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CLINICAL AND EXPERIMENTAL
OPTOMETRY

RESEARCH

Combined passive and active treatment in strabismic amblyopia with accommodative component

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Background: Treatment of amblyopia in esotropic subjects with accommodative component currently consists of optical correction and subsequent occlusion, or penalisation, of the dominant eye. This treatment obtains a good outcome in visual acuity but poor outcomes in binocular vision. An intervention protocol that could improve the outcome of conventional treatment is presented.

Methods: A retrospective study in subjects with amblyopia associated with both fully accommodative and partially accommodative esotropia is presented. Subjects were refracted under cycloplegia and treated with occlusion (passive therapy). Subjects who did not achieve orthotropia through optical correction (partially accommodative esotropia) performed an active therapy (full-time prismatic correction and subsequent fusional vergence therapy or surgery in larger angles >12 prism dioptres). After treatment, the subjects were examined by a masked optometrist in an external ophthalmology clinic.

Results: Twenty-six subjects (12 males and 14 females) aged from six to 13 years (median 8.50; interquartile range [IQR] = 3) were included. Median age of detection was three years (IQR 1). All the subjects were hyperopic. In the baseline, median best corrected visual acuity of the amblyopic eye was 0.40 logMAR (IQR 0.30) and 0.00 logMAR (IQR 0.01) in the dominant eye. After the treatment, the median best corrected visual acuity in the amblyopic eye was 0.06 logMAR; IQR 0.08. These differences were statistically significant ($p < 0.001$). All subjects acquired stereoacuity equal or better than 800″ with the Randot Preschool Stereoacuity Test.

Conclusions: The proposed treatment highlights the management of amblyopia in esotropic subjects with accommodative component. This treatment could help to determine if the treatment has to be passive (in fully accommodative esotropia) or a combination of passive and active therapies (in partially accommodative esotropia).

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Strabismic amblyopia is a neural disorder caused by a strabismus during the early critical period of development.[1] Consequently, active suppression in the primary visual cortex occurs to avoid cortical confusion.[2] Binocular presence is anecdotal among these subjects.[3] Difficulties in several areas such as fine motor skills[4,5] and reading[6,7] have been observed in subjects with strabismic amblyopia. These deficits are thought to be due to impaired stereopsis rather than reduced visual acuity.[8,9]

Clinical management of amblyopia in esotropic subjects with accommodative component currently consists of full optical correction and check-up visits to assess visual function and ocular alignment. Where the misalignment is resolved, fully accommodative esotropia is diagnosed; partially accommodative esotropia is diagnosed where partial misalignment persists. Once acuity has stabilised (two follow-up consecutive visits without visual acuity improvements), an occlusion or penalisation treatment is prescribed.[10] Outcomes of this conventional treatment are good in terms of improved visual acuity, but results in terms of binocular vision are only modest,[11] since these treatments fail to resolve either the active suppression in cases of fully accommodative esotropia, or the remaining strabismus under binocular conditions in cases of partially accommodative esotropia.

A number of authors have recently suggested that patients with strabismic amblyopia may be able to develop binocular vision[12,13] and, correspondingly, intervention protocols have been shown to restore simultaneous vision. In these studies, the dominant eye signal was penalised to achieve a balanced binocular response (dichoptic stimulation).[14–16] Notwithstanding, the latest research suggests that, in cases where strabismus is still present, although dichoptic stimulation reduces the extent and depth of the suppression and improves binocular function (restoring simultaneous binocular perception), this recovery is very rarely accompanied by improved stereoacuity.[17,18]

It must also be noted that simultaneous binocular perception should only be attempted in cases where this will not result in diplopia, that is, when the cause of the

suppression has been removed, as in cases of fully accommodative esotropia. The problem of dichoptic stimulation in cases of partially accommodative esotropia, on the other hand, is that we are only treating the consequence, that is, the active suppression, rather than the true cause of the suppression, that is, the remaining misalignment of the strabismic eye. In this regard, Read et al.,[19] point out that normal stereoacuity may require bifoveal fixation, that is, an alignment within 0.6 prism dioptres (Panum's area). Prismatic correction of the strabismic deviation, therefore, could solve the problem, specifically in cases of partially accommodative esotropia, by providing simultaneous bifoveal fixation.[20] The disadvantage of such treatment, although it provides good outcomes in subjects with normal retinal correspondence (without any sensory adaptations), is that the subject is dependent on the prismatic correction to achieve orthotropia, and no solution has yet been able to fully restore binocular vision without the use of prisms.

Our purpose in the present study is to demonstrate that stereopsis can be restored in patients with strabismic amblyopia, specifically when associated to acquired esotropia with accommodative component. Even in those patients with partially accommodative esotropia, stereopsis can be restored without the dependence of prismatic correction. An intervention protocol according to the patient's clinical characteristics was provided. A different combination of passive and active therapies is proposed to restore stereopsis according to the patient's profile: fully accommodative esotropia group versus partially accommodative esotropia group.

Methods

Study design

The present study is a retrospective analysis based on subjects who participated in a subsequent proof of concept study.[21] The study was approved by the Basque Country Ethical Committee of Clinical Research (CEIC-E) (Spain). Participants signed consent forms according to the Helsinki Declaration.

Subjects were previously treated by other practitioners with optical correction and occlusion therapy before our evaluation and came to a second opinion about the diagnosis and treatment. Participants were recruited and initially evaluated at two optometric centres, and were evaluated again at the end of the treatment at an ophthalmology clinic, where a masked optometrist, who was not aware of either the clinical profiles of the subjects or the previous treatment they had received, performed the final evaluation.

