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Efficacy of conservative treatment of children with exotropia depending of the baseline status of visual and binocular functions

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Background: *Exotropia is an eye misalignment in which one or both of the eyes turn outward due to congenital or acquired abnormalities of orbital structure, globe structure, extraocular muscle attachment and/or extraocular muscle location. Different treatment modalities are used in the treatment for exotropia: overminus lens therapy, prism therapy, occlusion therapy, extraocular muscle surgery, and orthoptic vision therapy.*

Purpose: *To assess the efficacy of conservative treatment for exotropia depending on the baseline status of visual and binocular functions.*

Material and Methods: *The study sample consisted of 51 patients with exotropia with their age ranging from 10 to 21 years. Of these, 24 (47.05%) had constant exotropia and 27 (52.95%) had intermittent exotropia (IXT). Of the 51 patients, 33 had a hyperopic refractive error of 0.5 to 6.5 diopters (D), and 18, a myopic refractive error of greater than −0.50 D to less than −5.5 D. Of the 51 patients, 27 had mild amblyopia, 22, moderate amblyopia, and 2, no amblyopia. The mean exotropia was 11.8 ± 3.12° by Hirschberg. Patients underwent a routine ophthalmological evaluation. In addition, the near point of convergence (NPC) was determined by the proximeter; the accommodative convergence–accommodation (AC/A) ratio was calculated by the heterophoria method (AC/A = ipd + (phoria at distance – phoria at near)/3, where ipd is the interpupillary distance in centimeters) and expressed in PD/D; fusional reserves were measured using the synoptophore; and binocular vision at distance and near, using the color test. Stereoacuity thresholds were assessed with the Lang-Stereotest II and Titmus Stereo Fly (circles and animals) tests at daylight at a viewing distance of 30 cm, and a Huvitz CCP3100 Chart Projector was used to assess whether stereopsis was present at a 5-m distance. Treatment procedures included optical correction, pleoptics, and direct occlusion in the presence of amblyopia, and orthoptic and diploptic treatment aimed at an improvement and strengthening of binocular functions (synoptophore, binocular vision training, Fialka apparatus, electric stimulation of the medial recti using Amplipuls apparatus, image fusion training using Mirage apparatus, electric stimulation of the medial recti, and computer-aided stereopsis training).*

Results: *The angle of deviation at near and at distance decreased significantly in the constant exotropia group ($p = 0.0001$ and $p = 0.0065$, respectively). In the IXT group, the angle of deviation at distance decreased significantly ($p = 0.0001$), and the angle of deviation at near, not significantly. Binocular vision restored in 38% and 70% of patients in the constant exotropia group and the IXT group, respectively. Convergence and AC/A ratio values improved, but not statistically significantly ($p > 0.05$). Fusional reserves improved significantly, stereo vision restored, and stereopsis at near (stereoacuity threshold as assessed by the Lang II Stereotest) improved in both groups, whereas stereopsis at distance improved only in the IXT group, and was present in 65.6% of patients in this group ($p = 0.01$). In the group with orthotropia after conservative treatment, there were 32/51 children (62.7%) with a deviation less than 6° (12.0 PD). The group with post-treatment exotropia included 19/51 children (37.3%) with post-treatment deviation exceeding 6° (12.0 PD); these children underwent subsequent surgery. The model of conservative treatment success was found to (1) include four variables (the NPC, fusion on the synoptophore, AC/A ratio, and stereoacuity threshold as assessed by the Lang II Stereotest) and (2) to predict the outcome of conservative treatment in 80.9% of cases ($R = 0.80902535$).*

Keywords:
exotropia, conservative treatment, visual functions

Introduction

Strabismus is a condition in which the eyes are out of alignment, with one or both eyes turned in (esotropia), out (exotropia), up (hypertropia) or down (hypotropia), or torsionally misaligned (cyclodeviation), and has a prevalence of 3%–5% in the general population.[1, 2] The deviation may be constant or intermittent. Strabismus is associated with sensory and motor abnormalities of the visual system. Exotropia is an eye misalignment in which

one or both of the eyes turn outward. Exophoria can be caused by congenital or acquired abnormalities of orbital structure, globe structure, extraocular muscle attachment and/or extraocular muscle location [2, 3].

