.*

Keywords: myopia, peripheral refraction, defocus, Perifocal-M, soft contact lenses, monofocal glasses.

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Until recently, various methods (or strategies) for the correction of ametropia were focused on refraction in the center (axial), and the peripheral defocus on the retina was not taken into account. However, numerous experimental animal studies [1] and clinical data [2, 3] has shown that the peripheral retina may play an important role in refractogenesis and in the progression of myopia. In particular, it has been suggested that hyperopic peripheral defocus may be a factor stimulating eye growth, while myopic peripheral defocus, on the contrary, inhibits eye growth. Any corrective applications using optical devices or surgical methods can affect not only central but also peripheral refraction (PR), and this should be taken into account in clinical practice.

According to some reports, conventional monofocal glasses for the correction of myopia induce significant peripheral hyperopic defocus in the horizontal plane of adults [4] and children [5]. At the same time, the magnitude of long-range defocusing increases with decreasing scattering lens power and increasing eccentricity. Thus, based on the theory of retinal defocus, an acceleration of eye growth can be potentially expected in standard monofocal glasses. Alternative eyeglass lens' designs were developed to reduce hyperopic defocus or even to create relative myopia at the periphery of the retina, while leaving a clear vision in the fovea [6, 7]. In Russia, such spectacle lenses have been presented and branded as "Perifocal-M". These lenses allow for the differentiating correction of the eyes' central and PR along the horizontal meridian. However, the achievement of the corrective effect from Perifocal-M glasses needs clinical confirmation.

When comparing the PR of moderately and highly myopic eyes in monofocal glasses to the same eyes in soft contact lenses (SCL), the opposite results were obtained: the glasses induced hyperopic defocus, and SCL induced peripheral myopia [8]. Some studies have shown that SCLs reduce relative hyperopic defocus on the periphery [9, 10] and even induce myopic defocus [8, 11]. Meanwhile in other studies, a hyperopic shift on the periphery has been demonstrated [10, 12] or the PR changed [9]. K. Moore et al. showed that SCLs effect of less negative (more positive) changes in spherical aberration (SA) is associated with a smaller hyperopic shift in PR [9]. The optical power of the SCL influenced the change in PR, in contrast to monofocal glasses in which more negative lenses caused a greater myopic shift at the periphery. In the work of E. Kwok et al., correction with standard spherical SCLs in patients with high myopia (-8.31 ± 2.10 D) has been shown to result in a significantly absolute myopic defocusing on the retinal periphery [11]. In different studies, the same SCL model has resulted in opposite changes in the PR [9, 10]. The reasons for this inconsistency may be related to the difference in the methods of measuring the PR, as well as the methods of selecting SCL (lens fit) in different patients. When studying peripheral defocus in relation to any contact lenses, the possible displacement of the lens associated with the rotation of the eye and eyelid movement must be taken into account, as this alone can lead to errors in measurement. The PURPOSE of this work was to study peripheral refraction in patients with myopia without correction, in SCL, in monofocal glasses, and in Perifocal-M glasses.

MATERIAL AND METHODS

A total of 97 patients (184 eyes) aged 9–18 years with myopia of various degrees were examined. All patients were divided into 2 groups. The first group consisted of 22 patients (44 eyes) ranging in age from 10 to 18 years and with myopia of various degrees (on average -5.30 ± 0.33 D). The PR was measured for patients in this group without correction, with SCL correction, and in the patients' monofocal glasses. The second group consisted of 75 children aged 9–14 years with myopia from -1.0 to -6.0 D (average -3.21 ± 0.32 D). The PR was measured in these patients without correction and in Perifocal-M glasses.

PR was determined using a Grand Seiko WR-5100K binocular open-field automatic refractometer. For the deviation of gaze, a nozzle was designed, which was attached to the device stand at a distance of 50 cm from the patient's eyes. On the nozzle, there were 4 marks for fixing the gaze in the position of 15° and 30° to the nose (N) and to the temple (T) from the central position. The distance was calculated in centimeters using the Bradis tables which based on the known length of one side (50 cm) and the deflection angle. The study was performed under cycloplegic conditions. First, refraction was determined when looking straight ahead, and then, when fixating at each of the marks. When looking towards the nose, refraction was measured in the nasal periphery of the retina; when looking towards the temple — in the temporal periphery of the retina. In each position, a spherical equivalent of refraction was calculated. To calculate the peripheral defocus, the value of the central (axial) refraction was calculated from the value of the peripheral spherical equivalent, taking into account its sign (in other words, an algebraic difference was obtained, for example: -4.0 - (-5.0) = + 1.0 D hyperopic defocus). The Perifocal-M glasses study was performed with the head turning in the direct direction of the gaze in order to preserve the natural conditions of the peripheral defocus which is induced by the glasses when the patient looks into the distance.

RESULTS

The results of the study showed that patients in the first group with myopia which was not corrected had formed hyperopic defocus in all zones on average. Hyperopic defocus grew from the center to the periphery. On average, the spherical equivalent equaled the following: 0.53 ± 0.07 D in the T15° zone; 0.51 ± 0.09 D in N15°; 1.15 ± 0.25 D in T30°; 2.55 ± 0.18 D in N30° (Table 1). The hyperopic defocus was greatest in the nasal periphery of the retina — in the N30° zone.

