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Multifactorial mechanisms of the therapeutic effect of perifocal glasses (Perifocal-M) on the progression of myopia in children



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The article discusses in detail the multifactorial mechanisms of the effect of glasses with perifocal defocus on the progression of myopia in children. The impact on the local retinal mechanisms of neuroregulatory control of eye growth is currently the most effective in preventing the development and progression of myopia. Optical correction of relative peripheral hyperopia with the formation of peripheral myopic defocus affects the manifestation of the biochemical cascade from the retina to the choroid and to the sclera, which restrains the growth of the eye. Optical methods of myopia control, including glasses, are widely used in domestic and foreign ophthalmic practice. Glasses with Perifocal-M lenses have been used in Russia since 2011, providing greater functionality of impact on the myopic eye in comparison with foreign counterparts. The design features of such spectacle lenses have a complex effect on different optical and physiological structures of the eye, each of which contributes to refractogenesis. Perifocal glasses take into account the features of the central and peripheral refraction characteristic of the myopic eye along the horizontal and vertical meridians. They have a stronger horizontal refraction, which eliminates the optical imbalance characteristic of the myopic eye and creates an emmetropic optical profile. The design of perifocal spectacle lenses allows you to correct the relative peripheral hyperopia, create a myopic defocus in the horizontal meridian, influence the ratio of the refraction values of the nasal and temporal half of the retina. This is due to the earlier onset and more pronounced optical impact on the nasal half of the retina relative to the temporal. Glasses with perifocal defocus induce positive spherical aberration in the eye, increase the accommodative ability of the eye, maintain high binocular visual acuity, improve binocular interaction when working close, and prevent the development of heterophoria. The optical properties of Perifocal-M glasses create conditions for a multifaceted functional effect on various structures of the eye, which leads to restraint of the process of myopia progression. Glasses with perifocal defocus induce positive spherical aberration in the eye, increase the accommodative ability of the eye, maintain high binocular visual acuity, improve binocular interaction when working close, and prevent the development of heterophoria. The optical properties of Perifocal-M glasses create conditions for a multifaceted functional effect on various structures of the eye, which leads to restraint of the process of myopia progression. Glasses with perifocal defocus induce positive spherical aberration in the eye, increase the accommodative ability of the eye, maintain high binocular visual acuity, improve binocular interaction when working close, and prevent the development of heterophoria. The optical properties of Perifocal-M glasses create conditions for a multifaceted functional effect on various structures of the eye, which leads to restraint of the process of myopia progression.

keywords: myopia, progression of myopia, prevention of myopia, peripheral refraction, myopic defocus

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Multi-Factoral Mechanisms of Therapeutic Effect of Perifocal Spectacles (Perifocal-M) on Progressive Myopia in Children

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There is a detailed review of multi-factoral mechanisms of spectacles with peripheral defocus influence in children with progressive myopia in this article. At present local retinal mechanisms of neuro-regulatory control of eye growth are most effective in prevention of myopia development and progression. Optical correction of relative peripheral hyperopia with following peripheral myopic defocus affects the biochemical cascade from retina to choroid and sclera, which constrains an eye growth. Optical methods of myopia control, including spectacles, widely used in native and foreign ophthalmology practice. Since 2011, in Russia Perifocal-M spectacles are using, said spectacles provides bigger functionality of influence on myopic eye comparing to foreign analogues. Construction features of said spectacle lens have a complex influence on different optic-physiological eye structures and each of said structures affects refractogenesis. Perifocal spectacles takes into account specific for myopic eye features of central and peripheral refraction along horizontal and vertical meridians. They have stronger refraction in horizontal, which allows to eliminate specific optical disbalance in myopic eye and to create optical balance in the eye. Perifocal-M lens construction with asymmetric horizontal progression allows to correct relative peripheral hyperopia, to create myopic defocus in horizontal and to affect relations between refraction of nasal and temporal halves of retina. The latter is due to the fact that optical influence starts earlier and has bigger effect on nasal half of retina relative to temporal. Perifocal spectacles are inducing positive spherical aberrations in the eye, increasing accommodation functions, supporting high binocular visual acuity, improving binocular interaction during near work, fighting against heteroforias. Thus, optical features of Perifocal-M spectacles for the first time creates conditions for versatile functional influence on main myopogenic factors simultaneously, it effectively stops myopia progression.