Subjects

Study subjects were chosen according to the following selection criteria: subjects with amblyopia previously treated with optical correction and occlusion, difference in logMAR acuity of ≥2 lines, best corrected visual acuity (BCVA) < 0.10 logMAR, and horizontal strabismus diagnosed with the Unilateral Cover Test and accommodative stimulus. In addition, only subjects with normal retinal correspondence (fusion at objective angle in peripheral slides with synoptophore) were included. Subjects with non-comitance (near-distance angle ≥ 5 prism dioptres [Δ]) due to accommodative esotropia with high accommodative convergence/accommodation ratio (AC/A), hypermetropic anisometropia > 3 D (spherical equivalent [SE]) if corrected with spectacles (to prevent aniseikonia), ocular pathology, strabismic surgery, vertical deviations, nystagmus and cognitive delay were excluded from the study.

Clinical evaluation

Visual evaluation included: best corrected distance visual acuity using an Early Treatment Diabetic Retinopathy Study-format logarithmic visual acuity chart (logMAR acuity) with a SIFIMAV Vision Tester; Unilateral Cover Test using accommodative stimuli to determine the presence of strabismus; refractive error by automated refractor under cycloplegia (cyclopentolate 1% and Topcon model TRK 1P); and evaluation of the anterior and posterior segment.

Binocular vision was evaluated using the Worth Four-Dot test and a projector at a distance of four metres in the dark. The results of the test were classified under fusion, suppression and diplopia. A synoptophore (Oculus, Germany) was used to evaluate the fusion capacity at the objective angle of deviation (normal retinal correspondence).

Stereoacuity measurements were analysed according to two different tests. The first was the Randot Preschool Stereoacuity Test (RPST; Stereo Optical, Inc., Chicago, IL, USA); if responses indicated nil stereopsis, stereoacuity was then evaluated with the TNO test (Lameris Intrumenten, Groenekan, The Netherlands) using the first plates (Pages III, IV and V). The manufacturers do not provide the stereoacuity value of these plates; an arbitrary measure of 1,200″ was therefore assigned to obtain a quantifiable value.

Treatment

The treatment included passive therapy and active therapy strategies, following the Suttle revision:[22] passive therapy includes forms of treatment which require no action from the patient; whereas active therapy requires the patient's active participation. Figure 1 summarises the treatment received by the participants between the baseline and the final evaluation.

PASSIVE THERAPY

Optical Correction

Treatment began by determining the patient's optimal optical correction under cycloplegia. Refractive errors were corrected following the Paediatric Eye Disease Investigator Group (PEDIG)[22] with full sphere and cylinder correction under cycloplegia. One month after prescription, the participants' visual acuity and strabismic deviation were checked. If visual acuity of the amblyopic eye improved, the patient was then evaluated again three months later. If visual acuity of the amblyopic eye did not improve at two successive check-ups, then occlusion was prescribed.

Occlusion

Participants were occluded following the PEDIG criteria: six hours in cases of severe amblyopia[23] (visual acuity 0.8 to 1.0 logMAR at baseline), and two hours in cases of moderate and mild amblyopia[24] (visual acuity 0.1 to 0.7 at baseline). Trimestral check-ups were scheduled at the centres which conducted the visual acuity and binocular vision tests (Worth Four-Dot test and stereoacuity). Occlusion was discontinued when the participant achieved a minimum logMAR visual acuity of 0.10 in the amblyopic eye.

ACTIVE THERAPY

If the strabismic deviation was present after optical correction (partially accommodative esotropia), the subject received complementary active therapy treatment.

MONOCULAR THERAPY

During the occlusion period, participants had to perform activities that demanded

