

# Effect of Visual Sensory Improvement by Amblyopia Treatment on Improvement of Ocular Functions

Jae-Do Kim\*

Dept.of Optometry and Vision Science, Kyungwoon University, Gumi 730-739, Korea  
(Received November 7, 2014; Revised November 21, 2014; Accepted November 28, 2014)

**Purpose:** This study is to investigate if the improvement of visual sensory (VS) by amblyopia treatment affects the ocular functions in refractive errors, accommodative errors and phoria at distance and near. **Methods:** 10 subjects (17 eyes, mean age of  $10.7 \pm 2.9$  years) who treated amblyopia completely, were participated for this study. Refractive errors, accommodative errors, and distance and near phoria were compared between before and after treatments of amblyopia. Refractive errors and accommodative errors at 40 cm were measured using open-field auto-refractor (N-Vision-5001, Shin Nippon, Japan) and using monocular estimated method (MEM) respectively. Phoria was determined at 3 m for distance and at 40 cm for near using Howell phoria card, cover test or Maddox rod. **Results:** Mean corrected visual acuity (CVA) significantly increased from  $0.46 \pm 0.11$  (decimal notation) for before amblyopia treatment to a level of  $1.03 \pm 0.13$  for after amblyopia treatment ( $p < 0.001$ ). For spherical refractive error, hyperopia significantly decreased from  $+2.29 \pm 0.86$  D to a level of  $+1.1 \pm 2.38$  D ( $p < 0.05$ ) but astigmatism did not significantly change;  $-1.80 \pm 1.41$  D for before treatment and  $-1.65 \pm 1.30$  D for after treatment ( $p > 0.05$ ). Accommodative error significantly decreased from accommodative lag of  $+1.1 \pm 0.75$  D to a level of  $+0.5 \pm 0.59$  D (accommodative lag) ( $p < 0.05$ ). Distance phoria significantly changed from eso  $2.9 \pm 6.17$  PD (prism diopters) to a level of eso  $0.2 \pm 3.49$  PD ( $p < 0.05$ ), and near phoria also significantly changed from eso  $0.4 \pm 2.32$  PD to level of exo  $2 \pm 4.9$  PD ( $p < 0.05$ ). There was a high correlation ( $r = 0.88$ ,  $p < 0.001$ ) between improvement of visual acuity and decrease of accommodative lag. **Conclusions:** Hyperopic refractive error decreased with improvement of CVA or VS by amblyopia treatment. And the improvement of VS by amblyopia treatment also improved accommodative error, and changed phoria coupled with accommodation.

**Key words:** Amblyopia, Visual sensory, Ocular functions, Refractive error, Accommodation, Phoria

## Introduction

Human's ocular functions rapidly develop over the few months of life under normal condition. Visual acuity grows from about 20/330 at 1 month old to 20/19 at 5 years old.<sup>[1]</sup> Accommodation response also improves with increase of age. Haynes *et al.*<sup>[2]</sup> reported that before 1 month of age, it showed poor accommodative response to the changing accommodative stimulus and wide range of accommodative response levels was observed, ranging from approximately 3.5 D to 8.75 D. The flexibility of the response improves with increase of age and adult-like response is achieved by 4 months of age. Banks<sup>[3]</sup> noted three changes

with increase of age, namely an increase in the gradient of the stimulus-response function, a decrease in variability within same age group, and decline in the mean accommodative error.

Infants have the ability to converge and diverge in the appropriate direction as early 1 month of age, but they cannot consistently converge to near targets until 2 months age.<sup>[4]</sup> Moreover, the ability to respond appropriately to faster target motion so increases with age increases.<sup>[5]</sup> Even through under the normal vision condition, ocular functions such as visual acuity, accommodation and eye movement change with increase of age, any visual deprivation for obstacle during early age have an extremely detrimental effect upon

\*Corresponding author: Jae-do Kim, TEL: +82-31-786-1146, E-mail: jdkim@yahoo.com

development.<sup>[6]</sup> The most common outcome of abnormal visual experience in early age is sensory disorder or amblyopia<sup>[7]</sup> which is lower corrective visual acuity. In addition to the lower sensory, previous studies have reported that amblyopia had lower ocular functions than normal vision. Amblyopia has been found to have longer reaction time than normal vision,<sup>[8,9]</sup> increased visual evoked potential (VEP) latency,<sup>[10]</sup> and deficits in velocity<sup>[11]</sup> and motion<sup>[12,13]</sup> discrimination.

