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·Clinical Research·

Improvement of visual acuity in children with anisometropic amblyopia treated with rotated prisms combined with near activity

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Abstract

• AIM: To evaluate the efficacy of a new modality for improving visual acuity (VA) in pediatric patients with anisometropic amblyopia.

• METHODS: Retrospective and interventional case series. Medical records of 360 children with anisometropic amblyopia treated with a modality that included rotated prisms, lenses, and near activities from January 2008 to January 2012 were analyzed. Characteristics such as improvement of VA and contrast sensitivity in amblyopic eyes and resolution of amblyopia (VA ≤0.1logMAR or a difference of ≤2 lines in logMAR between the eyes) were assessed.

• RESULTS: Among the patients, the mean VA of the amblyopic eyes improved from 0.48logMAR (SD=0.16) to 0.12logMAR (SD=0.16) and the mean VA improvement was 0.36logMAR (SD=0.10, *P*<0.001). Resolution of amblyopia was achieved in 233 of 360 patients (64.72%). The mean time for resolution of amblyopia was 8.05 weeks (SD=4.83) or 14.14 sessions (SD=8.76). Among the study group, refraction error did not change significantly after treatment (*P*=0.437). We found that better baseline VA may be related to success and shorten the time to amblyopic resolution.

• CONCLUSION: VA and contrast sensitivity improved with rotated prisms, correcting lenses, and near activities in children with anisometropic amblyopia. The VA improvement by this modality was comparable to other methods. However, the time to resolution of amblyopia was shorter with this method than with other modalities. Rotated prisms combined with near acuity could provide an alternative treatment in children with anisometropic amblyopia who can´t tolerant traditional therapy method like patching.

• **KEYWORDS:** amblyopia; near activity; perceptual learning; rotated prism
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INTRODUCTION

Amblyopia is a disorder that consists of functional abnormalities, such as visual acuity (VA) reduction, contrast sensitivity impairment, spatial distortion, abnormal spatial interaction, and contour interaction. Refractive amblyopia, either anisometropia or isometropia, results from relative high refractive errors in one or both eyes that cause blurred retinal images. The presumed mechanism is vision pattern deprivation. The affected eye provides a more blurred image to the retina and brain and amblyopia develops. Children carry the risk of developing amblyopia if the condition is untreated within their critical period. Previous studies show optimal spectacle correction is a major component in improving visual function in patients with anisometropic amblyopia [1, 2]. In addition, patching, or penalization of the sound eye, is a major used as an adjunct to the anisometropic amblyopia therapy.

In addition to patching, penalization, and refractive correction, there are a handful of methods to treat anisometropic amblyopia. Perceptual learning improves visual performance by repeating basic tasks and showed comparable effects in amblyopic therapy with patching [3-9]. However, the social stigma and anxiety of patching in elder children limited its compliance and thus its useful application. On the contrast, perceptual learning would be less efficient in younger children than elders. Therefore, in this study, we evaluated the efficacy of a new modality that combines rotated prisms, lenses, and near activities in pediatric patients with anisometropic amblyopia.

SUBJECTS AND METHODS

Subjects The study protocol complied with the requirements of the Institutional Review Board. Medical records of pediatric patients who underwent amblyopic therapy by this modality between January 2008 and January

Table 1 Setting of the modality in different activities

Parameters	Set A	Set B	Net effect
Original setting	0.5D plus lens	1.0D plus lens	
	5.0D prism	2.0D prism	
Watching television	6s		6s
(2.5-3.0m)	0.5 plus lens	No work	0.5 plus lens
	5.0D prism (base-down)		5.0D prism (base-down)
	9s		9s
	0.5 plus lens	No work	0.5 plus lens
	5.0D prism (base-in)		5.0D prism (base-in)
Reading	6s		6s
(30cm)	0.5 plus lens	No work	2.0 plus lens
Add 1.5D	5.0D prism (base-down)		5.0D prism (base-down)
	14s	1s	14s
	0.5 plus lens	1.0D plus lens	3.0D plus lens
	5.0D prism (base-in)	2.0D prism(base-in)	7.0D prism (base-in)
Playing computer games	6s		6s
(60cm)	0.5 plus lens	No work	1.0 plus lens
Add 0.5D	5.0D prism (base-down)		5.0D prism (base-down)
	14s	14s	14s
	0.5 plus lens	1.0D plus lens	2.0D plus lens
	5.0D prism (base-in)	2.0D prism(base-in)	7.0D prism (base-in)

D=diopters.

