Original Article

Long-Term Surgical Outcomes of Bilateral Symmetrical Superior Oblique Nasal Tenotomy in Patients of Large A-Pattern Exotropia

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Abstract

Purpose: To report the long-term outcomes of bilateral symmetrical superior oblique (SO) nasal tenotomy in patients with large A-pattern exotropia (≥25 prism diopter [PD]).

Methods: This retrospective study was conducted on 15 patients (aged: 4–28 years) of large A-pattern exotropia. An A-pattern was defined as >10 PD difference between up and down gaze at 6 m by use of the alternate prism cover test. Objective ocular torsion was assessed by fundus photography and subjective torsion by double Maddox rod test. All patients underwent horizontal muscle surgery according to the primary position horizontal deviation and bilateral symmetrical SO nasal tenotomy for A-pattern. Surgical success was defined as postoperative A-pattern of ≤10 PD, the absence of vertical and torsional diplopia, and the absence of V-pattern. The minimum follow-up period was 24 months.

Results: A total of 15 patients of large A-pattern exotropia (7 males and 8 females) with a mean age of 17.09 ± 7.9 years were included in the study. All patients had bilateral SO overaction of grade +3 or +4 with a mean preoperative A-pattern of 30.3 ± 3.9 PD. At 24 months of follow-up, esotropia in down gaze (V-pattern) was present in four patients with a mean of 11.25 ± 2.5 PD, (range, 10–15 PD). The rest of the 11 patients maintained successful alignment with a mean A-pattern of 3.18 ± 1.17 PD, (range, 2–5 PD). There was significant A-pattern collapse with a mean of 31 ± 9.1 PD after 2 years of follow-up, which was significantly associated with preoperative A-pattern (Pearson correlation, $r = 0.7$; t [15] = 4.0; $P = 0.002$). The mean of pre- and postoperative objective ocular torsion was found to be −0.5 ± 4° and −4.8 ± 3.8° with a mean extorsion effect of 4.67 ± 3.85°. There was a statistically significant difference between pre- and postoperative ocular torsion (°) (t [30] = 5.42; $P < 0.001$), the change in ocular torsion was significantly associated with preoperative torsion (Pearson correlation, $r = 0.5$; t [30] = 7.2; $P < 0.001$). None of the patients had subjective torsion on the double Maddox rod test pre- and postoperatively.

Conclusions: Bilateral symmetrical SO nasal tenotomy is effective in cases with large A-pattern (>25 PD). The reduction of A-pattern and postoperative change in fundus torsion have a positive correlation with preoperative A-pattern and preoperative torsion, respectively.

Keywords: A-pattern, Exotropia, Objective torsion, Superior oblique nasal tenotomy

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Introduction

A-pattern strabismus is commonly associated with superior oblique (SO) overaction (SOOA). Thus, the surgical correction aims at SO weakening to resolve this incomitance. The reported success rates of SO weakening procedures for the treatment of A-pattern strabismus secondary to bilateral downshoot in adduction range from 70% to 100%.[1-5]

The SO weakening procedure may be aimed toward reducing selective or all functions of the muscle. The posterior fibers

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of the SO muscle are mainly responsible for abduction and depression whereas anterior fibers are responsible for torsion. Prieto-Diaz[2] described a posterior tenotomy procedure on the SO muscle to reduce the abductor and depressor function of the muscle only. Literature suggests that SO recession, Z tenotomy, suture lengthening, tendon expanders, and SO hang back are more controlled techniques of SO weakening as compared to tenotomy.[1,6-8]

When A-pattern is ≤20 prism diopters (PDs), SO recession, a symmetrical SOPT, temporal tenotomy, Z tenotomy, or SO hang back are advisable whereas when A-pattern is ≥20 PD, SO nasal tenotomy is preferred.[2] SOPT is especially useful in patients of A-pattern exotropia without ocular intorsion as it aims to weaken the abduction effect of SO in down gaze by partial cutting its posterior fibers only and leaving anterior fibers intact.[5] However, the correction of the A-pattern achieved by SOPT is less than that achieved by full SO tenectomy or tenotomy.[9,10]

