

EXTENT OF IMPROVEMENT IN BINOCULARITY AND STEREOPSIS IN CONSTANT CONCOMITANT HORIZONTAL STRABISMUS AFTER SURGICAL MANAGEMENT AND ITS ASSOCIATION WITH THE POSTOPERATIVE OCULAR ALIGNMENT

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ABSTRACT

BACKGROUND

The gradual decrease in binocularity and stereopsis in patients with concomitant strabismus decreases the depth perception of the patients and adversely affects the reading speed and the motor dexterity skills of the individuals. It had been observed earlier that early management is necessary to help patients regain their binocularity, but recent studies indicate that binocularity and stereopsis may improve in these patients even if they are treated later in life, provided they are managed well. Hence, we undertook this study to determine the extent of improvement in binocularity and stereopsis in patients with long-standing large angle constant concomitant horizontal strabismus after surgical management after the age of 16 years and its association with the postoperative alignment.

MATERIALS AND METHODS

A prospective clinical trial was conducted in 30 patients with constant concomitant horizontal strabismus of more than 25 prism dioptres who presented after the age of 16 years. Binocularity and stereopsis were measured in the patients with the help of Worth 4-dot test, synoptophore, Lang II test plate, Randot test plates and TNO test plates. The measurements were done preoperatively and 6 weeks after surgical treatment. The changes in the measurements were associated with the postoperative alignment.

RESULTS

Preoperatively, the patients demonstrated either alternating or unilateral suppression with no measurable stereopsis. Postoperatively, satisfactory surgical alignment defined as tropia less than or equal to 8 Prism Dioptres (PD) was achieved in 23 (76.6%) of the patients. 19 (63.3%) patients achieved binocularity on Worth 4-dot test and synoptophore, but alternating or unilateral suppression was still present in 11 (36.6%) of the patients. 17 (56.6%) of the 30 patients achieved stereopsis on Lang II, Randot and TNO test plates. Development of stereopsis was associated with postoperative alignment with 16 (69.5%) of the 23 satisfactorily aligned patients and only 1 (14.3%) of the 7 patients with a residual deviation of ≥ 10 PD achieving stereopsis.

CONCLUSION

Significant improvement in binocularity and stereopsis can be achieved in patients with long-standing large angle constant concomitant horizontal strabismus after surgical management even after the age of 16 years and the development of binocularity and stereopsis is associated with the final postoperative alignment.

KEYWORDS

Stereopsis, Binocularity, Concomitant Strabismus, Ocular Alignment.

HOW TO CITE THIS ARTICLE: Kohli V, Mehta B, Kumar S, et al. Extent of improvement in binocularity and stereopsis in constant concomitant horizontal strabismus after surgical management and its association with the postoperative ocular alignment. J. Evid. Based Med. Healthc. 2017; 4(2), 80-85. DOI: 10.18410/jebmh/2017/16

Financial or Other, Competing Interest: None.
Submission 12-12-2016, Peer Review 20-12-2017,
Acceptance 03-01-2017, Published 05-01-2017.

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DOI: 10.18410/jebmh/2017/16



BACKGROUND

Strabismus or misalignment of the eyes is a common condition affecting 1-4% of the world population.¹ The presence of strabismus profoundly affects the life of the individual not only due to the cosmetic effect and the associated psychosocial implications, but also due to the decrease in binocularity, fusional amplitudes and stereopsis. It may also lead to a decrease in the visual acuity of an eye due to strabismic amblyopia, if strabismus develops during the early years of life. It has been seen that this decrease in

binocularity also adversely affects the reading speed and the motor dexterity skills of the individuals.²⁻⁴

It has been observed in several studies that if constant concomitant strabismus is managed appropriately during early childhood, significant gain in binocularity and stereopsis can be obtained and if the treatment is delayed, the patients gain in terms of cosmesis, but their chances of functional improvement decrease.^{5,6} But, recent studies indicate that binocularity and stereopsis may improve in these patients even if they are treated later in life provided they are managed well.⁷⁻¹⁰

Hence, we conducted this prospective study to evaluate the extent of improvement in binocularity and stereopsis in patients with long-standing large angle constant concomitant horizontal strabismus after surgical management after the age of 16 years and its association with the postoperative alignment.