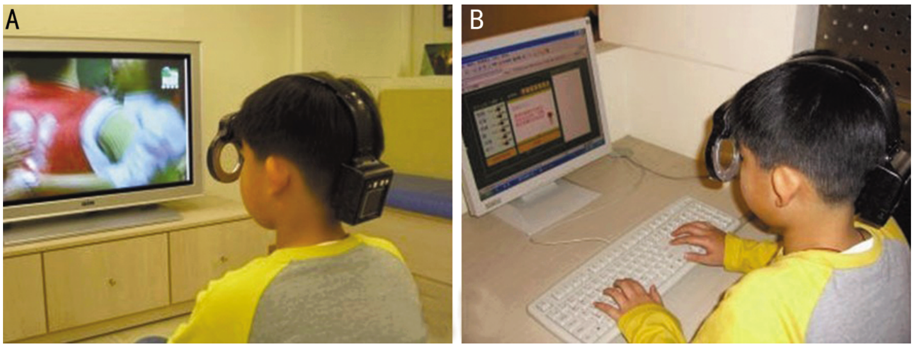

Figure 1 One patient used this modality A: Watching television; B: Playing computer games.

2012 in the ophthalmology department of Lin Amblyopic Eye Center were reviewed.

Patients were recruited into this study if they met the inclusion criteria. The inclusion criteria were children age from 3 to 11 years, VA worse than 0.3logMAR or at least two lines of difference between the eyes in anisometropic amblyopia, and without existence of strabismus or other ocular diseases that could result in reduced VA. Anisometropia was defined as a difference of ≥1.00D in the myopic, hyperopic, or astigmatic refractive error between the patient's eyes. Correction of refractive error was accepted in this study. Spectacles were prescribed by two ophthalmologists (Chao-Chyun Lin, MD and Po-Liang Chen, MD). We excluded patients if they did not meet the definition for amblyopia or failure during the follow-up period, and concurrent amblyopia treatment, such as cycloplegics, patching, or other perceptual learning tasks.

Methods The new modality we used contains two sets of lenses for "flippers" in our visual training program. Set A was constructed with a 0.5D plus lens and a 5.0D prism (alternative base-in or base-down); set B included a +1.0D plus lens with a 2.0D base-in prism.

When eligible patients performed their training for near activities at a distance between 2.5 and 3.0m, such as watching television, this modality switched to only set A for function. The training program, which lasted for 50min, consisted of using the 0.5D plus lens and 5.0D base-down prism for six seconds followed by the 0.5D plus lens and 5.0D base-in prism for another nine seconds (Table 1, Figure 1).

In another type of training performed at closer distances ranging from 30cm to 60cm, sets A and B were worked together for 50min while we added a 1.50D plus lens in front of the eye for reading or doing homework (distance 30cm) and a 0.5D plus lens for playing computer games (distance 60cm). In the initial six seconds of this training, there was only the set A lens with a 0.5D plus lens and 5.0D base-down cylinders. In the following 14s, sets A and B were used together with a 1.5D plus lens with 7.0D base-in prism (0.5D plus lens with 2.0D base-in prism in set A and +1.0D plus lens with 5.0D base-in prism in set B). Net effects for different purposes differed according to the additional plus lens (Table 1).

Visual training using this modality was conducted twice a week in our outpatient department. The VA, contrast sensitivity, and cycloplegic refraction error were recorded for each patient at the beginning of the study, every four sessions during the study and at the end of the study.

The primary endpoint in this study was a difference in VA of less than 2 lines difference or a VA better than 0.1logMAR in amblyopic eye. The secondary endpoint was that the amblyopic eye did not gain >0.1logMAR improvement in six consecutive sessions.

Reliable measurements of VA, refraction error, and contrast sensitivity were recorded. VA was measured by logMAR VA testing (Chart 2210; Precision Vision, La Salle, IL, USA). Refraction error was checked by retinoscopy after the instillation of 0.1% cyclopentolate eye drops. Contrast sensitivity was recorded at the beginning and end of the study.

Statistical Analysis Data were analyzed using SPSS software (version 13.0 for Windows; SPSS Inc., Chicago, IL, USA). Student's *t*-test was used for comparing characteristics before and after treatment. $P<0.05$ was considered significant. Regression analysis was adopted to evaluate the factors concordant with improvement of the VA and amblyopia resolution among the patients.

RESULTS

There were 380 children who attended this study. Twelve children were excluded because they could not complete training course and six children loss of follow-up. In total, we report the results of 360 children with anisometropic amblyopia. In the group, there were 20 children with myopic amblyopia, 60 with hypermetropic amblyopia, 75 with astigmatic amblyopia, and 205 with mixed refractive amblyopia. In our study, the mean age was 6.43 years (SD= 1.40) and the baseline mean refraction error in spherical equivalent was -1.06D (SD=0.67). The mean VA of the amblyopic eyes at baseline was 0.48logMAR (SD=0.16). The baseline characteristics of these patients are listed in Table 2.