The SO weakening procedures have various postoperative troubles such as the development of postoperative V-pattern, upshoot in adduction, primary gaze vertical misalignment, under correction of horizontal deviation, and horizontal and vertical incomitance. These are the expected fellow travelers of SO weakening procedures.[1-5] Interestingly, postoperative change in ocular torsion is also a significant problem for visual rehabilitation of patients as it can lead to torsional diplopia. However, only a few studies have focused on pre- and postoperative characteristics of SO tenotomy with respect to A-pattern and change in the ocular torsion and even fewer have discussed the long-term outcomes.[1-5] Hence, the purpose of this study is to report the long-term outcomes of bilateral symmetrical SO nasal tenotomy and its impact on A-pattern and ocular torsion in patients of large A-pattern exotropia.

Methods

This retrospective study was conducted after approval of the institutional ethics committee (letter no. AIIMS/IEC/21/374, dated 11/05/2021) and adhered to the Declaration of Helsinki. The records of 28 consecutive patients in a tertiary care institute from January 2017 to December 2019, who underwent surgical intervention by a single surgeon for large A-pattern (≥25 PD) exotropia associated with bilateral SO overaction were retrospectively analyzed. Patients with prior strabismus surgery, paralytic strabismus, congenital anomalies, musculoskeletal disorders, craniofacial syndrome, any organic lesion of the orbit, and follow-up of fewer than 24 months were excluded from this study. Finally, 15 patients were enrolled in this retrospective study after obtaining written informed consent.

The data collected included age, sex, cycloplegic refraction, pre- and postoperative prism cover test at 33 cm and 6 m, A-pattern, ocular motility assessment including SOOA, head tilt test, objective ocular torsion, subjective ocular torsion, stereopsis, and binocularity. An A-pattern was defined as >10 PD difference between 25° up and 25° down gaze at 6 m by use of the alternate prism cover test.

The SOOA was graded between 0 and +4, according to the downward deviation of the pupil in adduction with patients looking inferonasally. A score of 0 was given for none, +1 for 1 mm, +2 for 2 mm, +3 for 3 mm, and +4 for 4 mm of deviation. The SO underaction was graded from −4 to 0 according to the upward deviation of pupil in a similar manner. The severity of IOOA was rated from 0 to +4 in a similar way as SOOA was, except it was assessed when the patient was looking superonasally.[11] Sensory status was assessed by random dot test, Bagolini striated glass test, and distant worth four dot test in all patients after neutralizing horizontal and vertical deviation with appropriate prisms. Pre- and postoperative dilated fundus evaluation was done in all patients by indirect ophthalmoscopy and fundus photography using VISUCAM 524 (Zeiss, Germany) fundus camera binocularly after ensuring proper head alignment.

The extent of objective torsion in degrees was evaluated by measuring the angle between the line drawn from the geometric center of the disc and the line connecting this point of the disc to the center of the fovea by CorelDRAW 11.0 (Corel Corporation).[12] The angle was measured thrice and the average of the readings was included for final analysis. Incyclotorsion was expressed in degrees with a + sign and excyclotorsion with a − sign. With this method, even the individuals having normal torsion had some degree of extorsion, therefore, change in ocular torsion (extorsional effect) was considered a parameter for statistical evaluation. Subjective torsion was assessed by a double Maddox rod test.

After the perioperative exaggerated traction test, all surgical procedures were performed under operating microscope by a single surgeon (AS) after remeasuring preoperative findings. All patients underwent horizontal muscle surgery according to the primary horizontal deviation and bilateral symmetrical nasal SO tenotomy was done to address A pattern. Bilateral symmetrical nasal SO tenotomy was performed by the fornix-based incision, isolating and dividing the tendon 4 mm from the nasal border of the superior rectus muscle, leaving the nasal intermuscular septum intact. An exaggerated traction test was repeated after the procedure. Surgical success was defined as postoperative A-pattern of ≤10 PD, the absence of torsional diplopia, and the absence of V-pattern. All patients were followed up to 24 months at least. Pre- and postoperative nine gaze photographs and fundus photographs were taken at all follow-up visits at 1 week, 6th week, 6th month, 12th month, and 24th month.

