

Impact of strabismus management on the retinal microstructure

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Abstract

Aim: To examine whether change in retinal structure can improve vision and stereoacuity following strabismus management.

Methods: We recruited patients who presented with strabismus from 2017 to 2019. Information on demographics, posterior and anterior segment findings, and strabismus surgery was collected using a pretested online form. Patients' stereoacuity was examined by employing the Titmus test. The central macular thickness and retinal nerve fiber layer (RNFL) thickness of all the eyes were evaluated through SD-OCT. Stereoacuity examination and OCT were performed again 3 months postoperatively.

Result: We recruited 54 patients (mean age: 19.74 ± 9.2 years). Stereoacuity and vision exhibited significant improvements after treatment. Both eyes showed improvement in RNFL thickness but not CMT.

Conclusion: Functional stereoacuity changes and structural RNFL changes were noted following appropriate treatment for strabismus.

Introduction

A crucial dimension of vision is stereoacuity (1, 2, 3). It is a vital type of binocular vision responsible for depth perception (2). In aniseikonia, stereoacuity is affected (4). Stereopsis is absent in strabismus (5, 6) and refractive errors (7, 8). Numerous factors affect stereopsis including literacy, poor vision, age, amblyopia, and deprivation (9, 10). Stereoacuity can be improved by treating its cause including refraction, strabismus, or cataract (11, 12, and 13).

This study explored whether strabismus management can improve alignment. The aligned eye may exhibit improved stereopsis and thus binocular vision (ref).

We explored the association of functional improvement with retina structure changes. We evaluated whether functional improvement leads neuroanabolism.

Materials And Methods

Both the study protocol and informed consent form were approved by the Hospital Ethical Committee of Drashti Netralaya and were according to the guidelines of the Helsinki Declaration. We obtained written informed consent from the legal guardian or parents of each child, and each patient provided consent before study participation.

This prospective cohort study recruited patients visiting the motility department who were diagnosed as having strabismus requiring surgical correction from 2018 to 2020. We excluded those with other pathology or neurological diseases that can affect the retinal nerve fiber layer (RNFL), optic nerve head (ONH), or central macular thickness (CMT).

All patients received comprehensive eye assessments, which included slit lamp biomicroscope or handheld slit lamp evaluation for ocular alignment, A-scan ultrasound biometry, and tests for refraction and visual acuity (VA). Assessments were conducted under anesthesia in younger children who were unable to cooperate. We examined intraocular pressure by employing Perkins applanation tonometer.

For children aged < 3 years, monocular distance VA was tested. For nonverbal children, VA was examined based on a child's ability to fix and follow objects. Fixation was determined by examining each eye's ability to fixate on an object, maintain the fixation, and subsequently follow the object through varying gaze positions. Children aged 3–6 years were shown wall charts containing Snellen letters and numbers and subjected to the tumbling E test and HOTV as per the standard VA assessment.

For children, single optotypes of ETDRS acuity charts with surrounding bars were presented. We examined cycloplegic refraction for all children.

An indirect ophthalmoscope with + 20 D lens was employed to examine the posterior segment.

We assessed near stereopsis using the Titmus circle (Titmus, Optical Co, Inc., Chicago, IL, USA) and the Randot circle (Stereo Optical Co). We examined distance stereopsis by employing the B-VAT II BVS contour circle of the Mentor BVAT II video acuity tester (Mentor O & O, Inc., Norwell, MA, USA).

Motor and sensory adaptation were assessed using various tests for all patients. All patients underwent surgery.

We measured distance stereopsis after strabismus and refractive error correction. An arc of 240 s was used with patients wearing liquid-crystal shutter glasses at a 6-m distance. A correct result indicated a successful test. However, for an incorrect result, patients were again shown the circle in different directions more than two consecutive times. If the patients obtained a correct result, they were administered next tests. However, in case of an incorrect result, patients were considered to have high stereopsis. If stereopsis was undetermined, previous steps were repeated again. When correct results were obtained for more than two consecutive times, we used the obtained result as the final finding. If 240 s were not perceived, patients were not included in statistical analysis. Moreover, we performed intraocular pressure and slit lamp, alternate prism cover, and fundus and refraction examinations .

