CHANGES IN ACCOMMODATION DISORDERS IN CHILDREN WITH ANISOMETROPIC AMBLYOPIA AND HYPERMETROPIA

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ABSTRACT

Background. *Accommodation disorders in children with hypermetropia is one of the main factors in emmetropization disorders and maintenance of image defocusing. The most severe changes in accommodation are observed in children with anisometropia and hyperopia.*
The aim of the work. *To evaluate the changes in the accommodative function of the eye in children with hyperopia, amblyopia, who underwent refractive laser surgery (RLS), as well as in children with spectacle and contact lens correction in combination with pleoptic treatment.*
Material and methods. *Group 1 consisted of 30 children after RLS; group 2 consisted of 29 children who had spectacle correction; group 3 consisted of 26 children who had soft contact lens correction; all children received pleoptic treatment. Clinical examination included the analysis of objective reserves of relative accommodation (RRA) and objective accommodative response (OAR) with an open field autorefractometer, and the results of accommodation measurement.*
Results. *In 1.5 years, statistically significant changes were observed in the coefficient of accommodation response (CAR) of the amblyopic eye between the groups 1 and 2 – 0.12 ± 0.02 and 0.00 ± 0.1 relative units, respectively (p = 0.01). Similar statistically significant changes were obtained in OAR and objective RRA of the amblyopic eye. At the end of the observation, the OAR in the group 1 was -2.1 ± 0.67 dpt, the objective RRA – -2.1 ± 0.67 dpt; in the group 2 the OAR was – 1.38 ± 0.19 dpt (p = 0.01), the objective RRA – -1.38 ± 0.19 dpt (p = 0.01). There were no statistically significant changes in these parameters of the amblyopic eye between the groups 1 and 3.*
Conclusion. *Refractive laser and contact correction provide reduction of accommodative disorders in children with anisometropia, amblyopia and hypermetropia. After RLS there was a tendency to more close to normal CAR, OAR and objective RRA indices due to the reduction of refractive indices of the amblyopic eye.*

Key words: *accommodation, amblyopia, hyperopia, anisometropia, refractive laser surgery*

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ИЗМЕНЕНИЕ НАРУШЕНИЙ АККОМОДАЦИИ У ДЕТЕЙ С АНИЗОМЕТРОПИЧЕСКОЙ АМБЛИОПИЕЙ И ГИПЕРМЕТРОПИЕЙ

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РЕЗЮМЕ

Обоснование. *Нарушение аккомодации у детей с гиперметропией является одним из главных факторов нарушения процесса эмметропизации и поддержания расфокусировки изображения. Наиболее тяжёлые изменения аккомодации наблюдаются у детей с анизометропией и гиперметропией.*
Цель работы*. Оценить изменения аккомодационной функции глаза у детей с гиперметропией, амблиопией, которым была выполнена рефракционная лазерная операция (РЛО), а также у детей с очковой и контактной коррекцией в сочетании с плеоптическим лечением.*
Материал и методы. *В 1-ю группу вошли 30 детей после РЛО, во 2-ю группу –29 детей с очковой коррекцией, в 3-ю группу – 26 детей с контактной коррекцией; все дети получали плеоптическое лечение. Клиническое исследование включало анализ объективных запасов относительной аккомодации (ЗОА) и объективного аккомодационного ответа (ОАО) на авторефрактометре открытого поля, результатов аккомодограммы на аккомодографе.*
Результаты. *Через 1,5 года отмечались статистически значимые изменения коэффициента аккомодационного ответа (КАО) амблиопичного глаза между 1-й и 2-й группами, где он составил 0,12 ± 0,02 и 0,00 ± 0,1 усл. ед. соответственно (p = 0,01). Аналогичные статистически значимые изменения были получены среди ОАО и объективных ЗОА амблиопичного глаза. В конце наблюдения ОАО 1-й группы составил –2,1 ± 0,67 дптр, объективные ЗОА – –2,1 ± 0,67 дптр, во 2-й группе ОАО составил –1,38 ± 0,19 дптр (p = 0,01), объективные ЗОА – – 1,38 ± 0,19 дптр (p = 0,01). Статистически значимых изменений данных показателей амблиопичного глаза между 1-й и 3-й группами зарегистрировано не было.*
Заключение. *Рефракционная лазерная и контактная коррекция обеспечивают снижение аккомодационных нарушений у детей с анизометропией, амблиопией и гиперметропией. После РЛО отмечена тенденция к более близким к норме показателям КАО, ОАО и объективных ЗОА за счёт снижения рефракционных показателей амблиопичного глаза.*