All statistical analyses were performed using SPSS version 21.0 (IBM New York, USA). Categorical data were expressed in frequencies with percentages and continuous data were expressed as means with standard deviation. Paired *t*-test was used to determine the statistical evidence for the mean difference between two paired observations (i.e., pre- and post-test between two-time points). In all cases, a $P < 0.05$

was considered statistically significant. Pearson correlation was used to calculate the significance of surgical outcomes. A positive value showed a significant correlation.

Results

A total of 30 eyes of 15 patients were included in the study. The mean age of the study population was 17.09 ± 7.9 years (median: 18, range: 4–28 years). Out of the 15 patients, 46.7% (n = 7) were males and 53.3% (n = 8) were females. The mean spherical equivalent after cycloplegic refraction was 0.33 ± 1.1 [Table 1].

All the patients underwent bilateral symmetrical SO nasal tenotomy along with simultaneous horizontal rectus muscle surgery (bilateral lateral rectus recession in 10 and bilateral lateral rectus recession with medial rectus resection of the nondominant eye in 5 patients). The dosage of horizontal muscle surgery was not adjusted in view of bilateral SO weakening. All 15 patients underwent bilateral symmetrical SO nasal tenotomy for the mean preoperative A-pattern of 30.3 ± 3.9 PD (range, 25–40 PD) and mean preoperative SOOA of +3.13 ± 0.34 (range, 3–4). No intraoperative complication was encountered in any of the patients.

The mean pre- and postoperative horizontal deviation was 49.6 ± 10.1 PD (range, 30–75 PD) and 4.5 ± 2.2 PD (range, 2–10 PD), respectively. The change in horizontal deviation was statistically significant (P < 0.0001). Ten patients (66%) had primary position horizontal alignment within 8 PD, one had consecutive esotropia of 10 PD, and 4 had residual exotropia within 10 PD. None of the patients had clinically significant vertical misalignment before and after strabismus surgery.

The mean preoperative A-pattern was 30.3 ± 3.9 PD (range, 25–40 PD). At 6 months of follow-up, 11 patients had clinically insignificant A-pattern, with a mean of 6.27 ± 2 PD (range, 4–8 PD), and 4 patients had esotropia in down gaze (V-pattern) with a mean of 6.25 ± 2.5 PD (range, 5–10 PD). The mean reduction in A-pattern was found to be 27.4 ± 4.1 PD. There was no significant change in pattern deviation at 12 months of follow-up. However, after 2 years, an increase in esotropia in downgaze was noticed in all four patients with a mean of 11.25 ± 2.5 PD, (range, 10–15 PD), but the patients were asymptomatic and did not require reoperation. The rest of the 11 patients maintained successful alignment with a mean A-pattern of 3.18 ± 1.17 PD, (range, 2–5 PD). Thus, there was significant A-pattern collapse with a mean of 31 ± 9.1 PD after 2 years of follow-up [Figure 1], and it was found to be significantly associated with preoperative A-pattern (Pearson correlation, r = 0.7; t [15] = 4.0; P = 0.002) [Figure 2 and Table 2].

The mean of pre- and postoperative objective ocular torsion was found to be −0.5 ± 4° (range, −8.87°– +8.07°) and −4.8 ± 3.8° (range, −13.12°– +1.01°) with a mean extorsion effect of 4.67 ± 3.85° (range, 0.81°–15.32°). There was a statistically significant difference between pre- and postoperative ocular torsion (in degrees) (t [30] =5.42; P < 0.001) [Figure 3]. The change in torsion postoperatively was significantly associated with preoperative torsion (Pearson correlation, r = 0.5; t [30] = 7.2; P < 0.001) [Figure 4 and Table 2]. None of the patients had subjective torsion on double Maddox rod test pre- and postoperatively.

Out of 30 eyes of 15 patients, all eyes had SOOA preoperatively with a mean grade of 3.1 ± 0.3 (median = 3; range = 3–4). The mean postoperative overall SO function was found to be −0.3 ± 0.7 (median 0; range = −2–1) [Table 2].