All OCT measurements (Cirrus Spectral Domain OCT 4000; Carl Zeiss Meditec, Dublin, CA) were performed after dilating patients' pupils to at least 5-mm diameter. A single skilled ophthalmologist conducted all measurements. SD-OCT was employed to measure ONH parameters, central macular thickness (CMT), and RNFL.

CMT is the average macular thickness in the 1-mm diameter in the center. The signal strength for all scans was set to six.

Patients were followed on the postoperative third day, first month, second month, and third month and then every 6 months.

Patients with strabismus were followed on the third day postoperatively, first month, third month, and then every six months. Patients underwent comprehensive examination during each follow-up.

All patients received stereoacuity tests and SD-OCT during all follow-up visits as a standard protocol.

Details regarding patient characteristics, strabismus surgery, and HD-OCT were collected from hospital records.

During follow-up visits, data were entered online using a pretested format and exported to an Excel spreadsheet (Microsoft Corp.). Data were audited periodically to ensure complete data collection.

Statistical analyses were conducted using SPSS (version 22.0; SPSS Inc., Chicago, IL, USA). Cross tabulation and descriptive statistics were employed to compare cause and effect among different variables.

Differences in mean MCT values were observed using Student's t test and one-way ANOVA. The Pearson correlation was used to evaluate agreements between the variables. $P < 0.05$ indicated statistical significance.

Results:

Our cohort comprised 54 patients (median: 20 years; mean age: 19.74 ± 9.26 years). Of the 54 patients, 25 (46.3%) were women and 29 (53.7%) were men (Table)

The mean stereopsis was -700 ± 792.84 (median: 400) preoperatively and -573.15 ± 708.76 (median: 200; Table 2) postoperatively during the last visit.

Of the 54 patients, 24 (44.4%) had amblyopia.

Of the 54 patients, 25 (46.3%) were children. No significant differences were determined between the adult and pediatric populations for both eyes ($p = 0.069$ and $p = 0.303$, respectively).

Many other variables were comparable with the final postoperative RNFL values.

Discussion

The results revealed improvements in stereopsis and vision following strabismus treatment. Moreover, mean RNFL but not CMT exhibited significant improvement after treatment.

Stereopsis indicates the vision quality (1, 2, 3, 6, and 7). Many conditions affect stereopsis in children (2, 6, and 7). Many methods are available to examine stereopsis (14–17). A study indicated interpersonal differences in stereopsis measurements (18). Another previous study compared measurements obtained using different methods (18). Stereopsis affects performance in learning, catching, and literacy (19–23).

A study revealed that stereopsis can affect movements in older patients (24, 25). Moreover, stereopsis causes a reading deficiency (26, 27).

Improvement in stereoacuity following squint management was reported (28–31). All strabismus types exhibited improvement including esotropia, accommodative esotropia, and exotropia; this result is similar to ours (28–31).

Here, we observed increases in RNFL following improved stereoacuity and vision. No study has demonstrated this improvement. This finding suggests neuroanabolism, which refers to functional improvements in affected retinal tissue structures. Studies have examined stereoacuity and retinal cellular structures (38, 309).

Many studies examined MCT in amblyopia (39–43).

A study revealed thickness changes in anisometropic amblyopia (44).

Araki et al observed the reversal of macular changes after amblyopia management but could not find any difference (45).

Okamoto et al found improved stereoacuity and retinal microstructure after macular hole surgery (46).

A study limitation is the inclusion of a small sample with a short follow-up.

Multicenter studies including individuals of different races and ethnicities should be conducted to establish this finding. Early improvement in strabismus can improve stereoacuity, thus resulting in structural improvement.

Conclusion

Functional improvement may be associated with structural improvement following stereoacuity correction and strabismus surgery.