Patients were classified into success or failure groups according to the resolution of their amblyopia. The criteria for success were amblyopia that resolved with a final VA ≤0.1logMAR in the amblyopic eye or an interocular VA difference ≤2 lines in logMAR. As a result, there were 233 patients in the success group. The overall success rate in this new modality was 64.72%. The mean VA of the amblyopic eyes improved significantly from 0.48logMAR at baseline to 0.12logMAR after VA stabilized with a mean improvement of 0.36logMAR (SD=0.10). The mean time to resolution of amblyopia was 8.05 weeks ranging from 5.0 to 24.0 weeks (SD=4.83). The mean number of sessions of visual training to resolution was 14.14 sessions (ranging from 6 to 50 sessions, SD=8.76) (Table 3). The mean difference in refraction error before and after treatment was -0.39 D without significance (SD=0.67, P=0.437). The better baseline VA was related to success and shorter of the time to amblyopic resolution (P= 0.001).

Table 2 Baseline characteristics of all patients studied (n=360)

Characteristics	*n* (%)
Male	200(55.5)
Age (a)	
Mean (SD)	6.43 (1.40)
Range	3.8 to 11.0
3 to <4	10 (2.8)
4 to <5	21 (5.8)
5 to <6	118 (32.8)
6 to <7	103 (28.6)
7 to <8	52 (14.4)
8 to <9	42 (11.6)
9 to <10	5 (1.4)
10 to 11	9 (2.5)
Visual acuity	
Mean logMAR (SD)	0.48 (0.16)
Range	0.40 to 0.80
0.40 to <0.50	182 (50.5)
0.50 to <0.60	75(20.8)
0.60 to <0.70	63 (17.6)
0.70 to <0.80	30 (8.3)
0.80 to ≤1.00	10 (2.8)
Type of refractive amblyopia	
Myopia	20 (4.3)
Hypermetropia	60 (12.9)
Astigmatism	75 (15.7)
Mixed	205 (67.1)
Spherical equivalent (D)	
Mean (SD)	-1.06 (5.35)
Range	-15.00 to 0.75
<-7.00	67 (18.6)
-7.00 to <-4.00	5 (1.4)
-4.00 to <0.00	93(25.8)
0.00 to <4.00	139 (38.6)
4.00 to <7.00	56 (15.5)

D=diopters; logMAR=logarithm of the minimum angle of resolution; SD=standard deviation.

Table 3 Resolution of amblyopic eyes after treatment (n=233)

Characteristics	*n* (%)
Improvement from baseline (logMAR)	
Mean (SD)	-0.36 (0.10)
Range	-15.00 to 0.75
<2 lines	10 (4.3)
2 to <3 lines	52 (22.3)
3 to <4 lines	135 (57.9)
4 lines	36(15.4)
Time to resolution (weeks)	
Mean (SD)	8.05 (4.83)
Range	5.0 to 24.0
<8 weeks	130 (55.8)
8 to <16 weeks	99 (42.5)
≥16 weeks	4 (1.7)
Sessions to resolution	
Mean (SD)	14.14 (8.76)
Range	6 to 50
<7 times	97 (41.6)
7 to <14 times	126(54.0)
≥14 times	10 (4.3)

logMAR=logarithm of the minimum angle of resolution.

Before treatment, contrast sensitivity in these patients was below the normal limit and the peak baseline contrast sensitivity shifted to a lower frequency (Figure 2). The

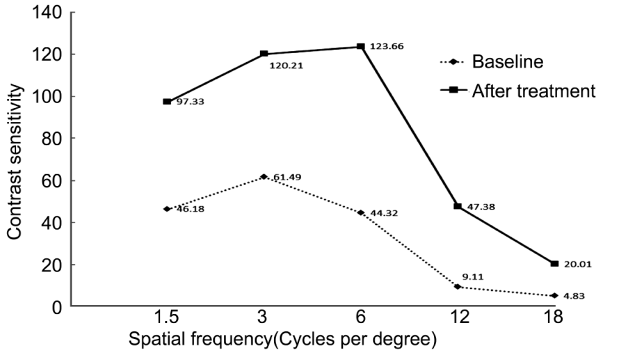

Figure 2 Mean contrast sensitivity of the amblyopic eye at different spatial frequencies in patients at baseline and after treatment.

contrast sensitivity showed significant improvement after therapy for all spatial frequencies and improved by factors of 2.11, 1.95, 2.79, 5.20, and 4.14 at spatial frequencies of 1.5, 3.6, 12, and 18 cycles per degree, respectively. The correlation between improvements in contrast sensitivity and VA was a factor of 0.28. Among all patients, we found that the baseline VA was the only significant factor to predict the success or failure of treatment (negative correlation, $P<0.001$, R^2=0.291). Baseline VA was also a factor for predicting faster improvement (＜8 weeks).