MATERIALS AND METHODS

After obtaining ethical approval from the institutional review board, thirty patients above the age of 16 years with a long-standing constant concomitant horizontal strabismus of more than 25 prism dioptres and whose best corrected visual acuity of the worse eye was $\geq 6/24$ were recruited for this study. Patients with previous strabismus surgery, best corrected visual acuity less than 6/36 in either eye, paralytic or restrictive strabismus, ocular disease other than strabismus and refractive error were excluded. Cycloplegic refraction, best corrected visual acuity and strabismus measurement with prism alternate cover test was done for all the patients. Binocularity and stereopsis was measured in the patients with the help of Worth 4-dot test, synoptophore, Lang Stereotest II plate (Lang Stereotest AG, Switzerland), Random Dot 2 test plates (Vision Assessment Corporation, Illinois, USA) and TNO test plates (Lameris Ootech, Netherlands). Stereopsis as measured through Lang test was graded from 600" to 200", through Random Dot plates was graded from 500" to 12.5" and through TNO test plates was graded from 'stereopsis present' to 480" to 15".

Surgical correction was then done by recession with or without resection of the appropriate medial or lateral recti. The amount of muscle recession and resection was according to the tables given by Rosenbaum.¹¹

The strabismus measurement and the measurements of binocularity and stereopsis were then repeated 6 weeks after surgery. The preoperative and postoperative measurements were then compared and the changes in the measurements were associated with the postoperative alignment. Statistical analyses were performed using chi-square test to compare preoperative and postoperative stereopsis and to see the relationship between postoperative surgical alignment and postoperative stereopsis. A p-value less than 0.05 was considered statistically significant.

RESULTS

Thirty subjects were recruited for this study out of which 18 had exotropia and 12 had esotropia. The age of the subjects ranged from 16 to 45 years with a mean age of 24.5 years.

The preoperative deviation ranged from 25 to 85 Prism Dioptres (PD) with a mean deviation of 55 PD. The best corrected visual acuity of the dominant eye ranged from 6/9 to 6/5 and the best corrected visual acuity of the non-dominant eye ranged from 6/24 to 6/5. Preoperatively, the patients had alternating or unilateral suppression and did not demonstrate any stereopsis. The preoperative details of the patients are given in Table 1.

	Number of Patients (Total - 30)
Age Distribution (years)	
16-25	20
26-35	6
36-45	4
Preoperative Deviation (PD)	
25-40	7
40-55	8
55-70	8
70-85	7
BCVA of Worse Eye	
6/24	4
6/12-6/18	4
6/5-6/9	22
Worth 4-Dot Test	
Suppression	30
Synoptophore	
Suppression	30
Lang II	
Stereopsis present	0
Randot	
Stereopsis present	0
TNO	
Stereopsis Present	0

Table 1. Preoperative Characteristics of the Patients

Abbreviations-

PD- Prism Dioptres.

BCVA- Best Corrected Visual Acuity.

The patients then underwent appropriate strabismus surgery. The patients with exotropia underwent lateral recti recession with or without medial recti resection and the patients with esotropia underwent medial recti recession with or without lateral recti resection. The amount of recession and resection was based on the tables given by Rosenbaum.¹¹ The patients with deviation ≤ 45 PD underwent bilateral muscle recessions alone and if the deviation was more than 45 PD, muscle resection was added. After 6 weeks, measurement of the alignment of the visual axes by prism alternate cover test and binocularity and stereopsis measurements were repeated. Satisfactory surgical alignment was defined as a postoperative tropia of ≤ 8 prism dioptres. The postoperative alignment of the patients and their postoperative binocularity and stereopsis measurements on Worth 4-dot test, synoptophore, Lang II test plate, Randot test plates and TNO test plates are depicted in Table 2 and Table 3.