If we analogize a cause of lower ocular functions out of previous studies, we can have a result that lower sensory influence on low ocular functions. Banks<sup>[3]</sup> also formulated 2 hypotheses for mechanism of accommodative development, namely “motor hypothesis”, which is development in the motor component of the accommodative control system accounts for the infant developmental changes observed with his study, and “sensory hypothesis” which programming of accurate accommodative response is dependent on the detection of the consequences of inaccurate accommodation. However, it still remains a question whether there are correlations between sensory and motor in ocular functions of accommodation and phoria. So this study is to investigate using a novel method whether improvement of visual sensory by amblyopia treatment affects ocular functions or not.

## Subjects and Methods

10 subjects (17eyes) (mean age of  $10.7 \pm 2.9$  years) who have treated amblyopia completely, were participated for this study. Amblyopes were 7 subjects for both eyes amblyopia and 3 subjects for one eye amblyopia. Refractive errors, accommodative errors, and distance and near phoria were compared between before and after treatments of amblyopia. For the treatment of amblyopia, it was prescribed with near addition lenses (NAL) to make non-accommodative lag measured by monocular estimated method (MEM) in amblyopic eye, and with NAL to make 0.50 D of accommodative lag in normal eyes.<sup>[14]</sup> Subjects were asked wearing near glasses for reading at near. Total period of amblyopia treatment was  $50 \pm 20$  months (about 4 years). Refractive errors and accommodative errors at 40 cm were measured using open-field auto-refractor (NVision-5001, Shin Nippon, Japan) and MEM respectively. Phoria was determined at 3 m for distance and at 40 cm for near using Howell phoria card, cover test or Maddox rod. Howell

phoria card was used for subjects who phoria could be measured with Howell card, otherwise Maddox rod or cover test was used.

## Results

Corrected visual acuity of pre- and post-treatments of amblyopia showed in Fig. 1. Mean corrected visual acuity (CVA) was significantly increased by  $0.46 \pm 0.11$  (decimal notation) for before amblyopia treatment to a level of  $1.03 \pm 0.13$  for after amblyopia treatment (paired t-test,  $p < 0.001$ ). For spherical refractive error, hyperopia significantly decreased by  $+2.29 \pm 0.86$ D to a level of  $+1.1 \pm 2.38$ D (paired t-test:  $p < 0.05$ ) but astigmatism did not significantly changed;  $-1.80 \pm 1.41$ D for before treatment and  $-1.65 \pm 1.30$ D for after treatment (paired t-test:  $p > 0.05$ ).

Fig. 2 shows accommodative lag at 40 cm of pre-treatment and post-treatment. Accommodative lag significantly decreased by  $+1.1 \pm 0.75$ D to a level of  $0.5 \pm 0.59$ D (paired t-test:  $p < 0.00$ ). This result means that eyes of post-treatment with distance correction can see clearer than eyes of pre-treatment.

Fig. 3 shows correlation between change of visual acuity

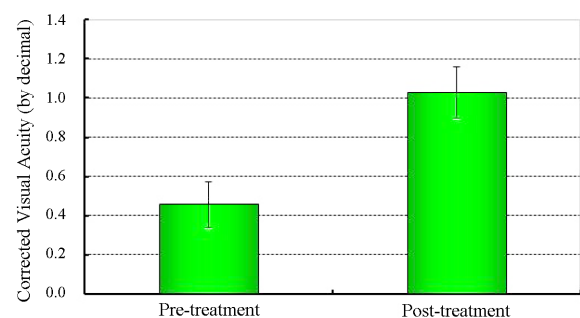


Fig. 1. Corrected visual acuity of pre-treatment and post-treatment of amblyopia. Error bars: Standard Error Mean.

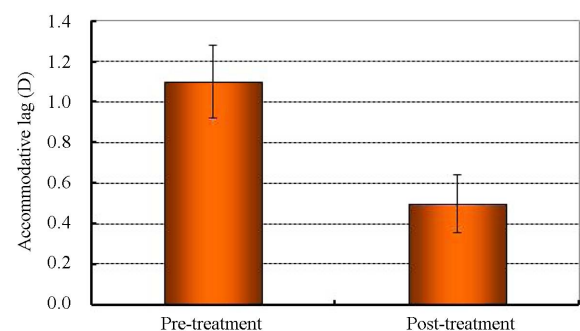


Fig. 2. Accommodative lag of pre-treatment and post-treatment of amblyopia. Error bars: Standard Error Mean.

