Original Article

To evaluate stereoacuity in patients with acquired esotropia and to determine factors associated with favourable outcomes

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Aim: To evaluate stereoacuity in patients with acquired esotropia and determine the factors associated with favorable outcomes. **Materials and Methods:** A total of 68 subjects aged 6 years and above were included in the study. Thorough clinical evaluation including binocular status examination using the Bagolini-striated glass test, The Netherland Organization (TNO), and Randot stereo test were done. The subjects were divided into two groups 1 and 2, based on the amount of deviation. Statistical analysis of the result was performed. **Result:** The duration of misalignment in the group with deviation less than or equal to 8 prism diopters (PD) was 1.49 ± 0.86 years, whereas in the group with deviation more than or equal to 10 PD was 4.64 ± 2.99 years (P = 0.000). Among the subjects in group 1, 89.5% achieved fusion and 52.6% had stereoacuity on both TNO and Randot, whereas in group 2 40% achieved fusion and 3.3% stereopsis on both TNO and Randot (one case with only coarse stereopsis). A subanalysis within group 1 revealed a statistically significant difference for the duration of misalignment (P = 0.02), but a marginal difference for the amount of deviation (P = 0.3). **Conclusion:** A horizontal deviation up to 8 PD was compatible with stereopsis. Also, the duration of constant misalignment affects the attainment of stereopsis despite successful realignment.

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Successful surgical outcomes of strabismic subjects are improvement in alignment, relief from diplopia, and normalization of head position. Alignment within 8 prism diopters (PD) of orthophoria was commonly aimed at by the strabismologists, in the belief that it was compatible with binocularity and stereopsis. Leske and Holmes,[1] however, showed that the maximum angle of horizontal deviation consistent with true stereopsis was only 4 PD. Of late, evaluation of stereoacuity is being increasingly used as one of the outcome measures of strabismus management.[2-5] Factors affecting the sensory outcomes in acquired and congenital strabismic subjects have been widely studied with varying conclusions.[4-6] Likewise, the grade of stereopsis attained by these subjects also differs.[5,7-10] The most extensively used stereoscopic tests have been the ones based on the random dot stereograms, namely, TNO, Randot, Random Dot-E (RDE), and Lang 1. Unlike the Titmus, these tests do not contain monocular clues and therefore give a purer test of stereopsis.

The purpose of this study was to evaluate the quality of stereoacuity in subjects with acquired (late onset) esotropia using two different stereo tests, namely, TNO and Randot, and also to correlate the factors responsible for good stereopsis after successful alignment. We studied the effect of the amount of deviation, the age of onset of deviation, age at alignment, duration of constant misalignment, and anisometropia on the binocular status and stereoacuity outcome.

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Materials and Methods

This was a cross-sectional study, where subjects were enrolled from the Squint Clinic of our Institute. Informed consent was obtained from the parents of all subjects. The study was approved by the institution review board and adhered to guidelines of the Declaration of Helsinki. Among the subjects evaluated, 68 met the inclusion criteria. The inclusion criteria were subjects 6 years or older, onset of strabismus after the first year of life, visual acuity of 6/18 or better in each eye, and neurologically and developmentally normal. Subjects were excluded if they had a significant vertical deviation (5 PD or more), intermittent esotropia, or any heterophoria. For the purpose of analysis, the subjects were divided into two groups based on the amount of deviation present following the treatment whether surgical or optical. Group 1, with an angle of deviation less than or equal to 8 PD, had 38 subjects and group 2 had 30 subjects, where the deviation was more than or equal to 10 PD.

Clinical evaluation included a detailed history, where the following details were noted/enquired: Age of the patient, age of onset of deviation, previous therapy including optical, surgical, and amblyopia treatment, age at alignment, and whether optically or surgically realigned. The duration of deviation was determined from the history as the difference between the age of onset and the age of alignment. Besides routine work up for squint assessment, sensory status examination using the Bagolini-striated glass test, TNO, and Randot stereo test was done.

