Binocular summation in comitant exotropia: Change after surgery

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Purpose: To assess the change in binocular summation (BiS) in comitant exotropia (XT) after strabismus surgery. **Methods:** This is a prospective study on 20 patients who underwent surgery for comitant XT over a one year period. Patients with sensory exotropia and nystagmus were excluded. Best-corrected visual acuity (VA) and contrast sensitivity (CS) of both eyes separately and together (binocularly) were recorded. BiS score was calculated as binocular score minus better eye score. BiS score at the end of 3 months was compared with the preoperative data. **Results:** The mean ± SD of BiS score increased from 2.95 ± 0.88 to 4.55 ± 0.68 (P-value < 0.0001) for VA (on ETDRS letters) and from 2.75 ± 0.44 to 4.5 ± 0.76 (P-value < 0.001 for CS (on Pelli–Robson chart) after surgery. **Conclusion:** There is significant improvement in BiS in XT after strabismus surgery. Authors recommend its inclusion in evaluation of functional outcome of XT surgery.

Key words: Binocular summation, comitant exotropia, contrast sensitivity, strabismus surgery, visual acuity

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Binocular summation (BiS) is defined as the superiority of binocular over monocular performance on visual threshold tasks.[1] It measures a binocular function that is not well characterized in strabismic patients.[1] Usual binocular functions are assessed in clinical settings by evaluating fusion and stereoacuity.[2] Some of these tests have questionable validity because of monocular cues or dissociative testing methods.[2] All tests require a minimum level of visual acuity in each eye to assess binocular status.[2] Accurately performing these tests is challenging in children, more so in the presence of ocular deviations.

Attempts to assess the surgical results following strabismus surgery have been made through various studies mainly in terms of motor outcomes.[3] There has also been an overemphasis on stereopsis and considering it pinnacle for binocular vision.[3,4] These studies lack evaluation of functional visual outcomes.

Unlike stereoacuity, BiS is simple, not affected by monocular cues and can be assessed in patients with childhood strabismus with relative ease.[2] BiS provides a measurement of functional binocular vision, especially in patients with limited potential for stereopsis. The ease of performing this test further enhances its utility.

Our study aims to compare preoperative and postoperative BiS in exotropes (XT) undergoing surgical correction. In this pilot study, we have studied only XT to have a homogenous study group.

Methods

All patients undergoing surgery for comitant exotropia over one year were included in this prospective study after approval from institutional ethical committee.

Patients uncooperative for examination, having sensory XT, other ocular disorders effecting VA (like corneal opacities, retinal disorders, etc.), and nystagmus were excluded.

Ophthalmological examination of patient included recording best corrected visual acuity (VA) using Early Treatment Diabetic Retinopathy Study (ETDRS) protocol and contrast sensitivity on Pelli–Robson chart. The score was recorded as the maximum number of alphabets read by the patient. This method is consistent with a previous study.[5] Each eye was tested separately and then both eyes together (binocularly). The deviation was corrected by prisms while making binocular measurements.

Detailed ocular examinations including facial symmetry, head posture, ocular position, ocular alignment, ocular movements, slit-lamp examination, and fundus evaluation were done and recorded.

BiS was calculated for VA and CS using formula:

BiS = Binocular score minus better eye score

For example, if on the ETDRS chart, a patient reads 17 optotypes correctly with the right eye, 15 with the left eye and

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20 with both eyes, his BiS would be 03 [binocular score (20) minus better eye score (17)].

If binocular score was found equal to better eye score, BiS was recorded as zero.

BiS for contrast sensitivity was calculated similarly on the Pelli–Robson chart. This chart has 6 optotypes in each line and a total of 8 lines, thus, making 48 as the maximum possible single eye score in a normal individual.

Surgery was done according to the standard protocol. Successful ocular alignment (motor outcome) was defined as ± 10 Prism Dioptres (PD) of orthotropia postoperatively.[4,6]

All the cases were followed up on day 1, day 7, and 3 months after surgery. On day 1 and day 7, wound healing and other early postoperative complications were noted. VA, CS, and BiS scores at the end of 3 months were compared with the preoperative data. For sensory evaluation, postoperative deviation was neutralized with prisms.

Statistical analysis

Statistical analysis was performed on SPSS software (Windows version 17.0). Data was entered on Microsoft excel sheet and compared using paired t-test. *P* value of less than 0.05 was considered statistically significant.

Results

Twenty patients were included in the study; 11 (55%) patients had intermittent exotropia (IXT) and 9 (45%) had alternating (AXT), mean age of the patients was 6.5 ± 1.6 years (range 3.9 to 8.8 years), and male/female ratio was 1.2:1. None of the participants were amblyopic.

