

# Macular fixation behaviors observed by optical coherence tomography in children with severe hyperopic amblyopia

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Received: 2011-10-15 Accepted: 2011-12-20

## Abstract

• **AIM:** To observe fixation behaviors in amblyopes by optical coherence tomography (OCT) and to explore the possible mechanism of eccentric fixation so as to guide amblyopia treatment.

• **METHODS:** OCT was performed on a group of 31 cases (40 eyes) aged 3 to 12 with severe amblyopia of hyperopia refractive error respectively before and after treatment. The results were recorded and compared to detect the change and mode of their visual fixation.

• **RESULTS:** Among the 31 cases (40 eyes), 63% was foveal fixation, and 38% was eccentric fixation. For unocular patients, eccentric and foveal fixation shared the same percentage of 50%. For binocular patients, eccentric fixation was present in 22% of the total cases; the remaining 78% was foveal fixation. After treatment, all of the 15 eyes with eccentric fixation visual acuity between 0.2-0.5 were successfully converted to foveal fixation. The time of treatment varied from one month to two years. Combined exotropia and accommodation esotropia did not affect the conversion. Moreover, regardless of the mode of fixation, there was no significant difference in the final visual acuity achieved after treatment.

• **CONCLUSION:** OCT examination is an objective and easy-to-operate means to assess of fixation behaviors in amblyopes. With the improvement of visual acuity during treatment, the patient's eccentric fixation converted to foveal fixation.

• **KEYWORDS:** hyperopia; amblyopia; optical coherence tomography; eccentric fixation

DOI: 10.3969/j.issn.1672-5123.2012.02.01

Liu H. Macular fixation behaviors observed by optical coherence tomography in children with severe hyperopic amblyopia. *Guji Yanke Zazhi (Int Eye Sci)* 2012;12(2):195-198

## INTRODUCTION

In clinical practice, close attention has been paid to the relationship between fixation mode and prognosis of amblyopia, the change of fixation mode and the improvement

in visual acuity. It is also of great importance to define the fixation mode in the diagnosis and treatment of amblyopia. Optical section function of optical coherence tomography (OCT) can be used to construct macular retinal tomography map to show the retinal structure of different regions in the macular area. The retinal map can be used to confirm its position and whether the macular fovea has developed. OCT examination is a new measurement of fixation. In practice, OCT was applied to observe fixation behaviors in a group of children with severe amblyopia of hyperopia refractive errors. The fixation mode was judged according to the position of fovea showed in the images. The present mechanism on eccentric fixation was further explored to give suggestions on amblyopia treatment.

## MATERIALS AND METHODS

**Materials** According to the classification of amblyopia<sup>[1]</sup>, the cases were diagnosed as severe amblyopia (legal blindness, 20/200 or worse) with unocular and binocular eyes. All of them were hyperopia cases ranged from moderate to high, including ametropic and anisometropic amblyopia. 31 cases (17 males and 14 females aged from 3 to 12) were enrolled in the study, of which 22 cases were with unocular amblyopia and 9 cases with binocular amblyopia. In total, 40 eyes were examined. Among the cases, there were 6 cases with accommodate esotropia and 1 case with exotropia. Treatment lasted from 1.2 to 5 years for these cases and the data were recorded completely.

**Methods** Routine examinations were performed on each of these cases including visual acuity measurements, ocular motility and alignment evaluation, cycloplegic retinoscopy, and examinations on the external eye, the anterior segment and the fundus. The Snellen chart was performed at a distance of six meters. Cycloplegic refraction examination: 1% atropine eye drop was used (1 drop tid × 3 days or bid × 5-7 days). Retinoscopic measurements should be made along the patient's visual axis. The significant hyperopic refractive errors are corrected by prescribing the cycloplegic retinoscopy findings. TOPCON 3D OCT-1000 was used to examine the macular tissue morphology. Seat the patient comfortably on an exam stool or chair in front of the instrument. Let the patient rest his/her chin on the chin-rest and rest his/her fore-head on the fore-head rest. Adjust the chin-rest height so that the patient's eye is at the same level with the Canthus marker on the chin-rest post. Instruct the patient to look at the green light (internal fixation target).

**Table 1 Approximate time and vision at which all the 15 eccentric fixation eyes converted to foveal fixation**

Vision	0.2 (20/100)	0.3 (20/67)	0.4(20/50)	0.5(20/40)
Time of treatment	1-3 months	3-6 months	1-2 years	1-2 years
Unocular	4	4	2	1
Binocular				4

The measurement was assessed with macular retinal tomography map. Internal fixation was used for macular scanning. The fast macular scan protocol consisted of six consecutive 6mm radial line centered on the macula; each scan was rotated by a 30 degree interval. Six sets of intersecting and equally spaced scans were obtained, each crossing the central fovea, to construct 2D tomography map of the macular area. Serial images would show the construction of the macular fovea. The scans were subjected to analyse with standard software provided with the apparatus.

