

Stereopsis before and after Inferior Oblique Weakening Surgery

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Purpose: To analyze stereopsis change before and after inferior oblique weakening surgery.

Methods: We retrospectively reviewed the medical records of 31 patients who had undergone inferior oblique weakening surgery. The factors analyzed included sex, age at surgery, preoperative and postoperative visual acuity (VA), time from first detection to surgery, degree of inferior oblique overaction (IOOA), primary/secondary IOOA, exotropia/hypertropia, bilaterality, and type of surgery.

Results: Eighteen patients with a mean age 7.3 ± 3.1 years exhibited stereopsis of 60 arc seconds or better before surgery and 17 had stereopsis better than 60 arc seconds after surgery. Postoperatively, stereopsis improved in 13 patients and deteriorated in 9. Better preoperative VA and the absence of superior oblique underaction were associated with better preoperative stereopsis. Better preoperative VA, postoperative VA, and the presence of head tilt were associated with better postoperative stereopsis. Unilateral inferior oblique weakening surgery and accompanying hypertropia were associated with improved stereopsis, while the absence of hypertropia was associated with deteriorated stereopsis.

Conclusions: In this retrospective study, 58.1% of patients tended to have bifoveal fixation. When a vertical deviation is present in the primary position due to unilateral IOOA, IO weakening surgery can be expected to improve binocular function.

Key Words: Depth perception, Strabismus, Surgery

Stereopsis is a high-level binocular function used for recognizing the relative depth of an object. Restoring binocular function is the ultimate goal of strabismus treatment. Therefore, evaluating stereopsis can help determine the strabismus severity and appropriate timing for surgery [1-3].

Numerous studies have examined the factors associated with stereopsis in intermittent exotropia and esotropia, but few have investigated these relationships in inferior oblique overaction (IOOA) combined with horizontal strabismus [4-8]. A review of the literature revealed that no previous study has evaluated stereopsis before and after inferior oblique weakening surgery. We therefore aimed to evaluate stereopsis before and after inferior oblique weakening surgery in patients with IOOA and to investigate the relevant factors. Because we studied patients who underwent inferior oblique weakening surgery

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with IOOA, we included IOOA both with and without exotropia.

Materials and Methods

We reviewed the electronic medical records of 31 patients who had undergone inferior oblique myectomy or myotomy between July 2008 and June 2013. All surgeries were performed under general anesthesia by one surgeon (SJK). Inferior oblique muscle myotomy was performed for cases that were IOOA graded as +1, and myectomy was performed for cases graded as +2 or more. Patients who had undergone horizontal muscle surgery for intermittent exotropia were also included, because horizontal muscle surgery (especially intermittent exotropia) is less effective for near stereopsis than is vertical muscle surgery. Also, IOOA is often accompanied by intermittent exotropia clinically [9-11]. We evaluated all patients more than 3 times at intervals of more than 3 months. If the patient's strabismus did not improve, surgery was performed. We excluded all patients with a history of strabismus surgery, accompanying esotropia, dissociated vertical deviation, constant exotropia, a systemic disease that affects assessment of visual acuity (VA) or amblyopia, as well as those who did not consent to a stereopsis test. Patients who were under three years of age also were excluded, so as to minimize the effect of known age-related variations in normal stereoacuity testing.

Preoperative and postoperative examinations (at least 6 months after surgery) were performed. Motor surgical success was defined as alignment with exotropia <10 prism diopters (PD), esotropia or hypertropia <5 PD, or IOOA grade <+1 with alternate prism cover testing. Sensory surgical outcome was measured with near stereoacuity using the Titmus stereo test (Stereo Optical, Chicago, IL, USA). Approval to conduct this retrospective chart review was obtained from the institutional review board of Seoul National University Hospital (1604-019-753) and informed consent was waived by the board. The study protocol adhered to the Declaration of Helsinki.

The subjects were divided into a better stereopsis group and a worse stereopsis group. The better stereopsis group was defined as those with 60 arc seconds or better of near stereopsis, and the worse stereopsis group, was those with worse than 60 arc seconds of near stereopsis [12,13]. The factors associated with better stereopsis before and after

surgery as well as those corresponding to improved or deteriorated stereopsis after surgery were evaluated. Improved stereopsis was defined as stereopsis that had improved by more than two octaves after surgery, and deteriorated stereopsis, as stereopsis that had deteriorated by more than two octaves [14].