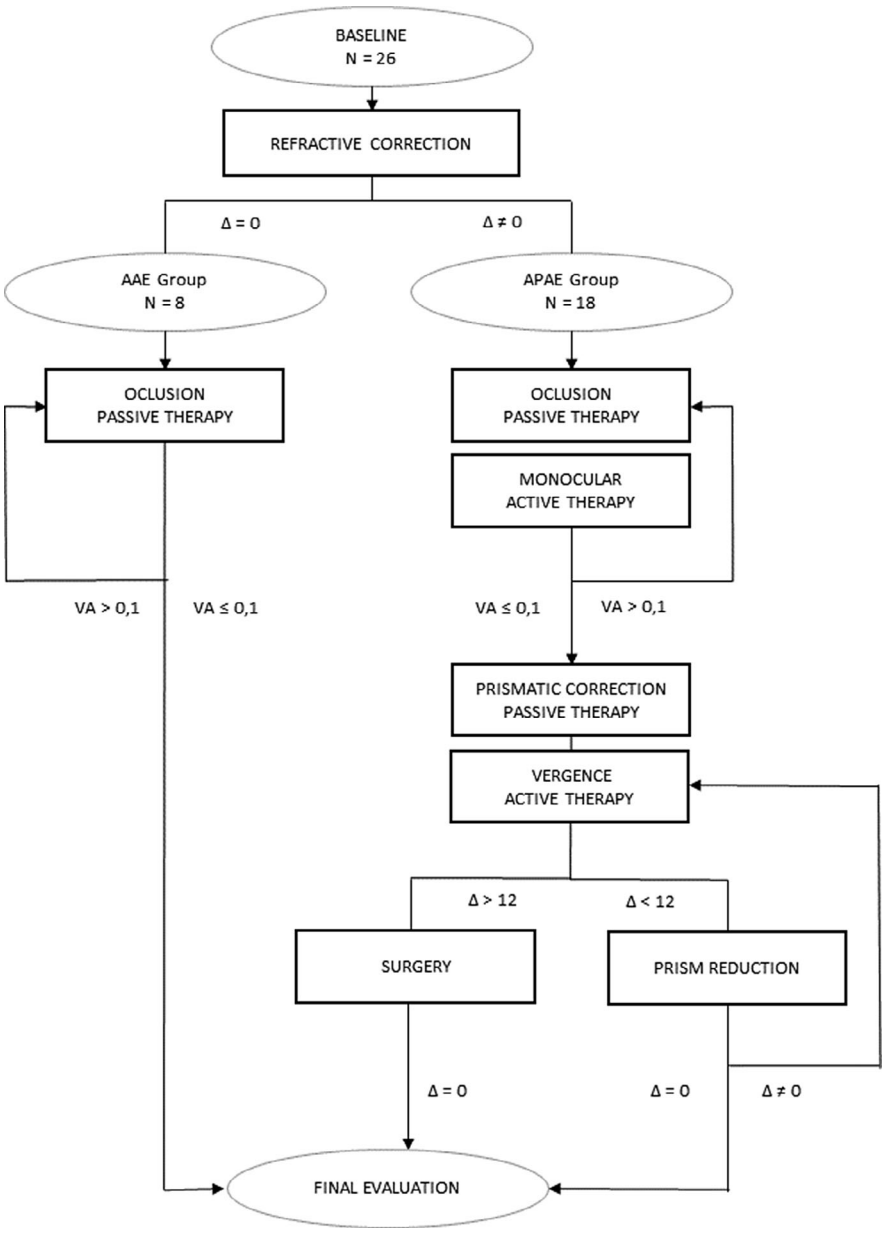

Figure 1. Scheme showing the study protocol. Abbreviations: Δ: esotropia in prism dioptres, AAE: acquired accommodative esotropia, APAE: acquired partially accommodative esotropia, VA: visual acuity.

their attention. In addition, participants were cited at the optometric centre one day a week to perform supervised active therapy by an optometrist. These procedures consisted of exercises involving accommodative and anti-suppression therapy following 'In-office Vision Therapy Manual of Procedures'[25] proposed by PEDIG.[26] The suppression was only treated in patients with normal retinal correspondence where the cause of the misalignment was able to be resolved with prisms.

PRISMATIC CORRECTION AND FUSIONAL VERGENCE THERAPY

Magnitude of prismatic correction was obtained using the Unilateral Cover Test, accommodative stimulus (visual acuity two lines higher than amblyopic visual acuity) and a prism placed in front of the dominant eye. All the magnitude was corrected. All subjects showed normal retinal correspondence, indicating that prismatic correction also provided simultaneous vision. Fresnel prisms were used in all cases.

In subjects with esotropia ≤ 12 prism dioptres (Δ), the prismatic correction was placed in front of the dominant eye. Where the esotropic deviation was > 12Δ, the prismatic correction was split between both eyes with the following criteria: the prismatic power in front of the dominant eye would be twice that in front of the amblyopic eye. A prism adaptation test was then performed to assess the viability of the prismatic correction.[27] This procedure consisted of testing if the subject tolerated the prism or the deviation appeared after a period of time. These subjects were required to wear the prismatic correction on a full-time basis.[28]

Since all subjects achieved binocular vision with the prism correction, treatment was complemented with fusional vergence therapy using a computer program in Random Dot format with anaglyph glasses (VisionBuilder Version 2.7 for Windows, Haraldseth Software, Hamar, Norway). VisionBuilder has two program versions, Office and Home. We used the Office version to measure negative fusional vergence at both optometric centres; and the Home version to strengthen negative and positive fusional vergence in the patient's home. In both cases, the distance was set to 40 cm, and participants were required to do the exercises at home for 16 minutes a day, five days a week.

Fusional vergence exercises (convergence or divergence) followed the same procedure with opposite disparity. A random dot cross shape with a hidden circle was presented at zero disparity (Figure 2). Stereoscopic demand and dot size were adjusted to ensure the patient was able to perceive the position of the hidden circle. Each time the patient selected the right answer, the vergence demand (positive or negative) was increased by one step. When the patient selected an incorrect answer, the vergence demand was reduced by four steps.

Fusional vergence therapy using the computer at home was complemented with monthly sessions at the optometric centres. Different orthoptic instruments (anaglyphic slides, vectograms and stereoscopes) were used at these sessions.[26] In addition, binocular vision at the objective angle was stimulated with the synoptophore.