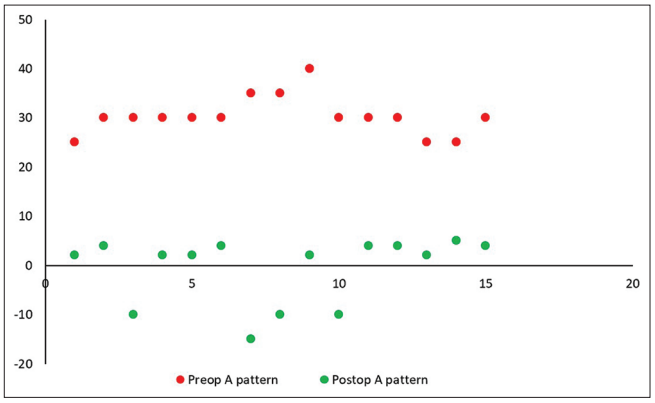

Figure 1: Pre- and postoperative A-pattern among the study participants

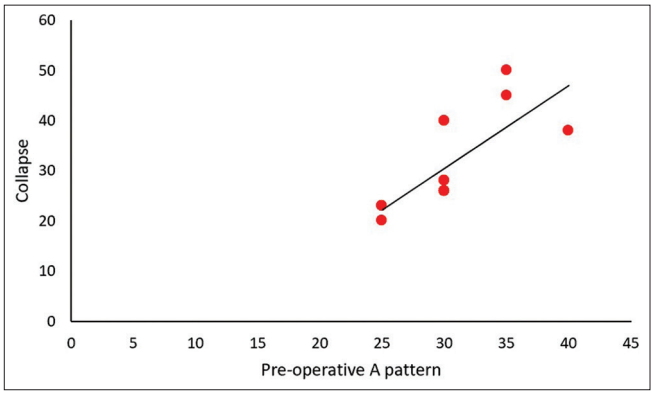

Figure 2: A-pattern collapse versus preoperative A-pattern

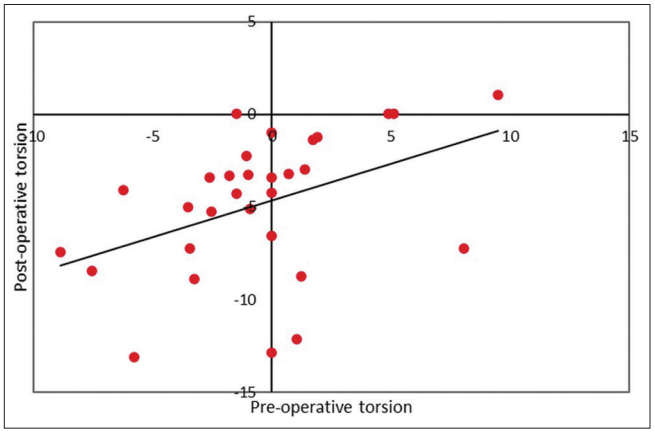

Figure 3: Preoperative torsion versus postoperative torsion

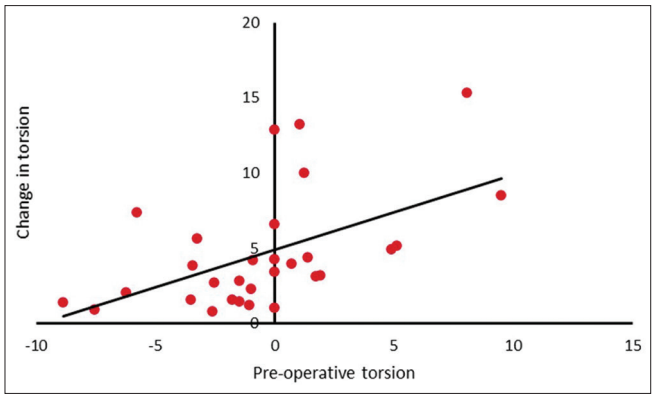

Figure 4: Change in torsion versus preoperative torsion

Postoperatively, 8 (26.6%) eyes had SO under action with a mean of −1.25 ± 0.5 (median-1; range = −2– −1), 2 (6.7%) eyes had SOOA with a mean of 1 ± 0.0 (median 1; range = 0–1), and it was noted that 4 eyes which had SO under action also had developed mild inferior oblique overaction (+1) over a period of 2 years [Table 2].