Sensory status examination for binocularity was done using the Bagolini-striated glass test, the three circles test on TNO (Lameris Instrumenten), and the R and L test in the Randot booklet (Stereo Optical Co.). The outcomes recorded on Bagolini glass test were either binocularity or suppression. The level of stereoacuity was evaluated using the TNO (plate

V–VII from 480 to 15 s of arc) and Randot stereo tests (circles test from 400 to 20 s of arc). The minimal value taken as positive for stereopsis in TNO was 480 s of arc and for Randot was 400 s of arc. The normal value for stereoacuity was considered ≤ 60 s of arc.

Data analysis

Statistical analysis was performed using the statistical package Statistical Package for the Social Sciences (SPSS) Version 17 (SPSS, Chicago, Ill).

Results

A total of 68 subjects (including 38 in group 1 and 30 in group 2) were recruited for the study. The mean deviation was 3.8 ± 1.0 PD in group 1 (range 2-8 PD) and 18.8 ± 11.4 PD in group 2 (range 10-45 PD). There were proportionately more males (n = 42; 62%) and the subjects ranged in age from 6 to 19 years with a mean age of 8.4 ± 2.4 and 8.5 ± 2.0 years, respectively, in the two groups (P = 0.92). The distribution of the type and amount of deviation is summarized in Table 1. In group 1, the major type of deviation was accommodative ET (55.3%), whereas in group 2 it was partially accommodative ET (36.7%).

Table 2 summarizes the comparison between the two groups of subjects. There were no statistically significant differences between the two groups in the age of onset of deviation (P = 0.81), age of alignment (P = 0.09), proportion of subjects who underwent surgical correction (P = 0.55), and the amount of preoperative deviation (P = 0.17).

Among the 38 subjects in group 1, eye realignment with optical correction alone was achieved in 24 subjects at 5.6 ± 2.2 years (duration of misalignment 1.1 ± 0.75 years), whereas in the remaining 14 subjects, realignment was achieved with both optical and surgical correction at 5.1 ± 2.3 years (duration of misalignment 1.95 ± 0.8 years). In group 2, consisting of subjects who were not realigned to within 8 PD, the duration of misalignment was taken up to the time of examination. This was 4.6 ± 3.0 years (P value between the groups was statistically significant at 0.02). Eight subjects in group 2 had undergone prior surgical correction at a mean age of 5.6 ± 1.8 years and were residual esotropes.

Evaluation of stereopsis

Sensory status examination on the Bagolini revealed binocular single vision (BSV) in 34 subjects (89.5%) and suppression in 4 subjects (10.5%) in group 1, whereas evaluation in group 2 showed BSV and suppression in 11 (36.7%) and 19 subjects (63.3%), respectively.

Tables 3 and 4 show the distribution of subjects as per deviation and level of stereoacuity in TNO and Randot, respectively. In group 1, there were 13 subjects with a stereoacuity of ≤120 s of arc on TNO and 14 subjects with ≤100 s of arc on the Randot. In group 2, there was only one subject (3.3%) who developed stereoacuity, which was 240 s of arc on TNO and 140 s of arc on Randot. This lone subject had a deviation of 10 PD. For each multiple of PD, the percentage of subjects who developed measurable stereopsis varied from 40 to 75%. For both TNO and Randot, it was 60% in those with 2 PD, 40% in 4 PD, 75% in 6 PD, and 50% in the subjects with 8 PD. It was noteworthy that performance on the different tests gave differing results.

Sub-analysis for subjects with deviation ≤8PD (Group 1)

Further analysis was performed within group 1, between those with presence and absence of stereopsis. Of the 38 subjects, there were 21 with stereopsis (on both TNO and Randot) and 18 without stereopsis. The mean age in these two groups were 8.4 ± 2.6 and 8.5 ± 2.2 years (P = 0.85); and the mean age of onset of deviation were 4.3 ± 1.8 and 3.8 ± 2.5 years respectively with P = 0.44. The age of alignment of deviation was 5.5 ± 1.5 and 5.6 ± 2.4 years respectively in those with and without stereopsis, with P = 0.8; and the duration of misalignment was 1.2 ± 0.8 and 1.8 ± 0.8 years respectively in the two groups. Only this difference between the two groups was statistically significant (P = 0.02).