The clinical literature related to five different treatment modalities used for intermittent exotropia (IXT) (overminus lens therapy, prism therapy, occlusion therapy, extraocular muscle surgery, and orthoptic vision therapy) has been reviewed. Based upon review of 59 studies of treatment of IXT, and using each author's stated criteria for success, the following pooled success rates were revealed: over-minus lens therapy (N = 215), 28%; prism therapy (N = 201), 28%; occlusion therapy (N = 170), 37%; extraocular muscle surgery (N = 2530), 46%; and orthoptic vision therapy (N = 740), 59%.[4-6] In most cases, a conservative approach is used for the treatment of IXT or as the preoperative treatment of constant exotropia to improve sensory and motor abnormalities of the visual system and thus facilitate a better outcome of surgery.[7-9]

The purpose of the study was to assess the efficacy of conservative treatment for exotropia depending on the baseline status of visual and binocular functions.

Material and Methods

The study sample consisted of 51 patients with exotropia with their age ranging from 10 to 21 years. Of these, 24 (47.05%) had constant exotropia and 27 (52.95%) had IXT, with the best connected visual acuity (BCVA; mean plus or minus standard deviation (SD)) being 0.81 ± 0.32 and 0.80 ± 0.31, respectively. Of the 51 patients, 33 had a hyperopic refractive error of 0.5 to 6.5 diopters (D), and 18, a myopic refractive error of greater than −0.50 D to less than −5.5 D. Of the 51 patients, 27 had mild amblyopia, 22, moderate amblyopia, and 2, no amblyopia. The mean exotropia was 11.8 ± 3.12º by Hirschberg. Patients with a deviation exceeding 15º for near fixation were excluded from the study.

Patients underwent a routine ophthalmological evaluation. In addition, the near point of convergence (NPC) was determined by the proximeter; the accommodative convergence–accommodation (AC/A) ratio was calculated by the heterophoria method (AC/A = ipd + (phoria at distance – phoria at near)/3, where ipd is the interpupillary distance in centimeters) and expressed in PD/D; fusional reserves were measured using the synoptophore; and binocular vision at distance and near, using the color test. Stereoacuity thresholds were assessed with the Lang-Stereotest II and Titmus Stereo Fly (circles and animals) tests at daylight at a viewing distance of 30 cm, under conditions of best-corrected vision. Moreover, a Huvitz CCP3100 Chart Projector was used to assess whether stereopsis was present at a 5-m distance. Treatment procedures included optical correction, pleoptics, and direct occlusion in the presence of amblyopia, and orthoptic and diploptic treatment aimed at an improvement and strengthening of binocular functions (synoptophore, binocular vision training, Fialka apparatus, electric stimulation of the medial recti using Amplipuls apparatus, image fusion training using Mirage apparatus, computer-aided stereopsis training).[10, 11]

Statistica 8.0 (StatSoft, Tulsa, OK, USA) software was used for statistical analysis. Mean (M) and standard deviations (SD) were calculated for quantitative variables. The level of significance $p \leq 0.05$ was assumed. Analysis of variance (ANOVA) with the Newmans-Keuls multiple comparisons test and Chi-square test were used for group comparisons as appropriate. A multiple regression analysis was used to determine the relationships between the pre-treatment vision characteristics and the outcome of conservative treatment for exotropia.[12]

The study followed the ethical standards stated in the Declaration of Helsinki, the European Convention on Human Rights and Biomedicine and relevant laws of Ukraine.

This study was conducted in the framework of a research program (2017-2019; state register number 0117U004354) aiming to "investigate and determine the role of visual factors (like stereopsis, pupillary responses to light of different spectra, and color perception) and psychophysiological factors (figure-ground discrimination as a component of visual perception) in the assessment of the maturity of the visual system".