Ключевые слова: *аккомодация, амблиопия, гиперметропия, анизометропия, рефракционная лазерная хирургия*

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BACKGROUND

Refractive anomalies are the primary cause of reduced visual acuity [1]. The prevalence of hypermetropia is influenced by a wide range of factors including ethnicity and socio-economic development [2]. Approaches to laser correction of hypermetropia require a comprehensive evaluation [3]. Hypermetropia correction tactics in children among doctors are ambiguous and include prescribing full and partial inadequate correction. In children with hypermetropia, correction is usually incomplete. Initially, the accommodation of children must overcome small hyperopic errors [4]. As a second, since a fuzzy image stimulates increased accommodation work and thus promotes emmetropisation, full correction may prevent this by removing the tendency of blur to emmetropise [5]. These assumptions have recently been questioned due to lack of objective evidence [6]. Children with moderate to severe hyperopia and amblyopia are not equipped to cope with residual hyperopia and thus are unlikely to be equipped to cope with hyperopia remaining after inadequate correction [7].

Accommodation disorders in children with hypermetropia is one of the main factors in emmetropization disorders and maintenance of image defocusing. The most severe changes in accommodation are observed in children with anisometropic amblyopia and hypermetropia, who develop anisoaccommodation and weakness of accommodation [8]. Contact correction is preferred in these children to avoid persistent functional impairment and to ensure full correction. In contrast to glasses, contact lenses more accurately convey the size of objects and the distance between them, contributing to the formation of a more correct worldview in the child [9]. It should be emphasised that spectacle and contact correction for anisometropia greater than 3 dpt cannot always ensure full rehabilitation of patients both clinically and socially. Therefore, refractive laser surgery (RLS) is one of the promising methods of correction of complex ametropia, which, according to the analysed literature, has proven to be safe and effective.

The issue of studying accommodative changes in hypermetropia, especially in anisometropia, remains incompletely understood. The prevention and rehabilitation of various types of accommodation disorders in children with hyperopic amblyopia and anisometropia also remain poorly studied.

THE AIM

To evaluate changes in the accommodative function of the eye in children with hypermetropia, amblyopia who underwent refractive laser surgery, as well as in children with spectacle and contact correction combined with pleoptic treatment.

MATERIAL AND METHODS

A total of 86 children aged 6 to 15 years with anisometropic amblyopia and hypermetropia were treated and divided into three groups. Group 1 included 30 children after RLS, Group 2 included 29 children with spectacle correction, and Group 3 included 26 children with contact correction. Inclusion criteria for the study were the presence of hypermetropia of 3.0 dpt or more, anisometropia of more than 3 dpt, and visual acuity of the amblyopic eye of 0.05 to 0.3. Children with strabismus were excluded from the sample. No statistically significant changes were revealed between the groups in terms of sex and age. Before and after treatment every 6 months within 1.5 years, all children underwent ophthalmological examination consisting of visometry, determination of retinal visual acuity, autorefractometry, biomicroscopy and ophthalmoscopy; additionally, the state of accommodation was examined in all children: objective relative accommodation reserve (RRA) and objective accommodative response (OAR) were studied on an open-field autorefractometer WR-5100K (Grand Seiko, Japan); accommodation was analysed using Righton Speedy-K (USA).

The OAR study was performed in a contact lens providing full correction of hyperopia, with binocular fixation of the gaze on the target at a distance of 33 cm and recording the results of each eye separately. Objective RRAs were determined by adding negative lenses with a power of -0.5 until no data were recorded close to the OAR.

During the study of accommodation on the Righton Speedy-K accommodationograph (USA), changes in the eye refraction were recorded in the form of a bar chart when a visual stimulus was presented at different distances with fixation of the value of accommodation response coefficients and microfluctuations.

The ethical review of the study was conducted at a meeting of the Local Ethical Committee of the S.N. Fedorov Eye Microsurgery Research Centre of the Ministry of Health of Russia (April 1, 2021, Minutes № 104.7).

Statistical processing of data was performed using Statistica 10 (StatSoft Inc., USA) and MS Excel 2007 (Microsoft Corp., USA) software. Statistically significant differences were determined using the criteria of nonparametric and parametric statistics: the Kruskall – Wallis test was used for independent samples, and the Wilcoxon test was used for dependent samples. A p value of < 0.05 was considered as a condition for determining statistically significant differences.