PROGRESSIVE REDUCTION OF PRISMATIC POWER AND SURGERY

In participants with a strabismic angle ≤ 12Δ, a progressive reduction of prismatic power was performed. The following criteria to change the prismatic correction were chosen:

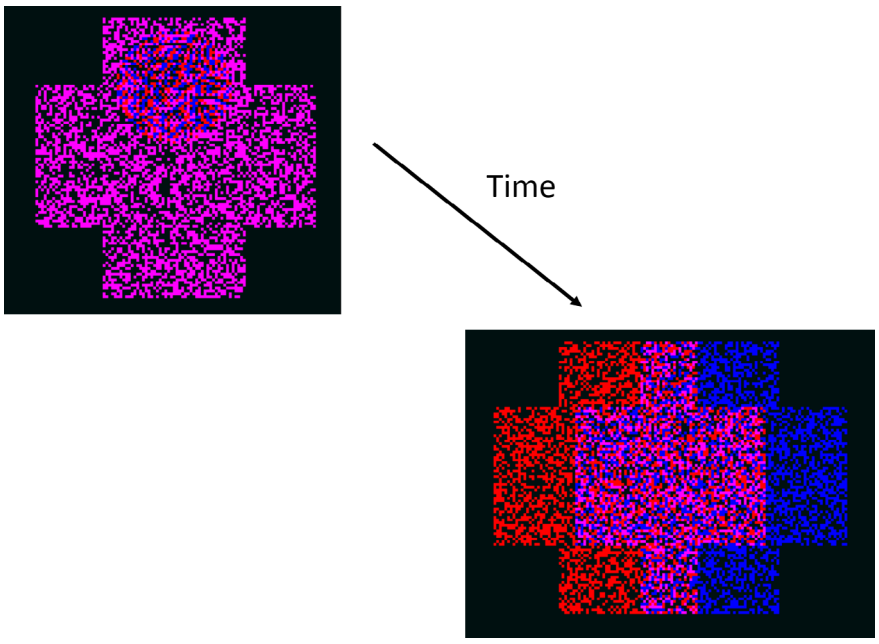

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Figure 2. Logical process of the game. The subject has to pinpoint a ball which is situated on one of the four extremes of a cross (top, bottom, right or left). The program automatically adjusts the vergence difficulty during the training session. If the patient's response is correct, the software will split the image into two anaglyph crosses which the subject must merge using their own vergence system. If the patient fails to respond correctly, the two crosses are merged by the program.

a change in the prismatic power was considered when the subject was able to diverge ≥ 4Δ over their prismatic correction with the computer software. The amount of prismatic reduction was equal to half the divergence capacity. For example, if a participant with esotropia compensated with an 8Δ Fresnel prism was able to diverge 6Δ, the new Fresnel prism would be 5Δ. The Fresnel prism was then changed, and the participant had to achieve orthotropia with the new prismatic correction. The ultimate objective was to achieve orthotropia without any prismatic correction.

In subjects with a larger strabismus angle (> 12Δ), surgery was required to eliminate prismatic correction. The ultimate objective of the fusional vergence therapy was to obtain a fusional vergence range of around 10Δ before surgery. Surgical planning took into account the prismatic correction (stable deviation angle) and the vergence amplitude (capacity to compensate the post-surgical deviation).

Statistical analysis

Statistical analysis of the results was performed using SPSS for Windows, Version 19.0 (SPSS Inc., Chicago, IL, USA). According to the Kolmogorov–Smirnov test, the studied parameters followed a non-normal distribution, and non-parametric tests were therefore applied. All descriptive variables were presented as median ± interquartile range (IQR). All statistical tests were two-tailed, and findings were considered significant at $p < 0.05$.

Comparisons between pre- and post-refraction, pre- and post-treatment outcomes have been analysed by the Wilcoxon test. An additional comparison between groups (occlusion alone versus occlusion plus active therapy) was analysed by the Mann–Whitney test.

The effectiveness of the proposed treatment was evaluated by means of objective refraction, BCVA and stereoacuity. To better analyse binocular vision changes, binocular function (BF) was used to describe the degree of binocularity, as proposed by Webber et al.[29] If stereopsis was not measurable on the Random Dot test but the child did not suppress on the Worth Four-Dot test (that is, they reported four lights), a log threshold of four was recorded. If the child reported only two red or three green lights on the Worth Four-Dot test, they were deemed to have complete suppression (recording a log threshold score of five). Assigning a value to represent the presence or absence of suppression in this way, enabled the inclusion of all participants in the analysis of BF as an extension of the stereoacuity scale.

Results

Baseline

All the subjects included in the present study were diagnosed with strabismic amblyopia at the baseline examination, that is, all subjects presented with strabismus even when wearing their spectacles. Constant esotropia was present in all subjects and, consequently, unilateral amblyopia of the non-dominant eye.

The sample size was 26 subjects (12 boys and 14 girls) aged from six to 13 years (median 8.50; IQR 3). The median age of detection was three years (IQR 1). All subjects were diagnosed with strabismic amblyopia, eight of them also presenting anisometropia. Hyperopia was present in all subjects. The median spherical refraction in spherical dioptres (D) of the amblyopic eye was +3.75 D (IQR 2.19) and the median spherical refraction of the dominant eye was +3.00 D (IQR 2.69). The median BCVA of the amblyopic eye was 0.40 logMAR (IQR 0.30) and 0.00 logMAR (IQR 0.01) in the dominant eye.

The median esotropia deviation was 4Δ (IQR 3). None of the subjects had binocular vision at the baseline examination using the Worth Four-Dot test (five subjects showed diplopia and 21 subjects showed suppression). Accordingly, none of the subjects showed stereoacuity with either the TNO test or the RPST. The BF values assigned to each subject varied from 4.00, in subjects with diplopia, to 5.00 in those with suppression, with a median value of 5.00.

The clinical characteristics of each subject at the baseline are summarised in Table 1.