When myopia was corrected by SCL, hyperopic and myopic defocus formed. The hyperopic defocus of spherical equivalent averaged 0.71 ± 0.09 D in the T15° zone; 0.26 ± 0.1 D in N15°; myopic defocus by the sphere equivalent averaged -1.47 ± 0.57 D in the T30° zone; -0.32 ± 0.44 D in the N30° zone (Table 1).

With myopia corrected by monofocal glasses, hyperopic defocus formed in all zones. Hyperopic defocus grew from the center to the periphery and the spherical equivalent averaged 0.54 ± 0.07 D in the T15° zone; 0.31 ± 0.12 D in N15°; 1.15 ± 0.23 D in T30°; 1.82 ± 0.19 D in N30° (Table 1). The hyperopic defocus was greatest in the nasal periphery of the retina, in zone N30° (Table 1).

In the second myopic group without correction, hyperopic defocus formed in all zones on average. The magnitude increased from the center to the periphery and equaled 0.36 ± 0.03 D in the T15° zone; 0.25 ± 0.04 D in N15°; 2.01 ± 0.15 D in T30°; 1.76 ± 0.12 D in N30° (Table 2). The hyperopic defocus was greatest in the temporal periphery of the retina — in the T30° zone.

Myopic defocus formed in the Perifocal-M glasses: in the T15° zone, the defocus was -0.05 ± 0.01 D, in N15° -0.25 ± 0.04 D; and in the T30° zone -0.44 ± 0.03 D. In zone N30°, the hyperopic defocus remained; however, its value decreased 4.6 times and averaged 0.38 ± 0.03 D (Table 2).

The following data was obtained in a comparative assessment of defocus in patients of group 1 with varying degrees of myopia (Table 3). As can be seen in table 3, on average, hyperopic defocus was noted in all zones of eyes which developed varying degrees of myopia and acquired no correction. Hyperopic defocus grew from the center to the periphery and reached maximum values at high degrees of myopia.

In mildly myopic eyes with the SCL correction, hyperopic defocus was detected in all zones. In moderate myopia, myopic defocus was detected in the zones T30° and N30°. With a high myopic degree, the myopic defocus was enhanced on the periphery, reaching -2.23 ± 1.35 D in the T30° zone and -1.56 ± 0.82 D in the N30° zone. At the same time, a mild myopic defocus appeared in the paracentral nasal zone of the retina (N15°). It is apparent that this effect could be explained by the design features of the SCL which gradually increase in thickness towards the paracentral section so that the refraction of the rays passing through these sections are intensified when the gaze is averted. Thus, with high myopia, SCL has an effect on the peripheral refraction of the eye similar to the effect of orthokeratology lenses (OK-lenses) and can therefore serve as an alternative to OK-lenses for correcting myopia above 7.0 D. In moderate myopia, myopic defocus in an SCL formed only at the extreme periphery. In low myopic eyes, the defocus remained hyperopic throughout. In these cases, OK-lenses retained a clear advantage over the SCL since it created a significant myopic defocus at 15° and 30° from the center of the fovea [13].

In monofocal glasses, hyperopic defocus was observed in all zones. Higher values were observed in moderate to high myopia. When comparing the peripheral defocus without correction and with correction by monofocal glasses, it is interesting to note that with mild myopia, the value of hyperopic defocus increased by 146 % in T30°, by 250 % in T15°, and slightly decreased in the nasal half (by 43 % in N15° and 23 % in N30°). When correction to moderate myopic eyes was made with monofocal glasses, the size of the initial hyperopic defocus practically did not change. Only with correction of high myopia, the value

Table 1. Parameters of relative peripheral refraction (D) in children of 1st group with various optical corrections (M ± m)

Retinal area	T30°	T15°	N15°	N30°
Without correction	1.15 ± 0.25	0.53 ± 0.07	0.51 ± 0.09	2.55 ± 0.18
Soft contact lenses	-1.47 ± 0.57*	0.71 ± 0.09	0.26 ± 0.1	-0.32 ± 0.44*
Single-vision glasses	1.15 ± 0.23	0.54 ± 0.07	0.31 ± 0.12	1.82 ± 0.19

Note. * — p ≤ 0.05 the difference is significant as compared to single-vision glasses and no correction.

Table 2. Parameters of relative peripheral refraction (D) in children of the 2nd group without optical correction and in Perifocal-M glasses (M±m)

Retinal area	T30°	T15°	N15°	N30°
Without correction	2.01 ± 0.15	0.36 ± 0.03	0.25 ± 0.04	1.76 ± 0.12
Glasses Perifocal-M	-0.44 ± 0.03*	-0.05 ± 0.01*	-0.25 ± 0.04*	0.38 ± 0.03*

Note. * — p≤0.05 the difference is significant as compared to monofocal spectacles and no correction.