	All Patients (30 pts.)		Exotropes (18 pts.)		Esotropes (12 pts.)	
	Postoperative Alignment		Postoperative Alignment		Postoperative Alignment	
	≤8PD (23 pts.)	≥10PD (7 pts.)	≤8PD (14 pts.)	≥10PD (4 pts.)	≤8PD (9 pts.)	≥10PD (3 pts.)
	Number of pts.	Number of pts.	Number of pts.	Number of pts.	Number of pts.	Number of pts.
Worth 4-Dot						
BSV	18	1	12	1	6	0
Diplopia	0	0	0	0	0	0
Suppression	5	6	2	3	3	3
Synoptophore						
Stereopsis present	15	0	10	0	5	0
SMP and Fusion	3	1	2	1	1	0
Suppression	5	6	2	3	3	3

Table 2. Postoperative Alignment and Binocularity of Patients on Worth 4-Dot Test and Synoptophore

Abbreviations- PD- Prism Dioptres, pts.- Patients, BSV- Binocular Single Vision, SMP- Simultaneous Macular Perception.

	All patients (30 pts.)		Exotropes (18 pts.)		Esotropes (12 pts.)	
	Postoperative Alignment		Postoperative Alignment		Postoperative Alignment	
	≤8PD (23 pts.)	≥10PD (7 pts.)	≤8PD (14 pts.)	≥10PD (4 pts.)	≤8PD (9 pts.)	≥10PD (3 pts.)
	Number of pts.	Number of pts.	Number of pts.	Number of pts.	Number of pts.	Number of pts.
Lang II						
Stereopsis Present	16	1	11	1	5	0
200"	9	0	7	0	2	0
400"	4	0	2	0	2	0
600"	3	1	2	1	1	0
Randot						
Stereopsis Present	15	1	10	1	5	0
40-100"	5	0	5	0	0	0
125-200"	6	0	3	0	3	0
250-500"	4	1	2	1	2	0
TNO						
Stereopsis Present	14	1	9	1	5	0
120"	1	0	1	0	0	0
240"	3	0	2	0	1	0
480"	4	0	3	0	1	0

Table 3. Postoperative Stereopsis in the Patients

Abbreviations- PD- Prism Dioptres, pts.- patients, TNO- The Netherlands Organization test plates.

A total of 23 (76.6%) of the 30 patients achieved satisfactory surgical alignment, which comprised 14 (77.7%) of the 18 exotropes and 9 (75%) of the 12 esotropes. Binocularity on Worth 4-dot test was achieved in 19 (63.3%) of the 30 patients. It was noted that 18 (78.2%) of the 23 satisfactorily aligned patients and only 1 (14.3%) of the 7 patients with a residual deviation of ≥10PD achieved binocularity and 13 (72.2%) of the 18 exotropes and 6 (50%) of the 12 esotropes achieved binocularity on Worth 4-dot test.

Preoperatively, all the patients demonstrated suppression on synoptophore, but postoperatively, 15 (50%) of the 30 patients demonstrated stereopsis on synoptophore, 4 (13.3%) demonstrated simultaneous macular perception and fusion, but no stereopsis and 11 (36.6%) still demonstrated suppression.

Preoperatively, all the patients had absence of stereopsis, but postoperatively, 17 (56.6%) of the 30 patients achieved stereopsis with 16 (69.5%) of the 23 satisfactorily aligned patients and only 1 (14.3%) of the 7 patients with a residual deviation of ≥10PD achieving stereopsis. 12 (66.6%) of the 18 exotropes and 5 (41.6%) of the 12 esotropes developed stereopsis. 11 (78.5%) of the 14 satisfactorily aligned exotropes and 5 (55.5%) of the 9 satisfactorily aligned esotropes developed stereopsis. The statistical analysis of the results is given in Table 4. It shows that there was a significant improvement in binocularity and stereopsis postoperatively (p<0.001) and it was significantly associated with the postoperative alignment (p=0.002). The improvement was more in exotropia than in esotropia though it did not reach a statistically significant number (p=0.215).