Examination using the Bagolini striated glass test showed that all the subjects with stereopsis had BSV. However, 14 of the 18 with no measurable stereoacuity showed presence of BSV. This was an interesting finding because it indicates that these subjects had achieved BSV but not stereopsis.

Subanalysis of subjects with measurable stereopsis

Fine stereopsis was defined as stereoacuity of ≤60 s of arc on TNO and ≤40 s of arc on the Randot, the rest being coarse. A total of 21 subjects had measurable stereoacuity both on the TNO and Randot [Tables 3 and 4]. Fine stereoacuity was seen in seven and five subjects, respectively, on the TNO and Randot, whereas the remaining 13 and 15 subjects had coarse stereoacuity. Of the subjects who had fine stereopsis, three were surgically realigned.

Subanalysis of duration of misalignment

The duration of misalignment for all the 38 subjects in group 1 was 1.49 ± 0.86 years. Of these, 24 were aligned with glasses alone and had a duration of misalignment of 1.1 ± 0.75 years, whereas the remaining 14 who additionally required surgery had a mean duration of 1.95 ± 0.8 years.

Table 1: Distribution of all patients in different categories of deviation after correction with glasses or surgery

ET	2 PD	4 PD	6 PD	8 PD	10 PD	12-24 PD	≥25 PD	Total
Accommodative	10	6	3	3	0	0	0	21
Partially accommodative	2	0	0	0	6	3	2	11
Residual	3	7	1	0	4	3	1	19
Non-accommodative	0	0	0	0	0	2	7	10
Treated anisometropic amblyopia with	0	2	0	1	2	0	0	7
Total	15	15	4	4	12	8	10	68

PD: Prism diopters, ET: Esotropia

Table 2: Comparison of the various parameters between the two groups

	Group 1 (*n*=38)	Group 2 (*n*=30)	*P* value
Age, years (SD)	8.4 (2.4)	8.5 (3.0)	0.92
Range, years	6-15	6-19	
Age of onset of deviation, years (SD)	4.1 (2.1)	3.9 (3.3)	0.81
Range, years	1.5-10.0	1.0-18.5	
Age of alignment, years (SD)	5.5 (2.0)	6.5 (2.8)	0.09
Range, years	2.3-11.1	3.5-18.6	
Duration of misalignment, years (SD)	1.5 (0.9)	4.6 (3.0)	<0.001
Range, years	0-3	0.5-13	
Surgical procedure, Number (%)	14 (36.8)	9 (30.0)	0.55
Preoperative deviation, PD	30.9 (8.2)	37.6 (13.7)	0.17
Range, PD	20-45	16-60	
Sensory status on Bagolini			
BSV	34 (89.5)	11 (36.7)	<0.001
Suppression	4 (10.5)	19 (63.3)	

BSV: Binocular single vision, SD: Standard deviation, PD: Prism diopters

Table 3: Distribution of cases as per stereoacuity and sensory status with deviation-TNO

TNO → Deviation ↓	60 s of arc	120 s of arc	240 s of arc	480 s of arc	Only BSV	No BSV	Total
2 PD	1	3	3	2	5	1	15
4 PD	3	1	2	0	7	2	15
6 PD	1	2	0	0	1	0	4
8 PD	2	0	0	0	1	1	4
10 PD	0	0	1	0	6	5	12
12-24 PD	0	0	0	0	5	3	8
≥25 PD	0	0	0	0	0	10	10
Total	7	6	6	2	25	22	68