The factors analyzed included age at surgery, preoperative and postoperative VA, time from first detection to surgery, degree of IOOA, primary/secondary IOOA, presence of superior oblique underaction (SOUA), Bielschowsky head tilt result (positive or negative), presence of ocular cyclotorsion, and accompanying vertical or horizontal deviation in primary position. The surgical factors included bilaterality and type of surgery.

The degree of IOOA was quantified by setting 1, 2, 3, and 4 mm equal to +1, +2, +3, and +4, respectively, depending on the degree of upward deviation of the adducted eye relative to the contralateral pupil margin. Secondary IOOA included cases with accompanying SOUA, head tilt, positive Bielschowsky test, or ocular cyclotorsion. Patients not classified as secondary IOOA were defined as the primary IOOA. Cyclotorsion was measured with a CF60U fundus camera (Canon, Tokyo, Japan) to objectively evaluate the fovea position relative to the optic disc. The angle of horizontal or vertical deviation was measured, with the patient fixated on a distant target at 6 meters, by using the alternate prism cover test. Some cases, when classified according to the surgical method, had inferior oblique myectomy in one eye and inferior oblique myotomy in the other. These cases were included in the inferior oblique myectomy group.

Statistical analyses were performed with the independent *t*-test, chi-square test, and Fisher's exact test with PASW Statistics ver. 18.0 (SPSS Inc., Chicago, IL, USA). A *p*-value lower than 0.05 was considered statistically significant.

Results

The patient characteristics are shown in Table 1. The 31 patients included 18 males and 13 females. The mean age at surgery was 7.3 ± 3.1 (range, 3.6 to 15.7) years, and the time from first detection to surgery was 9.6 ± 12.0 (range, 1.2 to 62.4) months. Postoperative stereopsis was examined at least 6 months after surgery and a mean of 16.1 ± 10.1 (range, 6 to 38) months after surgery.

The mean preoperative VA was 0.08 ± 0.13 (range, -0.10

to 0.50) logarithm of the minimum angle of resolution, the mean postoperative VA was 0.03 ± 0.10 (range, -0.10 to 0.30) logarithm of the minimum angle of resolution, and the mean degree of IOOA was 1.7 ± 0.8 (range, 1 to 3). Four subjects had primary IOOA (12.9%), and 27 had secondary IOOA (87.1%). Among the subjects diagnosed with secondary IOOA, 14 had SOUA (51.6%), 9 had head tilt (33.3%), 24 had a positive Bielschowsky head tilt test (88.9%), and 13 had ocular cyclotorsion (48.1%). Bielschowsky head tilt test and fundus photography were performed for 27 and 25 subjects, respectively, and the results were analyzed separately.

Twenty-six subjects had accompanying intermittent exotropia (83.9%) with a mean angle of 20.6 ± 12.7 PD (range, 4 to 40 PD). Twenty subjects had accompanying hypertro-

pia (64.5%) with a mean angle of 5.0 ± 5.6 PD (range, 2 to 25 PD), and all 11 subjects without accompanying hypertropia had pattern exotropia. Seventeen subjects (54.8%) had undergone unilateral surgery and 14 (45.2%) bilateral surgery. Eight patients (25.8%) had undergone myectomy, 23 (74.2%) had undergone myotomy, and 20 (64.5%) had undergone simultaneous surgery for horizontal deviation.

Preoperative and postoperative stereopsis results

Eighteen patients (58.1%) were classified in the better stereopsis group before surgery and 17 (54.8%) after surgery; thus the number of patients with better stereopsis before versus after surgery did not differ statistically significantly ($p = 0.798$). In 13 patients (41.9%), stereopsis improved more than two octaves, and in 9 (29.0%), the quality of stereopsis deteriorated.