	Number of Patients Showing Binocularity			Postoperative Alignment			Exotropia Versus Esotropia		
	Preoperative (30 pts.)	Postoperative (30 pts.)	p-value	≤8PD (23 pts.)	≥10PD (7 pts.)	p-value	Exotropia (18 pts.)	Esotropia (12 pts.)	p-value
Worth 4-Dot Test									
Binocularity present	0	18	<0.001	18	1	0.002	13	6	0.215
Synoptophore									
Binocularity present	0	19	<0.001	18	1	0.002	13	6	0.215
Lang II Test									
Stereopsis present	0	17	<0.001	16	1	0.009	12	5	0.176
Randot Test									
Stereopsis present	0	16	<0.001	15	1	0.018	11	5	0.295
TNO Test									
Stereopsis present	0	15	<0.001	14	1	0.031	10	5	0.456

Table 4. Statistical Analysis of the Results

Abbreviations- PD- Prism Dioptres, pts.- patients, TNO- The Netherlands Organization test plates.

DISCUSSION

Stereopsis is an important facility that humans have due to the presence of the two eyes in a straight-ahead position and due to the slightly disparate images that are formed in the two eyes due to their horizontal separation of approximately 6 centimetres. A prerequisite for the development of normal stereopsis is that the two eyes should be properly aligned so that the foveae are fixating on the same object of interest. Stereopsis helps in depth perception and has been correlated with better reading speeds, better prehension and better motor dexterity skills.²⁻⁴ It is also associated with long-term stability of ocular alignment.¹² In patients with concomitant strabismus, binocularity and stereopsis gradually decrease over time as a result of abnormal binocular experience.

It has been observed in several studies that if constant concomitant strabismus is managed appropriately during early childhood, significant gain in binocularity and stereopsis can be obtained and if the treatment is delayed, the patients gain in terms of cosmesis, but their chances of functional improvement decrease.^{5,6} But, recent studies indicate that binocularity and stereopsis may improve in these patients even if they are treated later in life provided they are managed well.⁷⁻¹⁰

In our study, we found that after strabismus surgery, 23 (76.6%) of the 30 patients achieved satisfactory surgical alignment, which was defined as a postoperative tropia of ≤8PD and 17 (56.6%) of the 30 patients achieved stereopsis with 16 (69.5%) of the 23 satisfactorily aligned patients and only 1 (14.3%) of the 7 patients with a residual deviation of ≥10PD achieving stereopsis.

In the study conducted by Lal et al, 21 adult patients with constant long-term acquired strabismus were evaluated and it was seen that none of them had any binocularity or stereopsis preoperatively and 67% of them gained measurable stereopsis postoperatively.⁷ In a study conducted in 23 adults with acquired strabismus by Fawcett et al, 30% of the patients demonstrated stereopsis on Preschool Randot test, but 70% of the patients demonstrated stereopsis on Titmus circles postoperatively.⁸

They also noted that the stereopsis is more if the patient is orthotropic postoperatively. Fatima et al studied 15 adult patients with long-standing strabismus and found that after successful surgical alignment, 13 of them demonstrated stereopsis on Titmus test and 10 of them demonstrated stereopsis on TNO test.⁹

Studies have also been conducted to find out the factors associated with the development of binocularity and stereopsis in these patients.¹³⁻¹⁸