Results

The angle of deviation and binocular functions in constant or intermittent exotropia before and after conservative treatment are presented in Table 1. After conservative treatment, visual and binocular functions improved both in the constant exotropia group and the IXT group (Table 1). The angle of deviation at near and at distance decreased significantly in the former group ($p = 0.0001$ and $p = 0.0065$, respectively), whereas in the latter group, the angle of deviation at distance decreased significantly ($p = 0.0001$), and the angle of deviation at near, not significantly. Binocular vision restored in 38% and 70% of patients in the constant exotropia group and the IXT group, respectively. Convergence and accommodative convergence–accommodation (AC/A) ratio values improved, but not statistically significantly ($p > 0.05$). Fusional reserves improved significantly, stereo vision restored, and stereopsis at near (stereoacuity threshold as assessed by the Lang II Stereotest) improved in both groups, whereas stereopsis at distance improved only in the IXT group, and was present in 65.6% of patients in this group ($p = 0.01$). The angle of deviation correlated negatively with the near point of convergence ($r = -0.38$, $p < 0.05$).

Table 2 compares the group with orthotropia after conservative treatment and the group with exotropia after conservative treatment in terms of pre-treatment visual functions.

In the former group, there were 32/51 children (62.7%) with a deviation less than 6º (12.0 PD), pretreatment values of NPC (7.7± 2.28 cm) and AC/A ratio were closer to the norm, and characteristics of stereopsis at near and stereopsis

Table 1. Angle of deviations and binocular function in constant and intermittent exotropia before and after conservative treatment (mean ± standard deviation of the characteristic or percentages and numbers of patients, as appropriate)

Characteristic		Constant exotropia (n=24)		p	Intermittent exotropia (n=27)		p
		Before treatment	After treatment		Before treatment	After treatment	
Angle of deviation at distance (degrees)		11.8±1.39	2.64±3.15	0.0001*	10.88±3.88	0.87±1.39	0.0001*
Angle of deviation at near (degrees)		6.28±5.7	2.7±2.3	0.0065*	1.2±2.5	0.4±0.8	0.1193
Type of binocular vision at a 5-m distance as assessed by the color test	Binocular	–	38% (9)	χ^2=21.8,* p=0.0000	35% (9)	70% (19)	χ^2=7.42* p=0.0065
	Monocular	100% (24)	39% (10)	χ^2=31.4, p=0.0000	25% (17)	5% (2)	χ^2=2.15 p=0.14
	Simultaneous	–	23% (5)	χ^2=21.8, p=0.0000	40% (11)	25% (6)	χ^2=6.86* p=0.008
Accommodative convergence–accommodation (AC/A) ratio (prism diopter/ diopter)		4.89±2.5	4.0± 1.4	0.13	1.9±3.8	2.4±2.2	0.44
Near point of convergence (NPC; cm)		7.7±2.8	7.2±1.5	0.55	6.57±2.4	6.0±1.2	0.27
Fusional amplitude on the synoptophore (prism diopter)		6.5±1.4	8.2±2.4	0.0044*	12.4±3.2	15.2±3.4	0.005*
Lang-Stereotest II (second of arc)	0	100%	40% (9)	χ^2=21.8,* p=0.0000	63% (17)	30% (8)	χ^2=6.03,* p=0.01
	200	–	6% (4)	χ^2=4.36,* p=0.03	7% (2)	25.6% (7)	χ^2=3,33, p=0.06
	400-600	–	43.4% (11)	χ^2=14.27,* p=0.0002	30% (8)	44.4% (12)	χ^2=1.25, p=0.25
Presence or absence of distance stereopsis	Absence	100%	91.7% (22)	χ^2=40.6,* p=0.0000	77.7% (21)	44,4% (12)	χ^2=10.31* p=0.0013
	Presence	–	8.3% (2)	χ^2=2.09, p=0.14	22.3% (6)	65.6% (15)	χ^2=6.01,* p=0.012

Note: n, number of patients; *, significant difference ($p < 0.05$) or $\chi 2$ for $p < 0.05$.