References

1. Crawford, M. L., G. K. von Noorden (1983). "Binocular neurons and binocular function in monkeys and children." *Invest Ophthalmol Vis Sci* **24**(4): 491–5.
2. Heron, G., S. Dholakia (1985). "Stereoscopic threshold in children and adults." *Am J Optom Physiol Opt* **62**(8): 505–15.
3. Ciner, E. B., G. S. Ying (2014). "Stereoacuity of preschool children with and without vision disorders." *Optom Vis Sci* **91**(3): 351–8
4. Rutstein, R. P., R. J. Fullard,(2015). " Aniseikonia induced by cataract surgery and its effect on binocular vision." *Optom Vis Sci* **92**(2): 201–7.

5. Endo, T., T. Fujikado (2016). "Stereoscopic perception of 3-D images by patients after surgery for esotropia." *Jpn J Ophthalmol* **60**(1): 7–13.
6. Pan, C. W., X. Chen, (2016) "Prevalence and causes of reduced visual acuity among children aged three to six years in a metropolis in China." *Ophthalmic Physiol Opt* **36**(2): 152–7.
7. Zhu, H., J. J. Yu(2015) "Association between childhood strabismus and refractive error in Chinese preschool children." *PLoS One* **10**(3): e0120720
8. Bodack, M. I., I. Chung (2010). "An analysis of vision screening data from New York City public schools." *Optometry* **81**(9): 476–84.
9. Wong, B. P., R. L. Woods (2002). "Stereoacuity at distance and near." *Optom Vis Sci* **79**(12): 771–8.
10. Haegerstrom-Portnoy, G., M. E. Schneck.(1999). "Seeing into old age: vision function beyond acuity." *Optom Vis Sci* **76**(3): 141–58.
11. Singh, D., R. Saxena. "Stereoacuity changes after laser in situ keratomileusis." *Optom Vis Sci* **92**(2): 196–200.
12. Kirwan, C. and M. O'Keefe (2006). "Stereopsis in refractive surgery." *Am J Ophthalmol* **142**(2): 218–22.
13. Shi, M., H. Jiang.(2014) "Hyperopic corneal refractive surgery in patients with accommodative esotropia and amblyopia." *J Aapos* **18**(4): 316–20.
14. Moganewari, D., J. Thomas.(2015) "Test Re-Test Reliability and Validity of Different Visual Acuity and Stereoacuity Charts Used in Preschool Children." *J Clin Diagn Res* **9**(11): NC01-5.
15. Holmes, J. M., E. E. Birch (2007). "New tests of distance stereoacuity and their role in evaluating intermittent exotropia." *Ophthalmology* **114**(6): 1215–20.
16. Han, S. B., H. K. Yang, (2016). "Quantification of Stereopsis in Patients with Impaired Binocularity." *Optom Vis Sci* **93**(6): 588–93.
17. Fan, W. C., B. Brown (1996). "A new stereo test: the double two rod test." *Ophthalmic Physiol Opt* **16**(3): 196–202.
18. Antona, B., A. Barrio(2015). "Intraexaminer repeatability and agreement in stereoacuity measurements made in young adults." *Int J Ophthalmol* **8**(2): 374–81.
19. Creavin, A. L., S. T. Creavin(2014) "Why can't my child see 3D television?" *Br J Hosp Med (Lond)* **75**(8): 457–60
20. Bogdanici, S. T., D. Costin(2015). "Quality of life for amblyopic children and their parents." *Rev Med Chir Soc Med Nat Iasi* **119**(1): 214–20
21. Ponsonby, A. L., K. Smith(2013). "Poor stereoacuity among children with poor literacy: prevalence and associated factors." *Optom Vis Sci* **90**(1): 75–83
22. Livingstone, M. S., R. Lafer-Sousa,(2011) "Stereopsis and artistic talent: poor stereopsis among art students and established artists." *Psychol Sci* **22**(3): 336–8.
23. Black, A. and J. Wood (2005). "Vision and falls." *Clin Exp Optom* **88**(4): 212–22.
24. Saladin, J. J. (2005). "Stereopsis from a performance perspective." *Optom Vis Sci* **82**(3): 186–205.