Post-treatment evaluation

After the treatment, all subjects were examined by an external optometrist at the ophthalmology clinic. Analysis of the data showed an improvement in the BCVA of the amblyopic eye in all subjects, from baseline evaluation (median value of 0.40 logMAR) to final evaluation (median 0.06 logMAR; IQR 0.08). These differences were statistically

No.		Age	Age at detection	Type of amblyopia	Refraction SE	BCVA	Δ	Worth Four-Dot test	Stereoacuity	BF
1	Dominant	13	2	Strabismic	4.25	0.00	8	Suppression	Null	5
	Amblyopic				4.25	0.52				
2	Dominant	8	2	Strabismic	4.75	−0.04	8	Diplopia	Null	4
	Amblyopic				5.50	0.40				
3	Dominant	12	2	StrabismicAnisometropia	1.75	0.00	6	Suppression	Null	5
	Amblyopic				3.00	0.52				
4	Dominant	9	3	StrabismicAnisometropia	1.00	−0.04	6	Suppression	Null	5
	Amblyopic				1.88	0.40				
5	Dominant	8	4	StrabismicAnisometropia	1.25	−0.08	2	Suppression	Null	5
	Amblyopic				3.75	0.40				
6	Dominant	6	4	StrabismicAnisometropia	3.25	0.00	30	Suppression	Null	5
	Amblyopic				3.25	0.70				
7	Dominant	8	3	StrabismicAnisometropia	2.50	0.07	5	Suppression	Null	5
	Amblyopic				3.75	0.30				
8	Dominant	8	3	Strabismic	5.88	0.00	4	Diplopia	Null	4
	Amblyopic				5.50	0.40				
9	Dominant	7	3	StrabismicAnisometropia	1.25	0.00	2	Suppression	Null	5
	Amblyopic				3.25	0.70				
10	Dominant	9	3	StrabismicAnisometropia	1.50	0.02	2	Suppression	Null	5
	Amblyopic				4.25	0.70				
11	Dominant	8	3	Strabismic	0.63	0.10	4	Suppression	Null	5
	Amblyopic				0.88	0.70				
12	Dominant	6	3	Strabismic	3.13	0.00	4	Suppression	Null	5
	Amblyopic				4.38	0.70				
13	Dominant	9	2	Strabismic	7.50	0.00	35	Diplopia	Null	4
	Amblyopic				7.63	0.40				
14	Dominant	10	2	Strabismic	6.50	0.00	30	Suppression	Null	5
	Amblyopic				6.50	0.40				
15	Dominant	6	3	Strabismic	3.00	0.00	40	Suppression	Null	5
	Amblyopic				3.00	0.30				
16	Dominant	11	3	Strabismic	0.13	0.00	6	Suppression	Null	5
	Amblyopic				0.50	0.40				
17	Dominant	11	2	Strabismic	3.50	−0.08	4	Suppression	Null	5
	Amblyopic				3.50	0.52				
18	Dominant	6	2	StrabismicAnisometropia	2.00	0.00	6	Suppression	Null	5
	Amblyopic				2.00	0.40				
19	Dominant	11	4	Strabismic	2.00	−0.04	2	Suppression	Null	5
	Amblyopic				1.75	0.30				
20	Dominant	8	2	Strabismic	2.00	0.00	4	Suppression	Null	5
	Amblyopic				5.00	0.40				
21	Dominant	11	2	Strabismic	5.00	0.00	4	Suppression	Null	5
	Amblyopic				5.00	0.70				
22	Dominant	7	3	Strabismic	4.00	−0.04	4	Diplopia	Null	4
	Amblyopic				4.00	0.40				
23	Dominant	8	2	Strabismic	2.25	0.00	2	Suppression	Null	5
	Amblyopic				2.25	0.70				
24	Dominant	13	4	Strabismic	4.00	0.00	4	Diplopia	Null	4
	Amblyopic				4.00	0.70				
25	Dominant	12	2	Strabismic	6.25	0.10	4	Suppression	Null	5

Table 1. Baseline clinical parameters. The BCVA is shown in logMAR acuity and stereoacuity in second arc

No.		Age	Age at detection	Type of amblyopia	Refraction SE	BCVA	Δ	Worth Four-Dot test	Stereoacuity	BF
	Amblyopic				6.88	0.40				
26	Dominant	12	3	Strabismic	3.00	0.00	2	Suppression	Null	5
	Amblyopic				3.50	0.50				

AE: amblyopic eye, BCVA: Best Corrected Visual Acuity, BF: Binocular Function, DE: dominant eye, SE: spherical equivalent, Δ: prismatic dioptres.

Table 1. Continued

significant ($p < 0.001$). Binocular vision also improved in all subjects as a result of the treatment, from a BF median value of 5.00 to 2.60 (IQR 0.30) and these differences were statistically significant ($p < 0.001$).

Each treatment was independently analysed to determine the therapeutic effect of the different treatments.

REFRACTION

Following the baseline examination, objective refraction was obtained by means of cycloplegia. The mean spherical positive and astigmatism were found to be hypocorrected in 10 of the 26 subjects. Then, the maximum positive was prescribed to all subjects. The median spherical refraction of the amblyopic eye was found to be + 4.25 D (IQR 2.50) and + 3.37 D (IQR 3.44) in the dominant eye. Comparing the spherical refraction obtained at baseline and post-refraction examinations, statistically significant differences were found in both amblyopic ($p = 0.002$) and dominant eyes ($p = 0.008$).