Table 2. Comparing the group with orthotropia following conservative treatment with the group of exotropia following conservative treatment in terms of the status of baseline visual functions (mean ± standard deviation of the characteristic or percentages and numbers of patients, as appropriate)

Characteristic		Orthotropia (n= 32)	Exotropia (n=19)	P
Angle of deviation after treatment (prism diopter)		2.5±3.35	13.0±1.84	0.00001*
Accommodative convergence–accommodation (AC/A) ratio (prism diopter/ diopter)		2.4±1.77	1.98±1.65	0.4
Near point of convergence (NPC; cm)		7.7±2.28	5.4±0.85	0.0001*
Lang-Stereotest II (second of arc)	0	15.5% (5)	45% (9)	χ^2 =6.03*, p=0.02
	200	46.6% (15)	20% (4)	χ^2 =5.14*, p=0.03
	400-600	37.9% (12)	35% (6)	χ^2 =0.18, p=0.66
Presence or absence of distance stereopsis	Absence	65% (21)	100% (19)	χ^2 =21.2,* p=0.0001
	Presence	35% (11)	0	χ^2 =8.33,* p=0.039

Note: n, number of patients; *, significant difference ($p < 0.05$) or χ^2 for $p < 0.05$.

Table 3. Results of Stepwise Multiple Regression for Dependent variable: Outcome of Conservative Treatment for Exotropia

Regression Summary for Dependent Variable: New Var (Spreadsheet1_(Recovered)) R= .80902535 R?= .65452202 Adjusted R?= .64572003 F(4.157) = 74.361						
	Beta	**Std. Err. - of Beta**	**B**	**Std. Err. - of B**	**t (157)**	**p-level**
Intercept			3.308806	0.122898	26.9231	0.000000
Near point of convergence	-1.22273	0.074948	-0.302071	0.018516	-16.3144	0.000000
Fusional amplitude on the synoptophore	1.09695	0.103213	0.241151	0.022690	10.6280	0.000000
Accommodative convergence–accommodation (AC/A) ratio	0.57909	0.084658	0.073957	0.010812	6.8404	0.000000
Lang-Stereotest II	-0.21698	0.047419	-0.000640	0.000140	-4.5758	0.000010

Notes: Intercept, estimation of the independent variable when the dependent variable is zero; Beta, coefficient of the dependent variable; Std.Err.-of Beta, standard error of Beta; B, constant; Std.Err.-of B, standard error of Beta; t (51), criterion for the estimation of a free member of the regression equation for the specified number of degrees of freedom; P-level, P-value for the estimation of a free member of the regression equation for the specified number of degrees of freedom

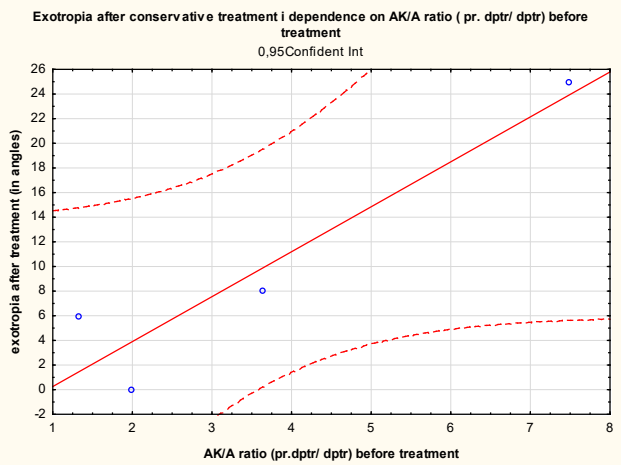

Fig. 1. The relationship between the accommodative convergence–accommodation (AC/A) ratio at baseline and the deviation angle following conservative treatment

at distance were better than in the latter group. In the group with post-treatment exotropia, there were 19/51 patients (37.3%) with post-treatment deviation exceeding 6º (12.0 PD), the mean pretreatment NPC value was smaller than the norm (the difference was not significant p = 0.0001), the mean pretreatment AC/A ratio value was larger than the norm of 5.0 to 6.0 PD/D, stereopsis at distance was not present in any patient, and stereopsis at near was not present in 45% of patients.