The topographic map of the macula was composed of three concentric circles: a central circle, an inner ring and an outer ring. The diameters of the concentric circles measured 1mm, 3mm and 6mm, respectively. When the normal macular retinal topographic map showed fovea centralis in the central circle, it was considered as foveal fixation; if the fovea centralis was out of the central circle, it was considered as eccentric fixation.

The amblyopic eyes with eccentric fixation were examined by OCT at the vision of 0.2(20/100), 0.3(20/67), 0.4(20/50), 0.5(20/40) respectively. OCT follow-up examination was performed each time the vision improved 0.1(20/200). The aim was to observe and compare the positions of fovea in OCT images and record the time and vision at which the eccentric fixation was converted to foveal fixation.

**Amblyopia therapy** (1) Refractive correction; according to the cycloplegic retinoscopy findings and ocular alignment, the significant hyperopic refractive errors are corrected by spectacles; (2) Occlusion therapy; occlusion of the sound or stronger eye has been the mainstay of treatment for amblyopia treatment, full-time or part-time occlusion was adopted (covering with a dark patch). Treatments such as pleoptics, gratings, Haidinger brushes, active therapy and so on are carried out at the same time. First re-checking was carried out after one month's treatment, each followed-up check-up was performed at an interval of 2-3 months.

**RESULTS**

Before the amblyopia treatment, among the 31 cases (40 eyes), 18 cases (25 eyes) were foveal fixation, taking up approximately 63%; 13 cases (15 eyes) were eccentric fixation, taking up approximately 38%. For unocular patients (22 cases, 22 eyes), eccentric (1 right, 10 left) and foveal fixation (3 right, 8 left) each accounted for 50%. For binocular patients (9 cases, 18 eyes), eccentric fixation (2 cases, 4 eyes) took up 22%; the remaining 78% were foveal fixation (7 cases, 14 eyes). OCT check-up after treatment showed that all of the 15 eyes with eccentric fixation had converted to foveal fixation, including one eye of exotropia and three eyes of accommodation esotropia.

Figure 1 shows the OCT images of unocular amblyopia in the left eye, whose eccentric fixation converted to fovea fixation. Previously, the retinal topographic map showed the fovea centralis out of the central circle and the retinal data map showed false thickened retinal nerve fiber layer in the central circle. When eccentric fixation converted to foveal fixation after treatment of over one month, the retinal topographic map showed the fovea centralis in the central circle and the retinal data map showed normal thickness of retinal nerve fiber layer in the central circle. Figure 2 shows binocular amblyopia whose eccentric fixation converted to foveal fixation after one year's treatment.

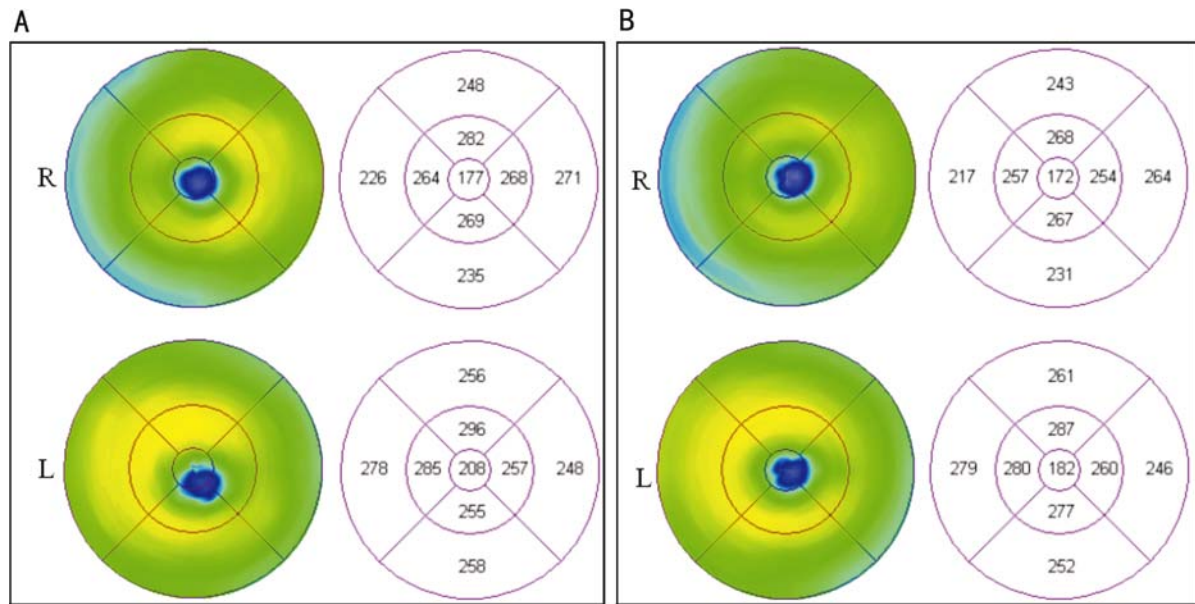
The vision at which eccentric fixation converted to foveal fixation ranges between 0.2(20/100)-0.5(20/40) and the time varies from one month to two years. The approximate time and vision when the eccentric fixation converted to foveal fixation of all the 15 eyes are presented in Table 1.