25. Kiely, P. M., S. G. Crewther, et al. (2001). "Is there an association between functional vision and learning to read?" *Clin Exp Optom* **84**(6): 346–353.
26. Palomo-Alvarez, C. and M. C. Puell (2010) "Binocular function in school children with reading difficulties." *Graefes Arch Clin Exp Ophthalmol* **248**(6): 885–92.
27. Noguera, H., J. C. Castiella Acha,(2014). "Medical and surgical treatment of primary divergent strabismus." *Arch Soc ESP Oftalmol* **89**(11): 431–8.
28. Mitchell, D. E., K. MacNeill(2016). "Recovery of visual functions in amblyopic animals following brief exposure to total darkness." *J Physiol* **594**(1): 149–67.
29. Guclu, H., V. P. Gurlu(2015). "Prognostic factors for stereopsis in refractive accommodative esotropia." *Pak J Med Sci* **31**(4): 807–11.
30. Endo, T., T. Fujikado (2016) "Stereoscopic perception of 3-D images by patients after surgery for esotropia." *Jpn J Ophthalmol* **60**(1): 7–13
31. Kim, J., H. J. Shin (2015). "Comparison of conventional versus crossed monovision in pseudophakia." *Br J Ophthalmol* **99**(3): 391–5.
32. Mansouri, B., R. C. Stacy(2013). "Deprivation amblyopia and congenital hereditary cataract." *Semin Ophthalmol* **28**(5–6): 321–6.
33. Choi, H. J., J. H. Lee,(2011). "Secondary intraocular lens implantation in longstanding unilateral aphakia." *Optom Vis Sci* **88**(5): 608–12
34. Kim, D. H., J. H. Kim,(2012) "Long-term results of bilateral congenital cataract treated with early cataract surgery, aphakic glasses and secondary IOL implantation." *Acta Ophthalmol* **90**(3): 231–6.
35. Hwang, J. M., E. R. Matsumoto, et al. (1999). "The relationship between stereopsis and monocular optokinetic nystagmus after infantile cataracts." *J Aapos* **3**(4): 221–6.
36. Wright, K. W. (1997). "Pediatric cataracts." *Curr Opin Ophthalmol* **8**(1): 50–5.
37. Ohzawa, I., G. C. DeAngelis, et al. (1996). "Encoding of binocular disparity by simple cells in the cat's visual cortex." *J Neurophysiol* **75**(5): 1779 – 805. Johnston, A. (1986). "A spatial property of the retino-cortical mapping." *Spat Vis* **1**(4): 319 – 31.
38. Shen Y, Zhao J, Sun L, et al. The long-term observation in Chinese children with monocular myelinated retinal nerve fibers, myopia and amblyopia. *Transl Pediatr.* 2021;10(4):860–869. doi:10.21037/tp-20-452
39. Repka MX, Kraker RT, Tamkins SM, et al. Retinal nerve fiber layer thickness in amblyopic eyes. *Am J Ophthalmol.* 2009;148(1):143–147. doi:10.1016/j.ajo.2009.01.015
40. Jun JH, Lee SY. The effects of optic disc factors on retinal nerve fiber layer thickness measurement in children. *Korean J Ophthalmol.* 2008;22(2):115–122. doi:10.3341/kjo.2008.22.2.115
41. Szigeti A, Tátrai E, Szamosi A, et al. A morphological study of retinal changes in unilateral amblyopia using optical coherence tomography image segmentation. *PLoS One.* 2014;9(2):e88363. Published 2014 Feb 6. doi:10.1371/journal.pone.0088363

42. Masri OS, Abiad B, Darwich MJ, et al. Morphological changes in amblyopic eyes in choriocapillaris and Sattler's layer in comparison to healthy eyes, and in retinal nerve fiber layer in comparison to fellow eyes through quantification of mean reflectivity: A pilot study. *PLoS One*. 2021;16(8):e0255735. Published 2021 Aug 6. doi:10.1371/journal.pone.0255735