Fig. 1 shows the relationship between the pre-treatment AC/A ratio and the post-treatment angle of deviation.

Patients with a pretreatment AC/A ratio exceeding 12.0 ± 3.5 PD/D exhibited no decrease in the angle of deviation after conservative treatment. Of note that a NPC value smaller than 5 cm was more frequently seen in the group with a larger post-treatment angle of deviation (Table 2). Forward Stepwise Multiple Regression [12] was conducted to identify the relationships of the pre-treatment characteristics of visual functions with the favorable outcome of conservative treatment for exotropia (i.e., the dependent variable: 1, a decrease in the angle of deviation to 2.5 ± 3.35 PD) (Table 3).

Four variables (the NPC, fusion on the synoptophore, AC/A ratio, and stereoacuity threshold as assessed by the Lang II Stereotest) remained in the model of conservative treatment success after stepwise data processing; this model enables to predict the outcome of conservative treatment in 80.9% of cases (R= 0.80902535).

Discussion

"In which case can the success of conservative treatment for exotropia be achieved?" is a question that frequently arises in the ophthalmologist's practice. The present study was conducted to answer this question and to assess the efficacy of conservative treatment for exotropia depending on the visual and binocular functions at baseline. The course of treatment included well-known methods mentioned above in the Methods section. We found that treatment success (i.e., orthotropia and a larger decrease in the angle of strabismus after treatment) was achieved in the group with pre-treatment NPC and AC/A ratio values closer to the norm and better values for stereopsis at distance and at near. After treatment, the angle of strabismus decreased and binocular vision restored in 38% of patients with constant exotropia and 77.7% of patients with intermittent exotropia. In addition, the mean decrease in the angle of strabismus in the former patients was 2.64 ± 3.15º, and in the latter patients, 0.87 ± 1.39º.

Based upon review of studies of conservative treatment for exotropia, binocular vision was found to be restored in 59% of patients.[4] Dzelkaleia [8] found that preoperative treatment (including spectacle correction; amblyopia treatment; treatment aimed at the restoration of bifixation; prism-assisted development of fusional reserves; training of binocular vision with the POZB, a special instrument for the development of binocular vision,[1]; and convergence exercises with the help of a special device, a "convergence trainer", allowed to improve abnormalities of convergence in 20/45 patients (44.44%), bifoveal fusion in 18/45 patients (40%), and unstable binocular vision at near in 20/45 patients (33.33%). However, a residual deviation following conservative treatment was present in many patients, which warranted surgery (37.3% of our study sample had surgery for the residual deviation). Others [7, 8] reported that surgery for the residual deviation following conservative treatment was required in 46% and 42.1% of patients, respectively. It has been found that, patients with exotropia will require an average of 2-3 years for the development of binocular vision after the initiation of conservative treatment. To the best of our knowledge, there have been no reports on the prediction of the outcome of conservative treatment for exotropia in the literature. The findings of this study indicate that attention should be given not only to the pre-treatment state of fusion and convergence involved in the control of eye position in exotropia, but also to the state of accommodation, accommodative convergence and stereopsis.

Conclusion

First, multicomponent conservative treatment for exotropia was found to enable (a) a reduction in the angle of strabismus to 2.5 ± 3.35 PD in 62.7% of patients, (b) restoration of binocular vision in 38% of patients with constant exotropia and 70% of patients with IXT, (c) and normal stereoacuity threshold as assessed with the with the Lang-Stereotest II (200 seconds of arc) in 16.6% of patients with constant exotropia and 70% of patients with IXT, and (d) a significant improvement in fusional amplitudes in both groups.

Second, it was for the first time found that pre-treatment NPC values smaller than the norm (5 cm against 6-8 cm), AC/A ratio values larger than the norm of 5-6 PD/D, the absence of stereopsis for distance and high stereoacuity thresholds for near (400 and/or 600 sec of arc) are unfavorable factors for the success of conservative treatment for exotropia.

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Disclosures

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