DISCUSSION

The modality used in this retrospective study was initially designed for myopia control [10]. In our prior study evaluating the short-term effect of this modality, mean reduction in refraction error of 0.28D (SD=0.03) was shown in the test group [10]. In addition to the refraction change, we found that the contrast sensitivity also improved in our patients. Prior studies found that perceptual learning improves visual performance in amblyopic eyes[4,7] and VA may also improve after contrast sensitivity improvement [8]. In this study of the long-term effects of the treatment, we designed a training program that consisted of 50min a session for two sessions a week. VA, contrast sensitivity, and refraction error change after treatment were analyzed.

The mainstream of refractive amblyopia therapy is refractive correction with patching, penalization, or their combination. Refractive correction alone has been proven to offer 3.9 lines of improvement during the first year in patients with bilateral moderate and severe refractive amblyopia [2]. Patching and penalization are well-known adjuncts for amblyopia treatment. Although study have reviewed the efficacy and frequency of patching to increase its compliance in such patients [11]. However, the social stigma and anxiety of patching in younger children limited its compliance and thus its useful application. Our prior study showed comparable results between patching and perceptual learning, but most younger children felt bored when doing training[5]. Therefore, we conducted this new training method for younger and older children.

The mean VA improvement in our study was 0.36logMAR, which was compatible with previous studies. In our prior study on VA improvement by perceptual learning or patching in anisometropic amblyopic eyes, VA improvement by perceptual learning was 2.5 lines [5,6] in amblyopic eyes. We believe that the different outcome in our study is attributable to different modality of visual training, or to different inclusion criteria.

Stewart and his coworkers[13] proposed that the dose-response rate for patching in patients aged between 3 and 8 years is around 0.1logMAR for every 120h of patching, and later they suggested that age may influence the dose-response rate in amblyopia therapy [14]. According to this conclusion, it may take about 420h of patching to achieve a mean improvement of 0.32logMAR. From the patching strategy in PEDIG studies, patients with moderate amblyopia (VA range from 20/80 to 20/40) should undergo a patching dose of two hours per day [11]. That regimen would require nearly seven months of patching to achieve an improvement of 0.36logMAR such as found in our study. Patients receiving the current treatment modality spent 8.05 weeks to reach resolution of refractive amblyopia. We believe that the faster resolution of five months over patching treatment is mostly attributable to this new modality.

Compliance in amblyopia therapy remains the major concern regarding its success. Loudon *et al* [15] stated that poor parental fluency in the national language, a low level of education, and poor baseline VA may lead to low compliance and then failure of therapy. Intense supervision of occlusion treatment and parental education greatly help to improve success rates [16]. Traditional patching failed in some patients due to social stigma or anxiety, but perceptual learning may also fail because the simple tasks are too boring [5]. Our treatment provided relative high compliance using this modality because of interesting tasks like playing interactive computer games, watching TV.

We thought that improvement in VA may result from several causes. First, similarly to other studies of perceptual learning, improved contrast sensitivity played a major role in improvement VA. Second, interactive activities consisting of watching favorite television programs, playing interactive computer games, and doing homework increased compliance compared with repetitive simple tasks. Since myopia has a relatively high prevalence in East Asians of 22.4% at the age of six years and 64.1% at 12 years [17], several factors including genes, environment, or near work are thought to be involved. Near work (＜30cm) and longer working time (＞30min) were related more refraction changes toward myopia. In our study, although amblyopia treatment was performed in near activities at a distance from 30cm to 3.0m, there was no significant refraction error addition noted after long-term treatment[18].

There were some limitations in our study. First, there was absence of a control group. Most parents requested this therapy after the failure of other therapies and were not willing to participate in the control group. Second, because this study was a retrospective, therefore, the data to do detail analysis were limited. Third, most patients enrolled in our study with moderate to mild amblyopia (most baseline VA ranged from 0.4 to 0.80logMAR) compared with moderate to severe amblyopia in previous studies. Further perspective studies with more patients should be needed to solve these problems.

In conclusion, our study showed good results for this modality in anisometropic amblyopia therapy. VA and contrast sensitivity improved after a biweekly training program. Patients aged from 3 to 11 years with anisometroic amblyopia could achieve improvement of visual acuity or resolution of their amblyopia. This modality, which combines rotated prisms, lenses, and near activities, may provide an effective alternative for treating anisometropic amblyopia.

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