43. Miki A, Shirakashi M, Yaoeda K, et al. Retinal nerve fiber layer thickness in recovered and persistent amblyopia. *Clin Ophthalmol*. 2010;4:1061–1064. Published 2010 Sep 20. doi:10.2147/oph.s13145

44. Chen W, Xu J, Zhou J, et al. Thickness of retinal layers in the foveas of children with anisometropic amblyopia. *PLoS One*. 2017;12(3):e0174537. Published 2017 Mar 22. doi:10.1371/journal.pone.017453

45. Araki S, Miki A, Goto K, et al. Macular retinal and choroidal thickness in unilateral amblyopia using swept-source optical coherence tomography. *BMC Ophthalmol*. 2017;17(1):167. Published 2017 Sep 15. doi:10.1186/s12886-017-0559-3

46. Okamoto F, Moriya Y, Sugiura Y, et al. Stereopsis and retinal microstructures following macular hole surgery. *Sci Rep*. 2020;10(1):19534. Published 2020 Nov 11. doi:10.1038/s41598-020-76648-4

Declarations

- No financial support was received from any company or institution.
- This study has not been presented at any conference or meeting.
- The authors have no financial interest in any aspect of this study.
- Conflicting interests: None to declare.

Tables

Table-1 Age and sex distribution

Age categories	Sex		Total
	Female	Male	
0-10	7	4	11
11-20	7	13	20
21-30	7	10	17
31-40	3	1	4
41-50	1	1	2
Total	25	29	54

Table-2 Mean values of central macular thickness and retinal nerve fibre thickness pre and post treatment for both eyes

Category	Mean	Std deviation	Median
Pre-operative central macular thickness od	226.49	39.59	226
Preoperative central macular thickness os	236.60	33.24	237.5
Pre-operative retinal nerve fibre thickness od	76.52	22.67	82
Pre-operative retinal nerve fibre thickness os	83.60	11.81	83.5
Final post-operative central macular thickness od	225.50	41.08	223.50
Final post-operative central macular thickness os	234.34	31.74	240
Final post-operative retinal nerve fibre thickness od	76.59	21.87	82
Final post-operative retinal nerve fibre thickness od	83.51	13.60	87

Table-3 comparative study of central macular thickness and retinal nerve fibre thickness pre and post treatment for both eyes

Variable-1	Variable-2	P value	Significance
Pre-operative central macular thickness od	Final post-operative central macular thickness od	0.341	No
Pre-operative central macular thickness os	Final post-operative central macular thickness os	0.167	No
Pre-operative retinal nerve fibre thickness od	Final post-operative retinal nerve fibre thickness od	0.006	Yes
Pre-operative retinal nerve fibre thickness os	Final post-operative retinal nerve fibre thickness os	0.014	Yes
Pre-operative stereopsis	Final post-operative stereopsis	0.049	Yes
Prep bcva od	Final post-operative bcva od	0.000	Yes
Pre op bcva os	Final post-operative bcva os	0.000	Yes

Table-4 comparative study of other variables and retinal nerve fibre thickness pre and post treatment for both eyes

Variable-1	Variable-2	P value
Hirschberg test	RNFL OD,OS	0.363,0.313
Worth for dot test	RNFL OD,OS	0.472,0.108
Amblyopia	RNFL OD,OS	0.202,0.647
Nystagmus	RNFL OD,OS	0.153,0.151
Alternate deviation	RNFL OD,OS	0.000,0.003
Near point of Accommodation	RNFL OD,OS	0.000,0.000
Near point of Convergence	RNFL OD,OS	0.000,0.000
AC/A ratio	RNFL OD,OS	0.000,0.000
Presenting Stereopsis	RNFL OD,OS	0.927,0.645
Final stereopsis	RNFL OD,OS	0.705,0.058