Keywords: myopia, progressive myopia, myopia prevention, peripheral refraction, myopic defocus**For citation:** Ibatulin RA, Proskurina OV, Tarutta EP Multi-Factoral Mechanisms of Therapeutic Effect of Perifocal Spectacles (Perifocal-M) on Progressive Myopia in Children. *Ophthalmo-logy in Russia.* 2018; 15 (4): 433-438. https://doi.org/10.18008/1816- 5095-2018-4-433-438

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At the 16th International Myopia Conference (IMC), held in September 2017 in Birmingham (Great Britain), it was once again noted that local retinal mechanisms of neuroregulatory control of eye growth in model experiments on animals, previously identified by J. Wallman [1], have now been widely confirmed in clinical practice. Methods affecting these mechanisms proved to be the most effective in preventing the development of myopia [2, 3]. Optical correction of relative peripheral hyperopia with the formation of peripheral myopic defocus affects the manifestation of the biochemical cascade from the retina to the choroid and to the sclera, which inhibits the growth of the eye. Optical methods of influencing progressive myopia by creating a peripheral myopic defocus are widely used in foreign and domestic ophthalmological practice. In this case, both contact methods [4–6] and spectacle correction [7, 8] are used.

Modern possibilities of optical production, in particular, free form technologies, allow creating new designs of free non-axisymmetric forms of optical surfaces, which predetermined the the appearance of new spectacle lenses for myopia control, providing differentiated correction of axial and off-axial refraction. Currently, three lenses of this type are best known in world practice.

Since 2011, mainly in Southeast Asia, the Myovision radial progression lens has been used, in the creation and study of the effectiveness of which the famous Australian scientist participated B. Holden. The design feature of this lens is a central aperture of stable refraction with a diameter of 20 mm with an additional positive refraction of 1.9 diopters at the periphery 25 mm from the optical center. The lens design is asymmetrical, with lens separation for the right and left eyes. The results of a study conducted in 2009, in which 210 children participated, showed that in the treatment group during the year the progression of myopia according to the data of refractometry and measurement of the PZO was 30% less than in the control group [9] ... The authors also noted that the greatest effect of restraining the progression of myopia when using glasses with Myovision lenses was in children of myopic parents.

At the above-mentioned XVI International Conference on Myopia (The 16th International Myopia Conference, IMC), in the section on optical methods of con-

Troll myopia, CSY Lam, T. Chi-ho and HG Leong presented the results of clinical studies of the use of a multi-segment lenses in children with progressive myopia. The lens was developed with the participation of specialists from the Hong Kong Polytechnic University. The design features of the lens are in the original approach of creating a rapid progression from the border of 10 mm of the central zone due to numerous point micro-segments with a diameter 1.5 mm, each with an additional refractive power of 3.5 diopters. According to the results of the presented two-year randomized clinical study, which involved 160 children divided into treatment (79 children) and control (81 children) groups, it was noted that children wearing glasses with multisegment lenses had 59% ($p < 0.0001$) less progression according to refractometry data and 60% ($p < 0.0001$) lower axial elongation of the eye in comparison with the control group using glasses with monofocal lenses [10].

Almost simultaneously with the Myovision lens, they began to use the Perifocal lens, developed by a well-known specialist in the field of optical design of spectacle lenses, Professor J. Alonso (University Complutense of Madrid). The optical design features of the Perifocal lens provide more functionality in the impact on the near-sighted eye, in contrast to the described lenses. The optical design of the Perifocal lens provides stable refraction at the geometric center and asymmetric progression of refraction on one side and the other with respect to the vertical passing through the geometric center of the lens. The enhancement of refraction for each side has an asymmetrical origin relative to the geometric center. Refraction along the vertical meridian is comparable in magnitude with refraction in the geometric center. The lens has a nasal and temporal halves relative to the position in front of the eye. The addition in the nose part of the lens begins 6 mm from the optical center, in the temporal part - 4 mm, reaches its maximum value by 25 mm, which is 2.0 diopters in the nasal half, and 2.5 diopters in the temporal half.