Three patients had stereoacuity of 400 s of arc, eight had stereoacuity of 800 s of arc, and four had nil stereopsis preoperatively on the random dot test. Only five patients had fusion on Bagolini striated glass and distant worth four dot tests. Four patients showed clinically improvement in stereopsis postoperatively (2 improved from 400 to 200 s of arc and 2 from 800 to 400 s of arc) but none of the patients showed any significant change in fusion postoperatively. None of the patients had diplopia before surgical intervention. Only two patients with V-pattern complained of diplopia in downgaze in the first 2 weeks postoperatively, which subsided on subsequent visits.

Table 1: The baseline characteristics of the study participants

Baseline characteristics	*n*=15
Age, mean±SD	17.09±7.9
Median (years) (range)	18 (4–28)
Preoperative spherical equivalent	
Mean±SD	0.3375±1.176175
Median (range)	0.125 (−1.25–3.5)

SD: Standard deviation

Table 2: Details of pre- and postoperative clinical variables

Clinical variables	Mean±SD
A-pattern (*n*=15)	
Preoperation, mean±SD (range)	30.3±3.9 PD (25–40 PD)
Postoperation, mean±SD (range)	
A-pattern (*n*=11)	3.18±1.17 PD (2–5 PD)
V-pattern (*n*=4)	11.25±2.5 PD (10–15 PD)
Total collapse	31±9.1 PD
Torsion (*n*=30)	
Preoperative, mean±SD (range)	−0.5±4° (−8.87– +8.07)
Postoperative, mean±SD (range)	−4.8±3.8° (−13.12– +1.01)
Extorsional effect, mean±SD (range)	4.67±3.85° (0.81°–15.32°)
Surgical outcome of SO function, *n* (%)	
Preoperative	
Overaction	15 (100)
Postoperative	
Overaction	2 (6.7)
Underaction	8 (26.6)
The scale of SO function	
Preoperative, mean±SD (range)	+3.1±0.3 (+3– +4)
Postoperative, mean±SD (range)	−0.3±0.7 (−2– +1)

SD: Standard deviation, SO: Superior oblique, PD: Prism diopter

Discussion

Many SO weakening procedures have been used in the past, including nasal/temporal tenotomy, Z-tendon lengthening, tenectomy, posterior tenotomy, tendon lengthening using silicone tendon expanders or tendon suture spacers, and hang back recession of the muscles.[1-10] Graduated SO recession is believed to be more controlled and reliable procedure as compared to tenectomy and tenotomy.[1] Buckley and Flynn[6] compared SO recession and SO tenotomy retrospectively and concluded that SO recession is equally effective in eliminating A-pattern strabismus regardless of the initial size of the pattern. It should be noted that postoperative outcomes of unilateral SO recessions are more predictable than tenotomies but lead to slight undercorrection. Li *et al*.[8] conclude that SO hang back is an effective and safe procedure to correct A-pattern due to overdepression in adduction, but thought that it can lead to undercorrection in cases of large A-pattern due to severe overdepression in adduction.

However, only a few procedures such as SO tenectomy and hang-back recession have been found to be effective for large A-pattern deviation but with inconsistent postoperative A pattern collapse and torsional changes.[1-10,13] In the present study, we aim to report the long-term impact of bilateral symmetrical SO nasal tenotomy on A-pattern and ocular torsion in patients with large A-pattern exotropia after 2 years of follow-up.

Eleven out of 15 patients (73.3%) had criteria of success that is, a collapse of A-pattern to <10 PD, which is consistent with published success rates of SO weakening procedures (70%–100%).[1-5] There was significant A-pattern collapse with a mean of 31 ± 9.1 PD after 2 years of follow-up and it was found to be significantly associated with preoperative A-pattern (Pearson correlation, $r = 0.7$; $t[15] = 4.0$; $P = 0.002$). This is consistent with the findings of the retrospective study done by Shuey *et al*.[14] which found a positive correlation between the magnitude of reduction of the A-pattern and the size of the preoperative A-pattern ($r = 0.69$) after SO nasal tenotomy. The success rate of their study was 84% (27 of the 32 patients) in terms of satisfactory reduction in A-pattern.