PD: Prism diopters, BSV: Binocular single vision

Table 4: Distribution of cases as per stereoacuity and sensory status with deviation-Randot

Randot → Deviation ↓	20-40 s of arc	50-100 s of arc	140-200 s of arc	400 s of arc	Only BSV	No BSV	Total
2 PD	2	2	3	2	5	1	15
4 PD	1	5	0	0	7	2	15
6 PD	1	1	0	1	1	0	4
8 PD	1	1	0	0	1	1	4
10 PD	0	0	1	0	6	5	12
12-24 PD	0	0	0	0	5	3	8
≥25 PD	0	0	0	0	0	10	10
Total	5	9	4	3	25	22	68

PD: Prism diopters, BSV: Binocular single vision

For group 2, the duration of misalignment was taken up to the time of examination, which was 4.64 ± 2.99 years (*P* value between the groups was statistically significant at 0.02).

Discussion

Normally, the ocular dominance column (ODC) representing the foveola (0° eccentricity) of the right eye is adjacent to that of the left eye. The adjacent arrangement is well within the range of horizontal connections required for binocular fusion. The horizontal axon length across ODC's is the same in normal and in those with strabismus. It has been experimentally found that the horizontal axons that are about 7-mm long can connect the ODCs that are within 2.5° (4.4 PD) apart. One neuron representing the fovea could therefore link to a field that is about 4.4 PD apart. Two horizontal neurons together could link to a receptive field about 5° (8.7 PD) apart.[11] These data on human infants justify realignment of the eyes to within 8 PD.

Successful outcome of strabismus surgery has most commonly been defined as alignment to within 8-10 PD of orthophoria.[5,12,13] But the hallmark of binocular vision is stereopsis. Several studies have begun to include stereoacuity as an outcome measure in both surgical and optical treatments of strabismus.[2-5]

Leske *et al.*, showed stereopsis with minimum 4-PD deviation.[1] However, in our study, there were five (28.5%) subjects (of those with stereopsis) with deviation more than 4 PD who had fine stereopsis. This appears as a small percentage because the total number of subjects with a deviation of 6-8 PD was itself small. In fact, the percentage of subjects who acquired stereopsis was 50% in the 2-4 PD group and 62.5% in the 6-8 PD group. This again reiterates our findings that deviation up to 8 PD, and not just 4PD, is compatible with development of stereopsis and also that the interplay of other factors may be important.

In a prospective study, on accommodative esotropic children, Birch *et al.*,[8] found 46% of them had stereopsis, of which only 18% had normal stereoacuity levels. A total of 39% had nil stereopsis, 10% never attained orthophoric position, and the remaining 5% had dense amblyopia. In the present study, 20 of 38 (52.6%) subjects within 8 PD (group 1) developed measurable stereopsis, and only one of 30 (3.3%) with a deviation of ≥10 PD (group 2) developed stereopsis. Of those who developed stereopsis and were within 8 PD, only 25-35% had fine stereopsis. The sole patient in group 2 with stereopsis had a deviation of 10 PD (just on the fence!) and was previously operated for a partially accommodative esotropia. The duration of deviation prior to surgical intervention was 8 months. Hence, we can infer that deviation upto 8 PD is a factor that determines stereopsis. However, on further subgroup analysis, we found that level of stereoacuity was not dependent on the amount of deviation, as long as deviation was within 8 PD.

The relationship of duration of deviation and development of stereoacuity has been extensively studied.[3-5,14] Studies in children have shown that a shorter duration of misalignment was consistent with fine stereopsis, whereas in adults, Ohtsuki *et al.*,[3] found no correlation between stereopsis and duration of deviation. In our study (which included mainly children of mean age 8.42 ± 2.42 years), the subjects with stereopsis had a significantly shorter duration of constant misalignment as compared with those with no stereopsis. No subjects with stereopsis had duration of constant misalignment for more than 3 years.