It has been seen that stereopsis is easier to achieve if the strabismus is intermittent rather than constant.¹³⁻¹⁵ Most intermittent exotropes attain good binocularity and stereopsis after treatment and many have good binocularity and stereopsis even before treatment due to the lack of amblyopia and the presence of time intervals in which they are orthotropic. The constant exotropes, whereas, have poorer preoperative binocularity and though they have substantial improvement in binocularity postoperatively, it is less than that of the intermittent exotropes. In our study, we evaluated patients with constant strabismus only to see the improvement that occurs in this group, which has poor preoperative binocularity. We found that 56.6% of the patients did achieve measurable stereopsis. Wu et al evaluated 34 patients of intermittent exotropia and 29 patients of constant exotropia and observed that all of the intermittent exotropes and only 5 (33.3%) of the 15 constant exotropes developed stereopsis of 800" or better postoperatively.¹³ Koc et al evaluated the stereoacuity in surgically corrected visually mature exotropes and found that 77% of them achieved stereoacuity, but only 9% achieved fine stereoacuity.¹⁴ They found that intermittency of strabismus, onset of strabismus after 1 year of age, absence of interocular difference of visual acuity and strabismus duration of less than 20 years were the strongest predictors of attainment of stereopsis with decreasing power. Na et al evaluated long-term outcomes in intermittent and constant exotropia after surgical correction and observed that cumulative probability of satisfactory surgical alignment three years after surgery was 92% in intermittent exotropia and 70% in constant exotropia and

there was significantly more distance suppression ($p=0.029$) and poor stereopsis ($p=0.002$) in constant exotropes even after surgical treatment.¹⁵

We also observed in our study that exotropes had a much higher chance of achieving stereopsis than esotropes. 12 (66.6%) of the 18 exotropes and 5 (41.6%) of the 12 esotropes developed stereopsis and 11 (78.5%) of the 14 satisfactorily aligned exotropes and only 5 (55.5%) of the satisfactorily aligned esotropes developed stereopsis. This can be explained by the fact that most constant exotropes have probably had a period of intermittency of strabismus earlier in their life though they may not have been aware of it and may have developed their binocular pathways during their early period of visual maturation before the development of their intermittent strabismus. Esotropes, on the other hand consisted mainly of infantile esotropes and neglected partially accommodative esotropes who possibly had lost their binocular functions quite early in life during the early critical period of visual development.

It has also been seen that success in achieving stereopsis after strabismus management is also associated with the age of onset of strabismus.¹⁶⁻¹⁸ Iordanous et al did a retrospective review of charts of 57 patients with partially accommodative esotropia and found that only 42% of them achieved stereopsis of 100 arc sec or better after treatment.¹⁶ They found that achievement of stereopsis was significantly correlated with the age of onset of strabismus (31.8 months versus 23.9 months, $p=0.012$) and not significantly correlated with the duration of alignment ($p=0.57$) or the age at surgery.

Thus, studies indicate that attainment of stereopsis is significantly correlated with three factors.¹³⁻¹⁸ First, stereopsis is significantly associated with the age of onset of strabismus and the earlier the onset of strabismus, the lesser the chances of attaining stereopsis after appropriate treatment and the later the onset of strabismus, the higher the chances of attaining stereopsis after treatment.¹⁶⁻¹⁸ Second, stereopsis is significantly associated with the intermittency or constancy of strabismus with intermittent strabisms having a higher chance of attaining stereopsis than constant strabisms.¹³⁻¹⁵ Third, stereopsis is significantly associated with the postoperative alignment of the eyes and the closer the patient is to the orthotropic state after treatment, the higher the chances of the patient developing good stereopsis.^{8,19} Hence, as strabismologists, we should focus on achieving orthotropia in these patients.

CONCLUSION

Stereopsis, gross or fine, can be achieved in strabismic patients even when they are treated after the age of 16 years and the chances increase if the patient is close to orthotropia postoperatively and the patient is not amblyopic. Hence, it is essential to do a good prism alternate cover test and to develop and use alternate methods of measuring strabismus, which are less observer dependent and are more objective, reproducible and have less interobserver differences so that the accuracy of measuring strabismus can be improved. It is also imperative to follow a meticulous

surgical technique so that the desired and expected postoperative surgical alignment can be achieved. Early detection and prompt effective management of amblyopia is also necessary to achieve good long-term sensory and motor outcome in these patients.

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