The study of the influence of the Perifocal-M lens on the optical system and functions of the eye showed that the optical design of the Perifocal lens creates conditions for influencing various etiopathogenetic factors of myopia [7, 8].

The following mechanisms of the therapeutic effect of Perifocal-M glasses on the progression of myopia in children should be emphasized.

Spectacles with Perifocal lenses take into account the features of the central and peripheral refraction characteristic of the myopic eye along the horizontal and vertical meridians.

The well-known features of the ellipsoidal shape of the myopic eye, in contrast to the spherical shape of the eye in emmetropia, create an optical imbalance in it: along the vertical meridian is mainly determined by the relative peripheral myopia, and the horizontal - the relative peripheral far-sightedness [11, 12]. In this regard, according to the rationale given in the well-known scientific hypothesis*J. Wallman,*the nearsighted eye receives conflicting signals along the vertical and horizontal meridians. The eye will grow axially until the myopic central part of the retina balances the relatively far-sighted periphery, ignoring the relative peripheral myopia along the vertical meridian [1]. Functional and morphological features of the retinal topography also indicate the importance of correcting relative peripheral hyperopia in the horizontal meridian. Thus, the density of cones and ganglion cells decreases at a faster rate towards the periphery along the vertical meridian, in contrast to the horizontal, which reflects the potentially dominant effect of visual signals from the retina horizontally relative to the vertical [1, 13]. The Perifocal lens has stronger horizontal refraction,

Spectacles with Perifocal lenses correct relative peripheral hyperopia and create myopic defocus in the horizontal meridian.

According to the hypothesis *J. Wallman,* typical for close of the small eye, relative peripheral far-sightedness in the horizontal meridian contributes to the disruption of local homeostasis [1]. Research results show that hyperopic defocus in relation to the retina causes thinning of the choroid and lengthening of the eyeball; in turn, myopic defocus causes a thickening of the choroid and a decrease in the axial length of the eye [14]. Clinical studies have shown that the design features of Perifocal lenses correct relative peripheral hyperopia, induce a relative peripheral myopic defocus in the eye or significantly reduce hyperopic defocus [7, 8], which provides conditions for influencing local neuroregulatory mechanisms of eye growth control.

Spectacles with Perifocal lenses affect the ratio of refractive values of the nasal and temporal halves

Studies of off-axis refraction during the period of myopia progression have shown that the ratio of the refraction values of the nasal and temporal halves is asymmetric in most cases, this fact has been noted in numerous works since the first descriptions of the state of peripheral refraction in myopia [15]. As a result of a 24-month clinical study of the dynamics of the state of peripheral refraction in 1531 near-sighted children under the age of 13, it was revealed that a large naso-temporal asymmetry at 30 ° peripheral

baseline refractive index was associated with lower levels of myopia progression in the future [16]. According to the authors, these data can help predict and manage the progression of myopia. In earlier works, it was noted that in the process of myopia progression, according to off-axis refractometry and off-axis biometrics, the refraction of the nasal half of the eye increases more, in contrast to the temporal one [17, 18]. In more myopic eyes, in the case of anisomyopia, a stronger off-axis refraction in the nasal half of the eye relative to the temporal one was also revealed. The author believes that when developing potential methods to combat progressive myopia, it is important to understand the origin of this bias [19]. In model experiments on primates with the induction of myopia by means of two-zone contact lenses, forming a peripheral hyperopic defocus, the development of myopia with naso-temporal asymmetry of refraction and its large increase in the temporal half of the eye was noted. The authors associate the emerging naso-temporal asymmetry of peripheral refraction with eye growth and believe that the resulting asymmetry is a compensatory manifestation of axial eye lengthening [20].