Table 1. Characteristics of patients who had undergone inferior oblique weakening surgery

Characteristics	Value
Age (yr)	7.3 ± 3.1
Sex (male/female)	18 / 13
Preoperative visual acuity (logMAR)	0.08 ± 0.13
Postoperative visual acuity (logMAR)	0.03 ± 0.10
Inferior oblique muscle overaction (IOOA)	1.7 ± 0.8 (1-3)
Time from first detection to surgery (mon)	9.6 ± 12.0 (1.2-62.4)
Postoperative follow-up (mon)	16.1 ± 10.1

Values are presented as mean \pm standard deviation, number, or mean \pm standard deviation (range). logMAR = logarithm of minimal angle of resolution; IOOA = inferior oblique overaction.

Factors associated with better stereopsis before and after surgery

The better stereopsis-before-surgery group had better preoperative VA ($p = 0.046$) and absence of SOUA ($p = 0.003$) (Table 2). The better stereopsis-after-surgery group had better preoperative best-corrected visual acuity, postoperative best-corrected visual acuity ($p = 0.028$, $p = 0.002$), and head tilt ($p = 0.015$) (Table 3).

Factors associated with change in stereopsis after surgery

A postoperative improvement of more than two octaves

Table 2. Factors associated with better preoperative and postoperative stereopsis

Stereopsis	Better stereopsis group*	Worse stereopsis group†	p-value
Preoperative stereopsis			
Preoperative VA (logMAR) (n=31)	0.03 ± 0.10	0.13 ± 0.14	0.046‡
Absence of SOUA (n=17)	14 (82.4)	3 (17.6)	0.003§
Postoperative stereopsis			
Preoperative VA (logMAR) (n=31)	0.03 ± 0.09	0.13 ± 0.15	0.028‡
Postoperative VA (logMAR) (n=31)	-0.02 ± 0.08	0.09 ± 0.09	0.002§
Presence of head tilt (n=9)	8	1	0.015§

Values are presented as mean \pm standard deviation, number (%), or number. VA = visual acuity; logMAR = logarithm of minimal angle of resolution; SOUA = superior oblique underaction. *Better stereopsis was defined as 60 arc seconds or better of near stereopsis; †Worse stereopsis was defined as less than 60 arc seconds of near stereopsis; ‡ $p < 0.05$, independent t-test; § $p < 0.05$, Fisher's exact test.

Table 3. Factors associated with any change in stereopsis after surgery

Factors		Stereopsis		<i>p</i> -value
		Improved	Not improved	
Bilaterality	Unilateral (n = 17)	10	7	0.036
	Bilateral (n = 14)	3	11	
Combined vertical deviation: presence/absence	Presence (n = 20)	11	9	0.047*
	Absence (n = 11)	2	9	
Combined vertical deviation		Deteriorated	Not deteriorated	0.020*
	Presence (n = 20)	3	17	
	Absence (n = 11)	6	5	

Values are presented as number.

**p* < 0.05, Fisher's exact test.

Table 4. Motor success rate according to change of stereopsis after surgery

Success/failure	Improved stereopsis (n = 13)	Not improved (n = 18)	Deteriorated stereopsis (n = 9)	Not deteriorated stereopsis (n=22)	Total patients (n = 31)
Success	10	12	5 (2 showed <5 PD hypertropia)	17	22
Failure	3	6	4	5	9
Cause of failure					
Hypertropia	2	2	1	3	4
Exotropia	2 (1 showed exotropia with hypertropia)	2	2 (2 showed <5 PD hypertropia)	2 (1 showed exotropia with hypertropia)	4 (1 showed exotropia with hypertropia)
Esotropia	0	2	1	1	2
IOOA	0	0	0	0	0

Values are presented as number.

PD = prism diopters; IOOA = inferior oblique overaction.

was positively related to unilateral inferior oblique muscle surgery (*p* = 0.036) and hypertropia in primary position (*p* = 0.047). A postoperative deterioration of more than two octaves was positively related to the absence of hypertropia in the primary position (*p* = 0.020) (Table 4).