The uncorrected visual acuity (UCVA) of the amblyopic eye before treatment was 0.09 ± 0.06 in group 1, 0.11 ± 0.07 ($p = 0.24$) in group 2, and 0.13 ± 0.06 ($p = 0.16$) in group 3. Corrected visual acuity (CVA) of the amblyopic eye was 0.12 ± 0.1 in preoperative children, 0.14 ± 0.09 ($p = 0.53$) in spectacle-corrected children, and 0.15 ± 0.08 ($p = 0.49$) in contact-corrected children. Before treatment, the spherical equivalent (SE) of the amblyopic eye was +6.77 ± 1.8 dpt in group 1, +7.13 ± 3.3 dpt in group 2 ($p = 0.21$), and +5.91 ± 2.8 dpt in group 3 ($p = 0.26$). The degree of anisometropia in SE was +4.25 ± 1.4 dpt, +5.7 ± 1.9 dpt ($p = 0.09$) and +4.9 ± 2.4 dpt ($p = 0.32$) in groups 1, 2 and 3, respectively. No statistically significant difference between the refractive indices of the patients

was observed during the analysis using the Kruskall – Wallis criterion, indicating the homogeneity of the three groups. The UCVA and CVA of the paired eye were close to 1.0, and refraction was represented by emmetropia or mild hypermetropia.

RESULTS AND DISCUSSION

Statistically significant changes were revealed after 1.5 years against the background of treatment methods when comparing the three groups. The UCVA of the amblyopic eye was 0.25 ± 0.07 in group 1, 0.12 ± 0.08 in group 2 (p = 0.05), and 0.15 ± 0.05 in group 3 (p = 0.01). The CVA of the amblyopic eye in Group 1 in children after refractive surgery combined with pleoptic treatment reached 0.39 ± 0.04 by the end of the observed period, in the group of children with spectacle correction and pleoptic treatment the ROC was the lowest -0.19 ± 0.08 (p = 0.00), in the group of children with contact correction combined with pleoptic treatment the ROC was 0.31 ± 0.1 (p = 0.06). In the group of children after refractive surgery, the SE

TABLE 1

ACCOMODOGRAM COEFFICIENTS OF THE AMBLYOPIC EYE IN CHILDREN WITH HYPEROPIC ANISOMETROPIA AND AMBLYOPIA IN THREE COMPARISON GROUPS (n = 86)

Indicators	Standard	Groups	Before treatment	6 m	1 year	1.5 years	p_w
CAR, c.u.	0.25–0.65	1st (n = 30)	0.01 ± 0.08	0.06 ± 0.08	0.1 ± 0.06	0.12 ± 0.02	**0.02**
		2nd (n = 29)	–0.03 ± 0.15	–0.03 ± 0.1	–0.02 ± 0.14	0.00 ± 0.1	0.1
		p value	0.09	0.07	0.15	**0.01**	
		3rd (n = 26)	0.05 ± 0.08	0.04 ± 0.12	0.07 ± 0.1	0.08 ± 0.05	**0.04**
		p value	0.35	0.24	0.1	0.06	
SC, c.u.	0.00–0.30	1st (n = 30)	0.24 ± 0.09	0.22 ± 0.06	0.27 ± 0.08	0.23 ± 0.04	0.16
		2nd (n = 29)	0.23 ± 0.12	0.25 ± 0.09	0.25 ± 0.1	0.26 ± 0.12	0.14
		p value	0.34	0.28	0.19	0.3	
		3rd (n = 26)	0.27 ± 0.08	0.24 ± 0.13	0.25 ± 0.12	0.27 ± 0.15	0.31
		p value	0.41	0.25	0.28	0.11	
GC, c.u.	0.60–0.90	1st (n = 30)	0.49 ± 0.06	0.5 ± 0.06	0.53 ± 0.05	0.5 ± 0.02	0.13
		2nd (n = 29)	0.47 ± 0.1	0.5 ± 0.09	0.49 ± 0.07	0.5 ± 0.03	0.11
		p value	0.16	0.49	0.08	0.23	
		3rd (n = 26)	0.51 ± 0.09	0.5 ± 0.12	0.5 ± 0.14	0.52 ± 0.09	0.52
		p value	0.06	0.24	0.17	0.18	
MF, μf/min	up to 57	1st (n = 30)	56.5 ± 4.2	65.6 ± 4.1	63.5 ± 4.1	64.3 ± 2.5	**0.01**
		2nd (n = 29)	55.1 ± 5.1	57.8 ± 3.9	57.4 ± 4.0	59.1 ± 3.5	**0.05**
		p value	0.1	**0.01**	**0.02**	**0.03**	
		3rd (n = 26)	57.4 ± 5.5	59.8 ± 5.0	60.6 ± 4.0	61.5 ± 5.7	**0.03**
		p value	0.12	**0.01**	**0.04**	0.08	

Note. Here and in Table 2: p – Kruskall – Wallis test between groups; P_w – Wilcoxon intra-group criterion; SC – stability coefficient; GC – growth coefficient; MF – microfluctuation factor.