A study of off-axis refraction in emmetropes revealed naso-temporal asymmetry with stronger refraction in the temporal half [21], which is also more typical for eyes with stable myopia, in contrast to eyes at the onset of progression. According to other authors, the detection of a stronger refraction in the nasal half, in contrast to the temporal, may be a predictor of myopia in children who are not yet myopic [22].

Thus, the design features of the Perifocal lens are substantiated, which provide an earlier onset and more pronounced optical effect on the nasal half of the retina relative to the temporal.

In 2014, OOO Art-Optics performed a retrospective analysis of the refractometric data of 46 children aged 7–12 years with myopia from –1.0 to –3.75 diopters, who, while wearing glasses with Perifocal lenses, within 12 months, axial refraction decreased and myopia stabilized (Table 1). The analysis of cycloplegic refraction data before and after wearing glasses with perifocal defocus was carried out by transforming the Fourier of the spherocylindrical component into interconnected vectors in order to reduce the measurement error caused by oblique fall astigmatism and taking into account research data indicating that the retina determines defocus sign along the sagittal focal plane [23]. Available literature data indicate

According to the data given in table 1, in cases of weakening of axial refraction or stabilization of myopia, there is an increase in peripheral refraction in the temporal half of the eye and weakening in the nasal half. The results of this study may indicate that glasses with Perifocal lenses create conditions for a change in the ratio of peripheral refraction values between the nasal and temporal halves of the eye, which has a restraining effect on the progression of myopia.

Glasses with Perifocal lenses increase the accommodative ability of the eye (JSC, OAA)

A decrease in the accommodative function of the eye is considered as one of the important factors in the development and progression of myopia in childhood. The results of recent genetic studies have indicated an intriguing dilemma - whether an increase in the sensitivity threshold of the retina by the degree of blurring of the spot is

Table 1. Change aboutff-axis of sagittal focus (RF's) at 30 ° horizontally after 12 months of wearing glasses with monofocal and Perifocal lenses

table 1. Change the off-axis sagittal focus (RF's) to 30 ° horizontally after 12 months of wearing glasses with monofocal lenses and Perifocal lenses

Number of eyes Number of eyes	Right eye, OD			Left eye, OS		
	RF's T30	MC (Sph)	RF's N30	RF's N30	MC (Sph)	RF's T30
	Glasses with monofocal lenses Monofocal glasses					
60	0.2547	- 2.708	- 0.608	- 0.1713	- 2.4267	0.5953
60	- 0.336	- 3.2867	- 1.002	- 0.814	- 3.2413	- 0.3193
	- 0.5907	- 0.5787	**- 0.394**	**- 0.6427**	- 0.8147	- 0.9147
Test Wilcoxon	0.093	0.001	0.018	0.032	0.001	0.058
	Glasses with Perifocal lenses (stabilization cases) Perifocal glasses (stabilization cases)					
92	0.3577	- 2.855	- 0.36 0.2712		- 2.7087	0.5562
92	- 0, 0611	- 2.9688	0.0377 0.3612		- 2.825	0.4437
	- 0.42	- 0.12	**0.4 0.09**		- 0.12	- 0.11
Test Wilcoxon	0.026	0.02	0.013 0.049		0.032	0.057

the main reason for the decrease in the rate of the adaptive response of accommodation [24], or the morphofunctional state of the ciliary muscle is the root cause of accommodation disorders in myopia [25]. In turn, for many years in wide clinical practice, optical-reflex training has been used, which normalizes and improves the state of accommodation [26-29]. These techniques are based on various methods of micro-fogging of the visual image in order to obtain a "response" of accommodation. The optical design of the Perifocal lens creates the conditions for training accommodation. The progression of refraction in opposite directions horizontally relative to the optical center of the Perifocal lens provides conditions when, during voluntary and involuntary versional eye movements horizontally, the visual axis falls into the area of hypocorrection, which serves as a stimulus for the relaxation of the ciliary muscle. Thus, the alternation of vision through a stronger and weaker correction force creates conditions for training accommodation.