Regardless of the mode of fixation, there was no significant difference in the final visual acuity achieved after treatment. The 31 cases (40 eyes) were followed up for 1.2-5 years after treatment. Among the unocular amblyopes, 3 cases with foveal fixation and 3 cases with eccentric fixation achieved vision 0.6(20/33), the rest achieved a vision of 0.5(20/40) or above. Among the binocular amblyopes, the lowest corrected vision was 0.5(20/40) for the patient with foveal fixation, and 0.6(20/33) for the patient with eccentric fixation.

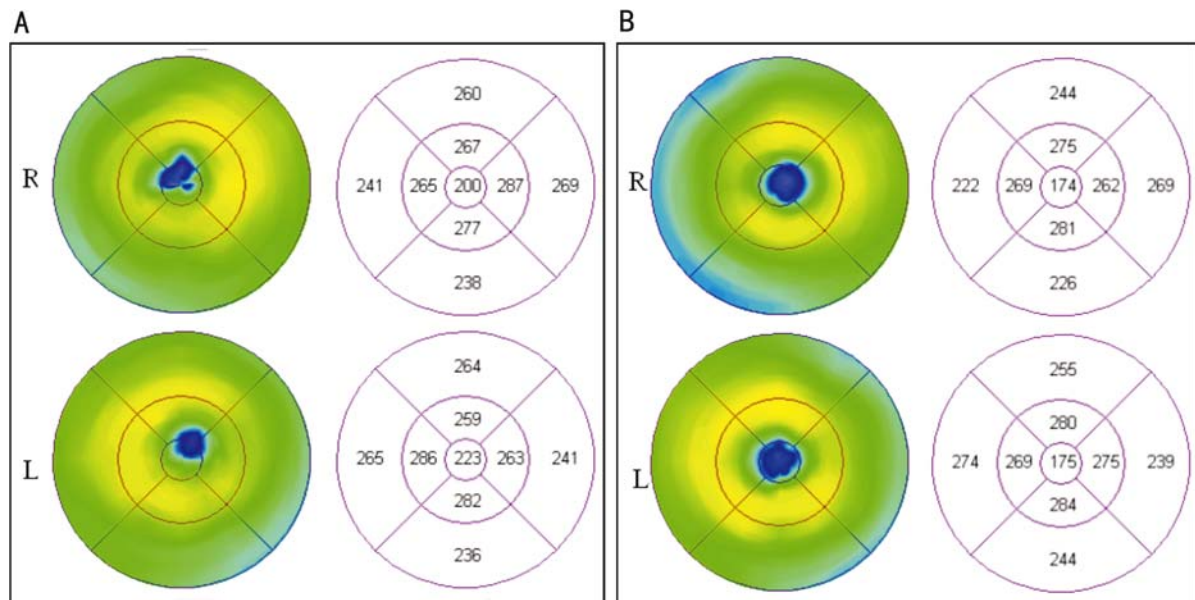
**DISCUSSION**

Visuscopy and other ophthalmoscope methods are widely applied in the assessment of fixation behavior on amblyopia<sup>[2,3]</sup>. The other method is such as to assess fixation by the visually evoked potential<sup>[4,5]</sup>. About the phenomenology of eccentric fixation there are a few different views, such as scotoma or correspondence hypothesis. Authors consider the loss of macular function, that is the central inhabitational scotoma as the cause of eccentric fixation or the eccentric fixation develops on the basis of an anomalous retinal correspondence, others regard eccentric fixation involves the retinal area which possesses relatively the highest resolving power under the prevailing stimulus condition<sup>[6,7]</sup>.