TABLE 2

ACCOMODOGRAM COEFFICIENTS OF THE PAIRED LEADING EYE IN CHILDREN WITH HYPEROPIC ANISOMETROPIA AND AMBLYOPIA IN THREE COMPARISON GROUPS (*n* = 86)

Indicators	Standard	Groups	Before treatment	6 m	1 year	1.5 years	p_w
CAR, c.u.	0.25–0.65	1st (*n* = 30)	0.39 ± 0.11	0.35 ± 0.04	0.41 ± 0.08	0.43 ± 0.1	0.06
		2nd (*n* = 29)	0.35 ± 0.24	0.39 ± 0.15	0.33 ± 0.14	0.34 ± 0.11	0.15
		3rd (*n* = 26)	0.41 ± 0.16	0.39 ± 0.19	0.42 ± 0.14	0.45 ± 0.16	0.07
		p value	0.21	0.18	0.26	0.12	
SC, c.u.	0.00–0.30	1st (*n* = 30)	0.28 ± 0.09	0.25 ± 0.07	0.26 ± 0.13	0.25 ± 0.07	0.24
		2nd (*n* = 29)	0.30 ± 0.07	0.28 ± 0.1	0.27 ± 0.15	0.27 ± 0.13	0.14
		3rd (*n* = 26)	0.27 ± 0.16	0.30 ± 0.12	0.28 ± 0.11	0.28 ± 0.14	0.36
		p value	0.38	0.06	0.09	0.11	
GC, c.u.	0.60–0.90	1st (*n* = 30)	0.51 ± 0.15	0.5 ± 0.08	0.52 ± 0.08	0.5 ± 0.13	0.47
		2nd (*n* = 29)	0.48 ± 0.08	0.49 ± 0.1	0.51 ± 0.08	0.52 ± 0.07	0.06
		3rd (*n* = 26)	0.52 ± 0.09	0.53 ± 0.12	0.53 ± 0.14	0.53 ± 0.16	0.41
		p value	0.16	0.22	0.25	0.09	
MF, μf/min	up to 57	1st (*n* = 30)	64.8 ± 5.2	64.1 ± 2.7	62.8 ± 4.9	60.5 ± 2.4	**0.05**
		2nd (*n* = 29)	65.4 ± 4.1	65.1 ± 4.9	64.4 ± 3.8	64.2 ± 5.5	0.07
		3rd (*n* = 26)	0.24	0.26	0.06	**0.04**	
		p value	63.2 ± 4.7	62.9 ± 3.6	62.5 ± 4.2	62.1 ± 4.4	0.06
		1st (*n* = 30)	0.12	**0.05**	0.18	0.06	

of the amblyopic eye was +1.23 ± 0.11 dpt, the degree of anisometropia according to SE was +1.25 ± 1.4 dpt; in Groups 2 and 3, these values were at baseline; the difference between the groups was statistically significant ($p < 0.001$). Consequently, all three groups observed an increase in visual acuity on the background of the treatment.

The data of the accommodation coefficients of the amblyopic eye are summarised in Table 1, of the leading paired eye in Table 2.

The accomodogram of the amblyopic eye had a gentle course due to a low response to the visual stimulus; «dips» were also recorded, which are the result of the lack of response of the ciliary muscle to the visual stimulus. In the paired leading eye, habitually excessive accommodation tension was registered, manifested by a high number of microfluctuations. Anisoaccommodation was revealed in all children. According to the data of the analysis, in the amblyopic eye there was a statistically significant increase in CAR among patients after refractive laser surgery and in children with contact correction, and in all three comparison groups there was a statistically significant increase in the microfluctuation factor (MF). In the paired leading eye, a statistically significant decrease in MF in children after refractive-laser surgery was found, which is probably related to the increase in corrected visual acuity in the paired amblyopic eye and redistribution of visual load.

According to computerised accommodationography, children in the amblyopic eye showed weakness of accommodation and combined accommodation disorders manifested as low accommodation response coefficient and high microfluctuation coefficient. S.V. Balalin and L.P. Trufanova were among the first to additionally identify this combined type of accommodation disorder [10].