All patients had a successful motor outcome after surgery. Eight patients had a small angle consecutive esotropia in the early postoperative period and complained of diplopia which resolved in all except one by the 3-month follow-up. Nine patients were orthotropic and 3 had a residual IXT but were able to easily control the deviation. Spectacle prisms were used in only one patient (with diplopia) for assessing BiS at 3 months postoperatively.

The mean BiS score of VA and CS was 2.95 ± 0.88 and 2.75 ± 0.44 preoperatively. The same values increased to 4.55 ± 0.68 and 4.5 ± 0.76 in postoperatively. This change was statistically significant (*P*-value <0.05). The results are summarized in Table 1 and Fig. 1.

The mean gain in BiSscore of VA and CS was 1.6 ± 0.20 and 1.75 ± 0.32, respectively. Postoperatively the BiS score improved in 17 patients (both VA and CS) and remained unchanged in 3 patients.

Number of children who demonstrated binocularity on Randot Charts and synoptophore are listed in Table 2.

Table 1: Binocular summation scores pre and postoperative

Binocular Summation Score					
BiS VA (Mean±SD)			BiS CS (Mean±SD)		
Pre-op	Post-op	*P*	Pre-op	Post-op	*P*
2.95 (±0.88)	4.55 (±0.68)	<0.001	2.75 (±0.44)	4.5 (±0.76)	<0.001

The responses were suboptimal due to children's inability to understand and optimally perform on these tests. The stereopsis could be accurately quantified in only 3 children preoperatively and 4 postoperatively.

On further analysis, we found that gain in BiS in AXT and IXT independently to be significant for both visual acuity and contrast sensitivity [Table 3]. However, when gain in binocular summation was compared between both the groups for VA (*P* = 0.59) and CS (*P* = 0.81), it was not found to be significant.

Discussion

There is a paucity of literature on change in binocular summation after strabismus surgery. Successful outcomes have been primarily assessed by motor alignment and sensory responses on various stereo tests.[3,4] Although BiS has been widely studied in laboratory settings for more than 50 years, it has not been well studied in patients with strabismus in clinical settings. Fewer studies have been done which compare the effect of surgery for strabismus on BiS.

Only 3 studies, conducted by the same study group, address change in binocular summation after strabismus surgery (search words used on PubMed with "and" function: binocular, summation, strabismus, surgery).[5-7] When a heterogenous group (both comitant and incomitant) has been studied, an improvement has been reported in BiS[5,6] but on analysis of specific subgroups, the results suggest more improvement in exotropes compared to other subtypes.[6] Another study by the same group of researchers has found a positive correlation between BiS and control in IXT.[8]

Stereo tests are dissociative in nature, complex, and time taking. Unlike these, our study uses visual acuity and contrast sensitivity measurements for the assessment of binocularity. These are not dissociative, easier to perform, and do not require additional tools or expertise. This is also obvious by the responses of our patients where only about 25% could respond on the standard tests against 100% on BiS tests.

A study by Kattan *et al*.[5] proved that binocular summation and stereocuity have common neural pathways and positive correlation. Visual task studies have also attributed the presence of neural binocular summation from binocularly driven cells in cortical areas of primary visual cortex.[9] Neural BiS has been shown to stem from interactions most likely in primary visual

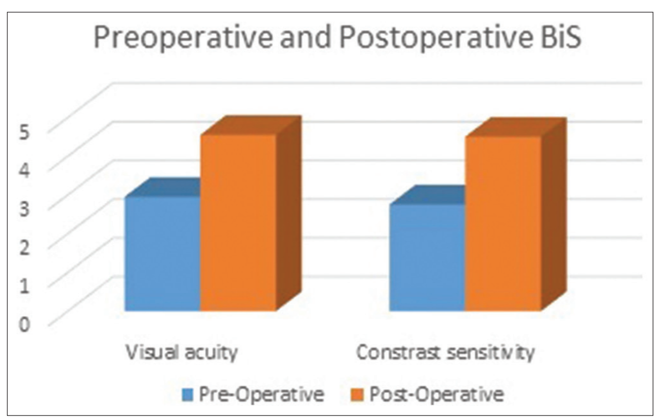

Figure 1: Change in binocular summation for visual acuity and contrast sensitivity

cortex (V1) and occurs for several electrophysiological and psychophysical tasks.[9] Also measuring stereoacuity requires a simulated environment of dissociating both eyes and specific types of charts. However, BiS can detect even a small difference of one letter on ETDRS charts and can be performed in normal surroundings.