Surgery success rate according to change in stereopsis after surgery

Twenty-two patients (71.0%) had successful motor surgery, and 9 patients (29.0%) had failure. In the improved stereopsis group, 10 of 13 (76.9%) patients had successful motor surgery, and 3 of 13 (23.1%) had failure. In the deteriorated stereopsis group, 5 of 9 (55.6%) patients had successful motor surgery and 4 of 9 (44.4%) had failure. One

patient had hypertropia ≥ 5 PD, 1 had esotropia ≥ 5 PD, and 2 had exotropia ≥ 10 PD with < 5 PD hypertropia after surgery. Among the 5 patients with successful surgery, 2 had < 5 PD hypertropia (Table 4).

Discussion

Stereopsis in patients with IOOA is not well understood. The main purpose of this study was to elucidate the basic characteristics of stereopsis in patients with IOOA. A review of the literature revealed less interest in binocular visual function in patients with oblique muscle dysfunction than in patients with horizontal muscle dysfunction [4-8]. Researchers might expect normal binocular vision in pa-

tients with IOOA, due to the lack of strabismus in primary position and the utility of head tilt in compensating for strabismus.

Clinically, IOOA is more common in patients with exotropia than in patients with IOOA alone, thus most patients in our study had IOOA with exotropia. Previous studies on IOOA with exotropia have shown that the success rate of treating pattern exotropia is about 60% to 91% [15-19]. Several studies have also revealed that horizontal muscle surgery has a smaller effect on IOOA, and IO weakening surgery has no effect on horizontal strabismus [19,20]. To our knowledge, no previous studies have examined postoperative changes in stereoacuity in IOOA patients with and without exotropia.

In the present study, the better stereopsis group accounted for approximately 50% of the total study population. Stereopsis was also associated with the presence of a vertical deviation in primary position, which was in turn associated with postoperative stereopsis improvement. The absence of vertical deviation, by contrast, was associated with postoperative deterioration in stereopsis. Hypertropia was thought to be severe enough to interfere with preoperative motor fusion in the primary position; thus, improved hypertropia postoperatively would improve stereopsis.

Head tilt can compensate for vertical deviations in the primary position, which can minimize the negative impact on binocular function [21-24]. However, an abnormal head position can affect head and neck muscles, resulting in fatigue and aesthetic issues. Therefore, active treatment might be needed for IOOA accompanied by vertical deviation in the primary position, regardless of head tilt.

Although many reports have examined the diagnostic criteria for superior oblique palsy, no consensus on those criteria has been reached [21,25-27]. However, SOUA and head tilt were identified as factors related to stereopsis. Additional research on the diagnostic criteria for primary and secondary IOOA is needed. The presence of head tilt was significantly related to better stereopsis after surgery. Head tilt is a compensatory mechanism that reduces vertical deviation in the primary eye position. Therefore, that sensory fusion is thought to be more likely to remain in cases of head tilt [21-24].

Unilateral inferior oblique weakening surgery was associated with improved stereopsis. In bilateral IOOA, the range of preoperative motor fusion was narrow, making it more likely to diminish sensory function.

In the present study, the motor success rate was 71.0% and was higher in the improved stereopsis group than in the deteriorated stereopsis group. In the deteriorated stereopsis group, even though only 1 patient had hypertropia ≥ 5 PD, 5 patients had hypertropia (including < 5 PD) after surgery. From this result, we suggest that new hypertropia after surgery might affect deteriorated stereopsis.

This study has several limitations. The sample size was small, and the study was retrospective in nature. Titmus stereopsis test results show both inter- and intra-observer variation. Distant stereopsis was not measured. The subject population was heterogeneous with respect to both IOOA and also other accompanying strabismus. However, to minimize bias, this study excluded subjects with esotropia, constant exotropia, or dissociated vertical deviation, all of which affect stereopsis. Also, as patients with unilateral IOOA and severe head tilt are likely to have undergone early surgery, young children (< 3 years old) were excluded.

This report showed that IOOA might have more significant effects on stereopsis than expected. In patients with IOOA, several important factors affect binocular vision. The present study focused on patients who needed aggressive treatment and examined factors that could predict the postoperative outcome of binocular function. Overall, 58.1% of patients with IOOA had the potential for bifoveal fixation. If vertical deviation in the primary position is caused by unilateral IOOA, surgery can be expected to improve binocular function. The results of this study could influence future studies on binocular function with vertical deviation.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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