E.G. Solodkova et al. (2019) used an accommodationograph to study changes in accommodation characteristic of children with hypermetropia [11]. According to their study, patients with moderate to severe hyperopia were diagnosed with accommodation weakness with low CAR

and normal MF, and a combination of accommodation weakness with habitual excessive accommodation tension – low CAR with high MF, which is also consistent with our data.

According to the open-field autorefractometer study, the OAR of the amblyopic eye was reduced in all three groups. At the beginning of follow-up, the findings were homogeneous between the groups. In the group of children after RLS the mean value of OAR was -1.1 ± 0.8 dpt, in children with spectacle correction this index was -1.22 ± 0.55 dpt (p = 0.34), in children with contact correction – -1.25 ± 0.23 dpt (p = 0.21). According to the Donders` formula, the norm of accommodative response was -3.0 dpt [12]. After 1.5 years of follow-up, the OAR of the amblyopic eye of group 1 was significantly close to normal and was -2.1 ± 0.67 dpt. The OAR of the 1st group was statistically significantly different from that of the 2nd group, where the OAR of the amblyopic eye was -1.38 ± 0.19 dpt (p = 0.01), in the 3rd group this index reached -1.8 ± 0.4 dpt (p = 0.07). In the paired leading eye, there was a decrease in OAR, but less pronounced compared to the amblyopic eye. Changes in OAR between groups in the paired leading eye as well as in the amblyopic eye were not statistically significant at the beginning of observation. The OAR of the paired leading eye in groups 1, 2 and 3 were -1.9 ± 0.4 dpt, -1.8 ± 0.56 dpt (p = 0.69) and -1.9 ± 0.42 dpt (p = 0.86), respectively. After 1.5 years of treatment, OAR also increased in the paired lead eye; no statistically significant differences between groups were found. In children after RLS this index was -2.4 ± 0.24 dpt, after spectacle correction – -2.2 ± 0.13 dpt (p = 0.11), after contact correction – -2.4 ± 0.24 dpt (p = 0.32).

The values of objective RRA of the amblyopic eye were reduced: in children after RLS and with spectacle contact correction the initial data of objective RRA were close and were -1.0 ± 0.2 and -1.0 ± 0.3 dpt (p = 0.89), respectively; in children with contact correction this index was at -1.2 ± 0.82 dpt (p = 0.54), respectively. Age norms of relative accommodation reserve were determined by E.S. Avetisov and K.M. Matz (1971) as -3.0 ÷ -5.0 dpt [13]. After treatment, objective RRA in children after RLS was -2.1 ± 0.67 dpt, in children with spectacle correction – -1.38 ± 0.19 dpt (p = 0.01), with contact correction – -1.8 ± 0.4 dpt (p = 0.06). Thus, all groups showed an increase in objective RRA of the amblyopic eye; statistically significant changes were observed only between groups 1 and 2. The registration of reduced indices of objective RRA was also revealed in the paired leading eye, which is probably related to the presence of concomitant accommodation. Initial objective RRA data of the paired eye in the group of children after RLS were -2.0 ± 0.48 dpt, in children with spectacle correction -1.8 ± 0.32 dpt (p = 0.34), and in the group of children with contact correction -2.0 ± 0.52 dpt (p = 0.67). After 1.5 years, these values between groups remained approximate and were -2.51 ± 0.31 dpt, -2.0 ± 0.6 dpt (p = 0.09), and -2.38 ± 0.42 dpt (p = 0.12) in groups 1, 2, and 3, respectively.

According to the works of E.P. Tarutta et al. (2012), in hypermetropia and in myopia there is a delay in accommodative response, which increases depending on the degree of ametropia, but in myopia the delay of OAR is stronger than in hypermetropia, and it should be noted that the studies of this group of authors were conducted on children without amblyopia [14, 15].

Therefore, according to the data of the present study, the recovery of accommodation disorders in children after refractive laser surgery and with contact correction were comparable. In the above groups, there was a statistically significant increase in CAR, MF, OAR and objective RRA of the amblyopic eye compared to the group of children with spectacle correction.

CONCLUSION

Refractive laser surgery and contact correction provide reduction of accommodation disorders in children with anisometropic amblyopia and hypermetropia. After refractive laser surgery, there was a tendency to closer to normal values of the accommodation response coefficient, objective accommodative response and objective relative accommodation reserves due to the reduction of refractive indices of the amblyopic eye

Conflict of interest

The authors declare no conflict of interest.

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