With the new prescription, the BCVA of the amblyopic eye improved in some subjects. The median value was 0.40 logMAR (IQR 0.15) compared to the baseline visual acuity (0.40 logMAR; IQR 0.30), these differences being statistically significant ($p = 0.01$). In the dominant eye, the new prescription was the same in most of the subjects with a median value of 0.00 logMAR (IQR 0.01), indicating no significant variation from the baseline value ($p = 0.32$).

The mean esotropia was also significantly reduced with the new prescription ($p = 0.002$), to a median deviation of 4Δ (IQR 7). In some subjects, strabismus was absent with the new prescription, and these subjects were therefore diagnosed as having acquired fully accommodative esotropia. In other subjects, the esotropic angle persisted despite full hyperopia correction, and these subjects were diagnosed with acquired partially accommodative esotropia. Binocular vision improved with the new prescription in one subject, who achieved stereoacuity of 1,200″. No significant differences in BF were found with the new prescription ($p = 0.32$).

The clinical characteristics of each subject with the new prescription are summarised in Table 2.

OCCLUSION

Occlusion therapy was prescribed to subjects with fully accommodative esotropia. The duration of the occlusion treatment varied for each individual, with a median duration of six months (IQR 3). After the occlusion, the median BCVA of the amblyopic eye improved in all subjects from 0.35 logMAR (IQR 0.25) to 0.05 logMAR (IQR 0.01). These differences were statistically significant ($p = 0.01$) when compared to the post-refraction BCVA. Binocular vision also improved in all subjects with the occlusion. All subjects showed stereoacuity below 800″, with a median BF of 2.60 (IQR 0.23) compared to a post-refraction BF median of 5.00 (IQR 1).

The clinical characteristics of each subject after the treatment are summarised in Table 3 (subjects 19 to 26).

OCCLUSION AND ACTIVE THERAPY

Occlusion combined with active therapy was performed in subjects with partially accommodative esotropia. The median duration of the treatment was four months (IQR 0). The outcomes showed an improvement of BCVA in the amblyopic eye, from a post-refraction median value of 0.40 logMAR (IQR 0.30) to 0.07 logMAR (IQR 0.06) post-treatment. These differences were statistically significant ($p < 0.001$). The median BF also improved after the treatment, from a post-refraction median value of 5.00 (IQR 0) to 2.90 (IQR 0.30). All subjects showed stereoacuity below 800″ with RPST. The partially accommodative esotropia group presented binocular vision with the use of prismatic correction with a median deviation of 6Δ (IQR 12).

The second purpose of treatment was to achieve orthotropia without the use of prisms. With this objective, surgery was prescribed for subjects with a deviation of > 12Δ, while fusional vergence therapy was applied to reduce the prismatic correction in subjects with a deviation of < 12Δ. Improvements in vergence values at each session were not recorded, nor was the number of the sessions needed. Treatment was deemed complete in each case when the subject was able to achieve orthotropia without prismatic correction.

The clinical characteristics of each subject post-treatment are summarised in Table 3 (subjects 1 to 18).

Acquired fully accommodative esotropia and acquired partially accommodative esotropia treatment

As stated above, patients were treated according to the type of esotropia they presented. Fully accommodative esotropia subjects were treated using occlusion; whereas subjects with remaining esotropia after full hyperopia correction (partially accommodative esotropia group) were treated using occlusion and active therapy.

The post-refraction median BCVA of the amblyopic eye for the fully accommodative esotropia group was 0.35 logMAR (IQR 0.25), and 0.40 logMAR (IQR 0.30) for the partially accommodative esotropia group, with statistically significant differences between them ($p = 0.03$). Esotropia had a median value of 0Δ in the fully accommodative esotropia group and 4.50Δ (IQR 10) in the partially accommodative esotropia group, with statistically significant differences between them ($p < 0.001$). The median BF was 5.00 (IQR 1) in the fully accommodative esotropia group and 5.00 (IQR 0) in the partially accommodative esotropia group, with no statistical differences between them ($p = 0.21$).

The post-treatment median BCVA of the amblyopic eye for fully accommodative esotropia group was 0.05 logMAR (IQR 0.1), and 0.07 logMAR (IQR 0.06) for the partially accommodative esotropia group, with no statistical differences between them (p = 0.63). Esotropia was absent in all groups. The median BF was 2.60 (IQR 0.23) in the fully accommodative esotropia group and 2.90 (IQR 0.30) in the partially accommodative esotropia group, with no statistical differences between them (p = 0.09).

Discussion

Treatment for strabismic amblyopia[30] is currently split into two types of passive therapy: full cycloplegic refraction followed by a prolonged period of spectacle wear, and subsequently by occlusion therapy to improve visual acuity outcomes.[10] Cotter et al.[31] demonstrated that optical treatment alone produced substantial therapeutic effects in many children with amblyopia (amblyopia was resolved in 34% of the sample). In fully accommodative esotropia subjects, full correction improves visual acuity and achieves ocular alignment, restoring binocular vision in most cases. However, in cases of partially accommodative esotropia and non-accommodative esotropia, full correction improves visual acuity but fails to achieve ocular alignment, and cortical mechanisms such as anomalous retinal correspondence and interocular suppression are employed to eliminate the unwanted consequences of confusion and diplopia.[10]

The present study shows that, in the fully accommodative esotropia group, this intervention protocol achieves good outcomes in terms of visual acuity and restoration of binocular vision. Full correction enabled full ocular alignment, rendering cortical mechanisms to eliminate confusion and diplopia unnecessary. At baseline, subjects with fully accommodative esotropia did not wear the correct optical prescription and were previously diagnosed with partially accommodative esotropia. Treatment in the partially accommodative esotropia group was a more complex proposition for practitioners that, in some cases, was resolved with a good refractive correction. Prescription error may condition the diagnosis and hence the results of the treatment, making cycloplegic refraction an essential