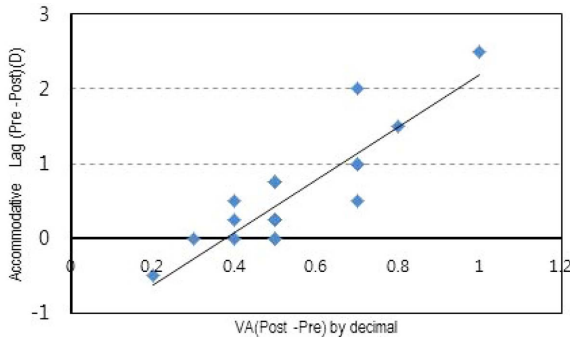


Fig. 3. Correlation between change of visual acuity and change of accommodative lag in pre-treatment and post-treatment. Post: post-amblyopia treatment, Pre: pre-amblyopia treatment.

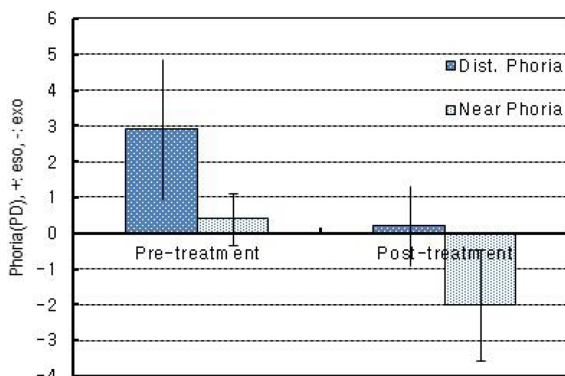


Fig. 4. Phoria changes of pre-treatment and post-treatment of amblyopia. Error bars: Standard Error Mean.

and change of accommodative lag in pre-treatment and post-treatment. Not only accommodative lag was decreased with increase of visual acuity by post-treatment, but also there was a high correlation ( $r = 0.88$ ,  $p < 0.001$ ) between improvement of visual acuity and decrease of accommodative lag.

Both distance and near phoria also showed significant changes in Fig. 4. Distance phoria was significantly changed by eso  $2.9 \pm 6.17$  PD (prism diopters) to a level of eso  $0.2 \pm 3.49$  PD (pair t-test:  $p < 0.05$ ), and near phoria also significantly changed by eso  $0.4 \pm 2.32$  PD to level of exo  $2 \pm 4.9$  PD (pair t-test:  $p < 0.05$ ). This means that phoria at both distance and near shift from eso-direction to exo-direction.

## Discussion

Hyperopic refractive error decreased 1.1 D during the amblyopia treatment period of  $50 \pm 20$  months (about 4 years). This study showed that refractive error in the amblyopic hyperopia was not much changed than in myo-

pia and hyperopia. In a study of refractive error for Korean myopia children, Kim and Kim<sup>[15]</sup> reported that myopia increased  $-0.78$  D per year. Previous hyperopia studies<sup>[16,17]</sup> also reported less change of refractive error than myopia change. Zadnik *et al.*<sup>[16]</sup> reported that refractive error decreased toward emmetropia with age from an average of  $+0.73$  D at age 6 years to an average of  $+0.50$  D by age 12 years. The hyperopic refractive error change in this study was extremely low as about 0.30 D per year, while in previous studies was about 0.60 D per year, which was twice of this study result (0.30 D). The cause that refractive error change is smaller in amblyopic eye than in non-amblyopic eye has never been found out, but still remains as a question. The more studies are required in the future.

This study showed that improvement of visual sensory by amblyopia treatment improved accommodative response or reduced accommodative lag. In this study, vision training by physical technic was not used for accommodative improvement, but used only added lenses for improving visual sensory. As results of this study, improvement of sensory may have a decisive effect on accommodative improvement. Banks<sup>[3]</sup> also suggested that visual accommodation is commonly viewed as a control system with two primary components; a sensory component which evaluates the clarity or sharpness of the retinal image in order to determine whether an accommodative change is required, and a motor component which implements the changes in lens shape needed to maximize images sharpness. Among two primary components, he hypothesized that sensory is programming of accurate accommodative responses being dependent on the detection of the consequences of inaccurate accommodation. Thus the sensory hypothesis holds that accommodative development results from development in the ability to detect the image blurring resulting from focusing error, and this study confirmed Banks' hypothesis. Banks<sup>[3]</sup> also stated another hypothesis to accommodation, namely "motor hypothesis" which development in the motor component of the accommodative control system accounts for developmental accommodative change in infancy. However, even all subjects participated in this study were not infants, they also improved accommodation with sensory change. We can infer through this result that improvement of sensory also improves accommodation, and both motor and sensory components are needed or required for

normal accommodation.