Spectacles with Perifocal lenses help to eliminate the stimulus to accommodation from the extra-foveal retina when working close

According to the literature [30, 31], the contour of the retina of the myopic eye does not change during accommodation during close work or even tends to become steeper, which, accordingly, preserves or increases the relative peripheral hyperopia. On the contrary, in the emmetropic eye during accommodation while working in the vicinity, the contour of the retina noticeably changes due to the enhancement of off-axis refraction [31–33]. Preservation of relative peripheral farsightedness in the myopic eye in the horizontal meridian when working near is a stimulus to accommodation, which creates conditions for its excessive stress. According to the literature, the stimulus to the accommodative response from the retinal periphery in the region up to 30 ° from the fovea can be 1.0–2.0 diopters [34]. The Perifocal lens, by correcting peripheral hyperopic defocus, helps to eliminate the non-physiological stimulus to the accommodation response from extra-foveal image focusing.

Spectacles with Perifocal lenses induce positive spherical aberration in the eye

It is known from the literature [35] that the sign of spherical aberration of the eye in children changes with age. Thus, when fixing into the distance in children under 6 years of age, negative spherical aberration prevails. After 6–7 years and throughout life, when fixing into the distance in the eye, only positive spherical aberration prevails, which has a physiological effect on the eye, suppressing its growth and minimizing the tendency to develop myopia [36, 37]. The Perifocal lens, due to the progression of refraction along the horizontal, provides conditions for a stronger refraction of the rays reaching the eye in the region of the pupil edge, which creates a positive sphere an aberration in the eye [8]. When correcting myopia with a monofocal lens, negative spherical aberration is created, which can stimulate axial growth of the eye.

Glasses with Perifocal lenses help maintain high binocular visual acuity, improve binocular interaction when working close, and prevent the development of heterophoria

The movement of the visual axes along the horizontal of the Perifocal lenses with asymmetric addition and with an asymmetric beginning creates, depending on the angle of deviation of the visual axes, monocular micro-blurring of the visual image or, with a small difference, the degree of severity for each eye (binocular micro-fogging of visual images), which causes a soft dissociation of the binocular visual image. Soft dissociation of the binocular visual image, according to the canons of orthoptics and diploptics [38], is a stimulus for enhancing retinal correspondence and the development of bifoveolar fusion, which improves binocular interaction, contributes to the preservation of high binocular visual acuity and prevents the development of heterophoria [8].

Clinical study on the effect of Perifocal spectacle lenses on axial and peripheral refraction in patients with myopia, carried out in 2013–2014 at the V.I. Helmholtz "of the Ministry of Health of the Russian Federation, revealed and confirmed the multifactorial effect of glasses with a Perifocal lens in case of progressive myopia, which helps to stabilize refraction or significantly slow down its progression. During 6 months of follow-up, stabilization of cycloplegic refraction was observed in 16.7% of cases, in 40% of cases - weakening of cycloplegic refraction. After 12-18 months of follow-up, stabilization of cycloplegic refraction occurred in 39.2%, weakening - in 9.8% of cases [7, 8]. According to some data, the effectiveness of glasses with Perifocal lenses in relation to the effect on the progression of myopia is in the range of 49–60% [39].

conclusion

The optical properties of the Perifocal lens create conditions for a versatile functional effect on various systems of the eye, which leads to stabilization or slowing down of refractive enhancement in case of myopia. Glasses with perifocal defocus can be used at any age to prevent the development and progression of myopia, to overcome the habitually excessive stress of accommodation, to improve accommodative functions and binocular interaction.

participation of authors:

Ibatulin R.A. - collection and processing of material, analysis of literature data, writing a text;
O. V. Proskurina - analysis of literature data, text writing; Tarutta E.P. - organization of research, analysis of literature data.

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