Lal and Holmes[5] evaluated the relationship of stereoacuity with duration of misalignment in adults with strabismus. They found that there was no statistical difference in the duration of constant misalignment in the subjects with or without stereopsis and also in those with fine or coarse stereopsis. This was unlike the observations made by Eustis and Parks,[15] wherein they noted that fine stereoacuity was possible only if duration of misalignment was for 2–3 months.

It has been widely reported that adult subjects with long-standing strabismus recover their binocular vision and stereopsis after surgical realignment. Mets[9] and associates studied the postoperative binocularity in 72 adult strabismic subjects and found that 30 (42%) had an improvement in binocularity, tested by the synoptophore, Worth 4 dot, and Titmus test. Our study noted that 89% (34 of 38) of subjects realigned to within 8 PD had BSV as measured by Bagolini lenses but only 40% (12 of 30) in those beyond 10 PD did so. Of the 30, 18 had previously been treated for amblyopia and five (28%) of them recovered binocularity.

Conclusion

In conclusion, a deviation of upto 8 PD was compatible with stereopsis. Moreover, the quality of stereopsis attained was not dependent on the amount of deviation as long as it was within 8 PD, but it was better in those subjects without anisometropia. Also, the duration of constant misalignment affects the attainment of stereopsis despite successful realignment. Therefore, we should aim to realign the eyes to within 8 PD of orthophoria, as early as possible to decrease the duration of misalignment.

References

1. Leske DA, Holmes JM. Maximum angle of horizontal strabismus consistent with true stereopsis. J AAPOS 2004;8:28-34.
2. Morris RJ, Scott WE, Dickey CF. Fusion after surgical alignment of longstanding strabismus in adults. Ophthalmology 1993;100:135-8.
3. Ohtsuki H, Hasebe S, Kobashi R, Okano M, Furuse T. Critical period for restoration of normal stereoacuity in acute-onset comitant esotropia. Am J Ophthalmol 1994;118:502-8.
4. Fawcett S, Leffler J, Birch EE. Factors influencing stereoacuity in accommodative esotropia. J AAPOS 2000;4:15-20.
5. Lal G, Holmes JM. Postoperative stereoacuity following realignment for chronic acquired strabismus in adults. J AAPOS 2002;6:233-7.
6. Tomac S, Birdal E. Effects of anisometropia on binocularity. J Pediatr Ophthalmol Strabismus 2001;38:27-33.
7. Wright KW, Edelman PM, Mcvey JH, Terry AP, Lin M. High-grade stereo acuity after early surgery for congenital esotropia. Arch Ophthalmol 1994;112:913-9.
8. Birch EE, Stager DR Sr, Berry P, Leffler J. Stereopsis and long-term stability of alignment in esotropia. J AAPOS 2004;8:146-50.
9. Mets MB, Beauchamp C, Haldi BA. Binocularity following surgical correction of strabismus in adults. Trans Am Ophthalmol Soc 2003;101:201-5.
10. Kassem RR, Elhilahi HM. Factors affecting sensory functions after successful postoperative ocular alignment of acquired esotropia. J AAPOS 2006;10:112-6.
11. Wong AM, Lueder GT, Burkhalter A, Tychsen L. Anomalous retinal correspondence: Neuroanatomic mechanism in strabismic monkeys and clinical findings in strabismic children. J AAPOS 2000;4:168-74.
12. Kushner BJ, Fisher MR, Lucchese NJ, Morton GV. Factors influencing response to strabismus surgery. Arch Ophthalmol 1993;111:75-9.
13. Abbasoğlu OE, Sener EC, Sanac AS. Factors influencing the successful outcome and response in strabismus surgery. Eye (Lond) 1996;10:315-20.
14. Fawcett SL, Birch EE. Risk factors for abnormal binocular vision after successful alignment of accommodative esotropia. J AAPOS 2003;7:256-62.
15. Eustis HS, Parks MM. Acquired monofixation syndrome. J Pediatr Ophthalmol Strabismus 1989;26:169-72.

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