Table 3. Parameters of relative peripheral refraction (D) in children of the 1st group with various myopia degree and various correction (M ± m)

Correction	Low myopia n = 18				Moderate myopia n = 28				High myopia n = 30			
Retinal area	T30°	T15°	N15°	N30°	T30°	T15°	N15°	N30°	T30°	T15°	N15°	N30°
Without correction	0.37 ± 0.22	0.06 ± 0.11	0.23± 0.15	1.53 ± 0.46	1.55 ± 0.33	0.59 ± 0.11	0.65 ± 0.14	2.53 ± 0.2	0.99 ± 0.52	0.66 ± 0.11	0.46 ± 0.17	3.03 ± 0.33
In soft contact lens	1.67 ± 0.41*	0.95 ± 0.2**	0.63 ± 0.07*	2.92 ± 0.67°	-1.99 ± 0.38**	0.76 ± 0.13	0.58 ± 0.14	-0.48 ± 0.47**	-2.23 ± 1.35	0.55 ± 0.17	-0.3 ± 0.15*	-1.56 ± 0.82*
Single-vision glasses	0.91 ± 0.28	0.21 ± 0.11	0.13 ± 0.34	1.18 ± 0.27	1.28 ± 0.33	0.66 ± 0.13	0.58 ± 0.16	2.08 ± 0.24	1.11 ± 0.45	0.55 ± 0.07	0.07 ± 0.19	1.77 ± 0.42*

Note. n — number of eyes. * — the difference as compared to no correction is significant, p ≤ 0.05; ** — the difference as compared to single-vision glasses and no correction is significant, p ≤ 0.05; ° — the difference as compared to single-vision glasses is significant, p ≤ 0.05.

of hyperopic defocus decreased significantly, especially from the nasal side: by 11 % in the T30° zone, by 17 % in the T15° zone, by 85 % in the N15° zone, and by 42 % in the N30° zone ($p \leq 0.05$) (see Table 3).

In eyes with low myopia which were corrected with Perifocal-M glasses, myopic defocus was formed in the following zones and values: -0.95 ± 0.12 D in the T15° zone, -0.24 ± 0.05 D in the N15° zone, and -1,14 ± 0.13 D in T30° zone. Hyperopic defocus was observed only in the N30° zone, and its value, 0.13 ± 0.05 D, was minimal compared to other types of correction (Table 4). In moderately myopic eyes, myopic defocus of -0.28 D was observed only in the N15° zone. In all other zones, hyperopic defocus remained; however, its magnitude was minimal compared to the resulting magnitude in monofocal glasses. The values were 0.6 ± 0.1 D in the T30° zone, 0.05 ± 0.04 D in the T15° zone, and 0.74 ± 0.11 D in the N30° zone.

Thus, the study showed that in comparison to other methods of correcting peripheral defocus, the perifocal glasses, Perifocal-M, have a clear advantage. This advantage is particularly evident in eyes with a low degree of myopia.

CONCLUSIONS

1. Different methods of optical correction affect peripheral refraction of the eye in different ways.

2. In monofocal glasses, hyperopic peripheral defocus formed in all the zones that were studied. Compared with the defocus of uncorrected eyes, with monofocal glasses the magnitude of defocus increased significantly in low myopic eyes, remained unchanged in moderately myopic eyes, and decreased slightly in highly myopic eyes.

3. In SCL, hyperopic defocus increased sharply in all zones of eyes with low myopia. With moderate myopia, it remained unchanged in the middle periphery, and myopia formed in the 30° zone. When high degrees of myopia were corrected with SCL, myopic defocus formed in all zones except in the middle periphery of the temporal half of the retina where hyperopic defocus remained unchanged.

4. When low myopic eyes were corrected with Perifocal-M glasses, myopic defocus formed in all zones, except for the extreme nasal periphery where hyperopic defocus was insignificant and reduced by 8.6 times from the initial measurement. Moderately myopic eyes in Perifocal-M glasses formed myopic defocus on the middle nasal periphery; in the remaining zones, the initial hyperopia significantly reduced by 3.7–10.6 times.

5. In relation to peripheral defocus, Perifocal-M glasses have an advantage in correcting myopia of a low and, in part, moderate degree.

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Table 4. Parameters of relative peripheral refraction (D) in children of the 2nd group with myopia of various degrees without correction and in glasses Perifocal-M (M ± m)

Retinal area	Low myopia n = 88				Moderate myopia n = 62			
	T30°	T15°	N15°	N30°	T30°	T15°	N15°	N30°
Without correction	1.45 ± 0.17	0.25 ± 0.05	0.20 ± 0.05	1.12 ± 0.12	2.84 ± 0.23	0.53 ± 0.06	0.31 ± 0.08	2.71 ± 0.22
Perifocal-M glasses	-1.14 ± 0.13*	-0.95 ± 0.12*	-0.24 ± 0.05*	0.13 ± 0.05*	0.6 ± 0.1*	0.05 ± 0.04*	-0.28 ± 0.04*	0.74 ± 0.11*

Note. n — number of eyes. * — the difference as compared to no correction is significant, $p \leq 0.05$.

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