This study showed that phoria at both distance and near shifted from eso-direction to exo-direction. There were also previous studies that reported change of ocular deviation.<sup>[18,19]</sup> Koc *et al.*<sup>[19]</sup> evaluated changes at the deviation angles of 63 partially accommodative esotropia patients, who had occlusion treatment for amblyopia, and reported that mean deviation angle at the start of therapy without glasses was 45 PD (10 – 90 PD) and became 27 PD (5 – 70 PD) after at least 2 months with glasses. This result can be proved by which accommodation and convergence are coupled physiologically.<sup>[20]</sup> When the eyes accommodate, they also converge, accommodative convergence, quantified by the AC/A ratio.<sup>[17,21]</sup> And the higher accommodative lag the higher convergence required. Higher accommodative lag in pre-treatment of amblyopia also needs higher accommodative efforts to detect the clear image, and induces accommodative convergence, but the lower accommodative lag after amblyopia treatment may induce the lower accommodative convergence, which is shifting to exo-deviation.

Vision therapies by physical methods such as +/- flipper lenses or loose lenses have mainly been used to improve ocular functions such as accommodation or binocular vision. However this study showed that sensory improvement by only correction of lenses correction also improved ocular functions. Therefore, improvement of sensory can be also as important as vision therapies by physical methods to improve ocular functions.

## Conclusions

Hyperopic refractive error decreases with improvement of CVA or VS in amblyopia treatment. The improvement of VS by amblyopia treatment improves accommodative error and changes phoria coupled with accommodation. Efforts for improvement of sensory are required to improve ocular functions with addition to vision therapy by physical methods.

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## 약시 치료에 의한 시각각 개선이 안기능 향상에 미치는 효과

김재도\*

경운대학교 안경광학과, 구미 730-739

투고일(2014년 11월 7일), 수정일(2014년 11월 21일), 게재확정일(2014년 11월 28일)

**목적:** 본 연구는 약시치료에 의한 감각개선이 굴절이상, 조절 및 원근 사위의 안기능에 영향을 미치는지를 알아 보고자 하였다. **방법:** 본 연구는 약시가 치료된 10명(17안, 평균나이 10.7±2.9년)을 대상으로 약시 치료 전과 치료 후의 굴절이상도, 조절오차 및 원근 사위를 비교하였다. 굴절이상도는 개방형 자동굴절검사기(N-Vision-5001, Shin Nippon, Japan)로 측정하였으며 조절오차는 40 cm 거리에서 단안평가법(MEM)을 이용하여 측정하였다. 사위는 원거리 3 m 근거리는 40 cm에서 Howell 사위카드, 차폐 또는 Maddox rod에 의한 방법으로 측정하여 비교 분석하였다. **결과:** 평균 교정시력은 약시치료 전에 0.46±0.11(소수시력)에서 약시치료 후에 1.03±0.13으로 유의하게 증가되었다( $p < 0.001$ ). 구면굴절이상도는 치료 전에 원시도가 +2.29±0.86 D에서 치료 후에 +1.1±2.38D로 감소하였지만( $p < 0.05$ ), 난시변화는 치료 전에 -1.80±1.41 D에서 치료 후에 -1.65±1.30 D로 유의적 변화가 없었다. 조절오차는 치료 전에는 조절지체 +1.1 ± 0.75D에서 치료 후에는 +0.5±0.59 D로 유의적 수준에서 감소하였다( $p < 0.05$ ). 원거리사위는 치료 전에는 eso 2.9±6.17 PD(prism diopters)에서 치료 후에 eso 0.2±3.49 PD로 유의 수준에서 감소하였고, 근거리 사위 또한 치료 전에는 eso 0.4±2.32 PD에서 치료 후에는 exo 2±4.9 PD로 유의 수준에서 변화하였다( $p < 0.05$ ). 시력 향상과 조절력 감소는 높은 상관관계( $r = 0.88$ ,  $p < 0.001$ )가 있었다. **결론:** 약시치료 후 교정시력과 시각각의 개선과 함께 원시성 굴절이상도는 감소하였으며 약시치료에 의한 시각각의 개선은 조절오차를 개선시키고 조절에 영향을 받는 사위를 변화시키는 것으로 나타났다.

**주제어:** 약시, 시각각, 안기능, 굴절이상, 조절, 사위