No.		Refraction SE	BCVA	Δ	Worth Four-Dot test	Stereoacuity	BF
1	Dominant	4.25	0.00	8	Suppression	Null	5
	Amblyopic	4.25	0.52				
2	Dominant	4.75	−0.04	8	Diplopia	Null	4
	Amblyopic	5.50	0.40				
3	Dominant	1.75	0.00	6	Suppression	Null	5
	Amblyopic	3.00	0.52				
4	Dominant	1.00	−0.04	6	Suppression	Null	5
	Amblyopic	1.88	0.40				
5	Dominant	1.25	−0.08	2	Suppression	Null	5
	Amblyopic	3.75	0.40				
6	Dominant	3.25	0.00	30	Suppression	Null	5
	Amblyopic	3.25	0.70				
7	Dominant	2.50	0.07	5	Suppression	Null	5
	Amblyopic	3.75	0.30				
8	Dominant	5.88	0.00	4	Diplopia	Null	4
	Amblyopic	5.50	0.40				
9	Dominant	1.25	0.00	2	Suppression	Null	5
	Amblyopic	3.25	0.70				
10	Dominant	1.50	0.02	2	Suppression	Null	5
	Amblyopic	4.25	0.70				
11	Dominant	0.63	0.10	4	Suppression	Null	5
	Amblyopic	0.88	0.70				
12	Dominant	3.13	0.00	4	Suppression	Null	5
	Amblyopic	4.38	0.70				
13	Dominant	7.50	0.00	35	Diplopia	Null	4
	Amblyopic	7.63	0.40				
14	Dominant	6.50	0.00	30	Suppression	Null	5
	Amblyopic	6.50	0.40				
15	Dominant	5.50	0.00	30	Suppression	Null	5
	Amblyopic	5.50	0.30				
16	Dominant	0.88	0.00	4	Suppression	Null	5
	Amblyopic	1.00	0.40				
17	Dominant	3.63	−0.08	2	Suppression	Null	5
	Amblyopic	3.63	0.52				
18	Dominant	2.00	0.00	4	Suppression	Null	5
	Amblyopic	2.75	0.40				
19	Dominant	2.75	−0.04	0	Fusion	1,200	3.08
	Amblyopic	3.00	0.20				
20	Dominant	3.75	0.00	0	Suppression	Null	5
	Amblyopic	5.50	0.30				
21	Dominant	6.50	0.00	0	Suppression	Null	5
	Amblyopic	6.50	0.40				
22	Dominant	5.00	−0.04	0	Diplopia	Null	4
	Amblyopic	5.50	0.20				
23	Dominant	2.63	0.00	0	Suppression	Null	5
	Amblyopic	2.63	0.50				
24	Dominant	3.50	0.00	0	Diplopia	Null	4
	Amblyopic	5.50	0.50				
25	Dominant	8.50	0.10	0	Suppression	Null	5

Table 2. Refractive therapy outcomes. The BCVA is shown in logMAR acuity and stereoacuity in second arc

No.		Refraction SE	BCVA	Δ	Worth Four-Dot test	Stereoacuity	BF
	Amblyopic	8.88	0.30				
26	Dominant	3.63	0.10	0	Suppression	Null	5
	Amblyopic	4.25	0.40				

AE: amblyopic eye, BCVA: Best Corrected Visual Acuity, BF: Binocular Function, DE: dominant eye, SE: spherical equivalent, Δ: prismatic dioptres.

Table 2. Continued

No.		Initial prismatic correction	BCVA	Worth Four-Dot test	Stereoacuity	BF
1	Dominant	10	0.00	Fusion	800	2.90
	Amblyopic		0.09			
2	Dominant	6	−0.04	Fusion	200	2.30
	Amblyopic		0.10			
3	Dominant	7	−0.04	Fusion	800	2.90
	Amblyopic		0.10			
4	Dominant	5	−0.04	Fusion	400	2.60
	Amblyopic		0.07			
5	Dominant	4	0.02	Fusion	800	2.90
	Amblyopic		0.02			
6	Dominant	32	−0.04	Fusion	800	2.90
	Amblyopic		−0.08			
7	Dominant	7	−0.04	Fusion	400	2.60
	Amblyopic		−0.08			
8	Dominant	6	0.07	Fusion	800	2.90
	Amblyopic		0.10			
9	Dominant	4	0.00	Fusion	200	2.30
	Amblyopic		0.10			
10	Dominant	4	0.00	Fusion	800	2.90
	Amblyopic		0.10			
11	Dominant	4	0.10	Fusion	800	2.90
	Amblyopic		0.10			
12	Dominant	6	0.00	Fusion	800	2.90
	Amblyopic		0.02			
13	Dominant	40	0.00	Fusion	400	2.60
	Amblyopic		0.07			
14	Dominant	32	0.00	Fusion	800	2.90
	Amblyopic		0.10			
15	Dominant	40	−0.04	Fusion	200	2.30
	Amblyopic		0.06			
16	Dominant	4	0.00	Fusion	400	2.60
	Amblyopic		0.05			
17	Dominant	6	0.05	Fusion	800	2.90
	Amblyopic		0.05			
18	Dominant	8	0.00	Fusion	400	2.60

Table 3. Outcomes after active therapy (prismatic correction and posterior vergence therapy) combined with occlusion (1–18). The subjects 6, 13–15 underwent strabismus surgery. The subjects 18–26 were treated only with occlusion therapy. The BCVA is shown in logMAR acuity and stereoacuity in second arc

preliminary step in patients with strabismic amblyopia.