To our knowledge, no attempt has been made to observe fixation behavior of amblyopic eyes by means of OCT. OCT was applied in this study to scan macular area in order to obtain macular retinal topographic map. By observing the position of macular fovea in retinal topographic map on OCT, fixation code was judged and the fixation behavior before treatment was compared with that after treatment. Usually the OCT examination takes about 1.92 seconds to complete scanning. OCT images may be captured when the patient is requested to



**Figure 1 Retinal topographic map and retinal data map of one case whose eccentric fixation converted to fovea fixation (uniocular amblyopia in the left eye) A: Before operation; B: One month postoperatively.**



**Figure 2 Retinal topographic map and retinal data map of one case whose eccentric fixation converted to fovea fixation (binocular amblyopia) A: Before operation; B: One year postoperatively.**

"look at" the green light (internal fixation target). Due to the efficiency and comfort, it is easier for children to cooperate. Thus, the examination result is considered to be more objective and accurate.

According to the follow-up examination result of the OCT, all the cases involved with eccentric fixation converted to foveal fixation when their vision reached 0.2 (20/100)-0.5 (20/40), regardless of exotropia and accommodation esotropia. For uniocular amblyopes with eccentric fixation, the majority converted to foveal fixation when their vision reached 0.2 (20/100)-0.3 (20/67), and the approximate time period was half a year. Few of the uniocular amblyopes and all the binocular amblyopes converted to foveal fixation at a vision range between 0.4 (20/50) and 0.5 (20/40), and the approximate time period was 1-2 years. For patients with

eccentric fixation, with the conversion to foveal fixation, their visual acuity increased accordingly. It has been assumed that fovea cone cells have been aroused and gradually strengthened. Although the time needed to activate foveal cone cells varies for each individual, and the visual acuity differs, normally patients with visual acuity around 0.2 (20/100)-0.5 (20/40) can convert to foveal fixation after treatment. Eccentric fixation occurs due to the fact that the retinal area possesses relatively the highest resolving power under the prevailing stimulus condition. The principal visual direction remains associated with the fovea under this circumstance. The fixation point may show on either side of fovea near nose or temple, above or below. Even if combined with strabismus, the eccentric fixation can still convert to foveal fixation. Therefore, strabismus is not an explanation for eccentric

fixation<sup>[8]</sup>. To review literature, some scholars considered that there was correlation between fixation code and curative effect of amblyopia, others thought there was no conclusive relation<sup>[9,10]</sup>. According to our follow-up of amblyopia treatment, regardless of the fixation mode, there was no significant difference in final vision achieved after treatment. According to pathogenesis discussed and the observation of eccentric fixation of patients with the severe amblyopia caused by hyperopia refractive errors, we came to the conclusion that in clinical management of amblyopia, the initial intervention is to prescribe necessary spectacle correction in order to form clear vision. Next, occlusion therapy shall be adopted with a patch placed over the sound eye. The same point of view has been proposed before. Furthermore, pleoptics has been proposed differently before, the recommended pleoptics shall be prescribed after eccentric fixation has converted to foveal fixation. If OCT examination is not accessible, it is better that pleoptics is adopted when the vision improves to 0.5(20/40) in order to keep fovea from being exposed to intensive light because of eccentric fixation.

The result also showed that the majority of unocular amblyopia occurred in the left eye, taking up 80% of the cases recorded. On the other hand, regarding the fixation code, though foveal fixation and eccentric fixation shared the same proportion in this study, left eye took up 70% of the eyes with foveal fixation, and 90% of eccentric fixation. This indicated that unocular amblyopia mainly occurred in the left eye, regardless of eccentric fixation or not. This may be related to right-handedness of Chinese. So, it is recommended that cases with amblyopia in left eye perform active therapy with left hand. Activities requiring eye-hand coordination would encourage the development of vision acuity in the left eye.

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## OCT对远视重度弱视患儿黄斑注视性质的观察

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#### 摘要

**目的:**通过 OCT 方法检查弱视患者的注视性质,思考和审视偏心注视的机制,指导弱视治疗。

**方法:**对一组 3~12 岁儿童远视屈光性重度弱视患儿 31 例 40 眼治疗前后做黄斑光学相干断层扫描(OCT)检查,观察其注视性质的变化。

**结果:**在 31 例 40 眼中,中心注视眼占 63%,偏心注视眼占 38%。单眼患者中心注视与偏心注视各占 50%,双眼患者 78%为中心注视,22%为偏心注视。治疗后 15 只偏心注视眼,分别在 0.2~0.5 视力之间全部转成中心注视,时间为 1mo~2a。合并外斜和调节性内斜没有影响偏心注视转中心注视,且无论中心注视及偏心注视,其视力恢复对比观察,无明显差异。

**结论:**采用 OCT 检查弱视眼注视性质客观、简便。在治疗过程中随着视力的提高,偏心注视转化为中心注视说明中心凹锥细胞功能被唤醒并且功能逐渐增强。

**关键词:**远视;弱视;光学相干断层扫描;偏心注视