Previous studies have measured change in BiS after strabismus surgery with respect to visual acuity; however, none have studied the change in contrast sensitivity. Numerous visual tasks are performed under low contrast such as driving at night or reading in low light, and an improvement in binocular contrast is likely to have significant consequences and directly impact patient's everyday life.[5]

Mean age in our study was 6.5 (±1.6) years. A similar study conducted earlier by Pineles *et al*.[6] had a larger sample size of ninety patients but included a heterogenous group with the mean age of 35.5 years. As expected BiS decreases with the increasing age; hence, our results should provide a more meaningful conclusion.[10] Pineles *et al*. in their study mentioned number of patients who showed improvement, indeterminate cases, and those who showed worsening after surgery but they have not indicated mean improvement in BiS.[6] The present study mentions the mean gain in BiS, in addition to the number of patients who improved. None of our patients showed worsening.

Early studies argued that amblyopic participants showed decreased BiS, or even binocular inhibition, when compared with normal controls.[6,11] However, recent studies have demonstrated that although BiS for contrast sensitivity is decreased in amblyopic participants, it can be improved by normalizing the interocular difference with neutral density filters, revealing that individuals with amblyopia likely retain the neural mechanisms for BiS but are at a disadvantage secondary to interocular differences in VA.[12] Chang *et al*. also revealed that strabismic amblyopes did not have worse BiS than nonamblyopic strabismic patients suggesting that there was no additive decremental effect of strabismus and amblyopia on BiS.[7] Thus, there are conflicting reports about the effect of amblyopia on BiS. Having XT as our study group has eliminated several confounders like a diverse age group, presence of amblyopia, and unsatisfactory motor outcome.

Table 2: Positive responses on synoptophore and Randot stereograms. Out of 20 patients, the number of number patients who responded on at least one of these tests was 5 preoperatively and 9 post operatively

	Preoperative	Post-operative
Fusion on Synoptophore	4	7
Distance stereopsis on Randot chart	3	6
Near stereopsis on Randot Chart	5	9

Significant improvement in BiS in XT is explained by the course of the disease that is slowly progressive from a phoria and these patients usually spend much of their critical visual developmental period either fusing or at least intermittently fusing, thus, having a normal amount of binocularly driven cortical cells and are not amblyopic.[9]

When BiS was calculated in preoperative workup after neutralizing the deviation, the values achieved were still lesser than postoperative values though motor correction obtained was similar. This difference can be attributed to momentary correction of deviation in preoperative period in a simulated environment; also use of multiple optical surfaces limits the accurate assessment of BiS. Both these factors are overcome by surgical correction.

Though not a part of this study, we measured BiS in 20 normal children below 10 years of age and found it to be 4.57 (±0.68) for VA and 4.62 (±0.74) for CS. These values are similar to the postoperative values achieved by us.

No significant difference between the AXT and IXT is probably because the two are the spectrum of the same disease and share an overlapping period of sensory development during the natural course of the disease. However, as expected, the preoperative BiS and the gain in BiS is greater in IXT compared to AXT as these patients have better binocular functions as they control the deviation and achieve fusion intermittently.

Binocular summation and inhibition have been earlier demonstrated on low contrast spatial frequency using Sloan low-contrast visual acuity chart. However, we have used a high contrast visual acuity ETDRS chart which is reliable and used worldwide. Sloan charts are similar to ETDRS charts, with each Sloan chart corresponding to different contrast levels.[2] This makes the process of testing cumbersome with limited utility. To overcome the possible limitation of the effect of contrast on BiS, we have separately studied BiS on Pelli–Robson chart specifically designed for assessment of contrast sensitivity.

The findings of our study must be understood within the context of their limitations. Small sample size and absence of a comparison group makes our study underpowered for the detection of BiS changes in various age groups and other types of strabismus. It would also be interesting to compare the sensory outcomes on standard stereograms with BiS. A similar study in esotropia would increase the applicability of BiS as a simple tool for the assessment of functional outcomes, particularly when it is difficult to test or quantify fusion and stereopsis.

Table 3: Pre and postoperative binocular summation scores among AXT and IXT

	VA			CS		
	Pre-op	Post-op	*P*	Pre-op	Post-op	*P*
AXT	2.44 (±0.88)	4.11 (±0.78)	0.0035	2.66 (±0.50)	4.44 (±0.72)	0.0006
IXT	3.36 (±0.30)	4.90 (±0.67)	<0.0001	2.81 (±0.40)	4.54 (±0.82)	0.0002

Conclusion

There is improvement in BiS in comitant XT after strabismus surgery. Authors recommend its inclusion for the evaluation of functional outcome of XT surgery.

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Conflicts of interest

There are no conflicts of interest.

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