Patients with fully accommodative esotropia resolved their amblyopia in a median of six months with spectacle correction and occlusion alone. In the partially accommodative esotropia group, the two passive treatments already described are not sufficient to restore binocular vision, which requires two more treatment phases: prismatic correction and posterior fusional vergence therapy. A number of studies have analysed the effect of prismatic correction on esotropia.[32] Although these studies present good results in the acquisition of binocular vision, they offer no protocol of action to achieve binocular vision without prismatic correction.

The following study presents an intervention protocol that facilitates the restoration of binocular vision through prismatic correction and posterior fusional vergence therapy. With small-angle strabismus, the prismatic correction was able to be removed with fusional vergence therapy alone. However, where larger angles (> 12Δ) were involved, strabismus surgery was necessary before the prisms could be removed. The sample size did not allow the comparison between the therapy and the surgical group; notwithstanding, all subjects in the surgical group achieved good outcomes in terms of residual angle (orthotropia) and fine stereoacuity. These good surgical results could be explained by the fact that the surgical angle of deviation was calculated according to a stable deviation angle, and this was possible thanks to the previous prismatic correction and visual therapy treatment. Prismatic correction was able to facilitate accurate calculation of the deviation before surgery. Fusional vergence therapy was able to provide subjects a range of fusion around this angle. The PEDIG analysed the stability of subjects with partially accommodative esotropia in a longitudinal study,[33] finding that only 39 per cent of the sample had a stable deviation (that is, a variation ≤ 5Δ between measures). Birch et al.[34] concluded that subjects with accommodative esotropia and null stereopsis present greater instability in their angle of deviation, hence the acquisition of stereoacuity may stabilise the angle after surgery.

The randomisation of this intervention protocol is not an option because subjects received one treatment or another according to their clinical characteristics, and no direct comparison between groups can be conducted, but differences between

No.		Initial prismatic correction	BCVA	Worth Four-Dot test	Stereoacuity	BF
	Amblyopic		0.05			
19	Dominant	0	−0.04	Fusion	400	2.60
	Amblyopic		0.00			
20	Dominant	0	0.00	Fusion	400	2.60
	Amblyopic		0.10			
21	Dominant	0	0.00	Fusion	800	2.90
	Amblyopic		0.02			
22	Dominant	0	0.05	Fusion	200	2.30
	Amblyopic		0.05			
23	Dominant	0	0.00	Fusion	400	2.60
	Amblyopic		0.00			
24	Dominant	0	0.00	Fusion	400	2.60
	Amblyopic		0.06			
25	Dominant	0	0.10	Fusion	400	2.60
	Amblyopic		0.10			
26	Dominant	0	0.10	Fusion	200	2.30
	Amblyopic		0.10			

AE: amblyopic eye, BCVA: Best Corrected Visual Acuity, BF: Binocular Function, DE: dominant eye.

Table 3. Continued

outcomes can be stated. Treatment duration in the fully accommodative esotropia group was longer than in the partially accommodative esotropia group, which combined both treatments. In addition, there were no significant differences in either BCVA or BF between the groups post-treatment. These findings indicate that the partially accommodative esotropia group achieved comparable values in a shorter period of time, despite being the more complex group at baseline, with lower BCVA and BF values; and suggest that active therapy could also be introduced in the fully accommodative esotropia group as a coadjutant to reduce occlusion times or shorten the treatment duration.[35,36] Dichoptic stimulation in serious games[26,27] or perceptual learning using Gabor patches[37] could also reduce the duration of treatments.

The present study is not exempt from limitations of sample selection, methodologies applied, or the absence of a control group. Subjects with near-distance incomitance (where the difference in the esotropia angle at near-distance fixation > 5Δ) were excluded from the sample, thereby facilitating the treatment of accommodative esotropia with single lenses. It is known that optical correction with bifocal lenses is necessary in cases of high AC/A ratio,[38] and it would be interesting in future studies to study whether the proposed treatment is also effective for this type of population.

Regarding the methodology, all the materials employed are well known in the literature and clinical practice, with the exception of the BF index. BF value has recently been introduced to facilitate statistical analysis of binocular vision data. The index assigns a numerical score to the subject's binocular vision to facilitate the numerical quantification of subjects with unquantifiable or null stereopsis. The tool, used by many other authors for similar purposes, proved highly useful for quantifying improvements in stereopsis, although it is not without limitations. Practitioners are not yet familiarised with the use of the index; all tables therefore include Worth Four-Dot test and Randot Preschool test results as well as BF index values.

The present study was conducted without a control group, although the treatment outcomes were verified by an external evaluator (visual acuity resolved and stereoacuity achieved). However, better designed studies are needed to support this intervention protocol.

Conclusion

An intervention protocol in which passive therapy (optical correction and occlusion) was combined with an active therapy program (prismatic correction and posterior vergence therapy) obtained good results in terms of visual acuity and stereoacuity in subjects with esotropic amblyopia. In subjects with a strabismus angle indicative of surgery, prismatic correction before surgery allowed them to obtain orthotropia and stereoacuity, while subjects with small-angle strabismus obtained comparable results with prismatic correction and fusional vergence therapy.

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