However, Debert *et al*.[15] in their retrospective study found that bilateral SO temporal tenectomy was a self-adjusting and

effective procedure for A-pattern strabismus associated with SO overaction. They found that the relative correction of the pattern was similar for deviations of <25 D or ≥25 D and a uniform dose of bilateral SO temporal tenectomy reduced A-patterns of all magnitudes. Furthermore, the change in the A-pattern was significantly correlated with the preoperative A-pattern ($r = 0.7$; $P < 0.001$). Few more studies concluded a similar correlation.[14,16,17] Our findings are partly consistent with the abovementioned study suggesting a positive association between preoperative A-pattern and mean reduction in A-pattern.[16,17]

Previous studies have suggested that SO weakening procedures should be used with caution, despite the good success in terms of collapsing the A-pattern, because of the torsional effect.[18,19]

Ducca *et al*.[20] have tried to address this concern by measuring ocular torsion using fundus photography before and after SO temporal tenectomy and found a significant extorsional effect. They noticed that incyclotorsion associated with SO overaction diminishes after the procedure. In their study, there was considerable variation in surgical torsion changes. According to them, this variation could be due to the lack of knowledge of the position of reinsertion of SO tendon to the sclera after tenectomy.

In the present study, we measured the ocular torsion using fundus photography. The mean of pre- and postoperative objective ocular torsion was found to be $-0.5 \pm 4°$ and $-4.8 \pm 3.8°$ with a mean extorsion effect of $4.67 \pm 3.85°$. There was a statistically significant difference between pre- and postoperative ocular torsion (°) (t [30] = 5.42; $P < 0.001$) [Figure 3]. The change in torsion postoperatively was significantly associated with preoperative torsion (Pearson correlation, $r = 0.5$; t [30] = 7.2; $P < 0.001$). This suggests that patients with larger preoperative ocular torsion had more extorsional effects.

Despite the significant change in ocular torsion, none of the patients had torsional diplopia in postoperative period. This finding can be explained by the absence of fusion in most of the patients and a significant range of cyclofusion which is more for excyclotorsion than incyclotorsion.[21]

Moreover, we found that 4 (26%) patients developed V-pattern (10–15 PD) which was in the range of previously reported risk of postoperative V-pattern (10%–33%) after various SO weakening procedures.[1-5]

It is worthwhile to mention that most of the existing alternative techniques for SO weakening procedures correct up to 20–25 PD of A-pattern except tenectomy and tenotomy procedures. None of the previous studies aimed to evaluate the long-term outcomes of SO nasal tenotomy procedure in patients of large A-pattern deviation (>25 PD).[22,23]

Özkan *et al*.[24] suggested that a total tenotomy of the SO muscle should be reserved only for severe A-pattern. According to them, there are various techniques from minimal to maximal weakening effect, which are as follows: posterior tenotomy, total tenotomy with a temporal approach, total tenotomy with a nasal approach with an intact intermuscular membrane, and total tenotomy with a nasal approach with the dissection of the intermuscular membrane. They recommended that one should not consider SO tenotomy as a uniform procedure; however, surgical technique for SO weakening procedure should be guided by the desired weakening effect. The adjustments should be done at the selected tenotomy procedure according to the amount of A-pattern, the degree of overaction of the muscle, and the presence of vertical deviation so that the results may be more predictable and complications of surgery may be prevented.

The success rate of our study in terms of surgical outcome of collapsing of A-pattern was very satisfactory except in 4 patients who developed V-pattern after 2 years of follow-up. However, none of the patients had undesired vertical misalignment or torsional diplopia. The present study is not without limitations as this is a retrospective study design with a small sample size and lack of a control group. Since no surgical procedures are without their downsides, so is the case with SO tenotomy which happens to be an irreversible procedure.

In conclusion, we recommend that though bilaterally symmetrical SO nasal tenotomy is highly effective in correcting the large A-pattern (>25 PD), still, the possibility of a postoperative V-pattern should be explained to the patient. It also leads to a significant extorsional effect but without any significant postoperative torsional diplopia or vertical misalignment. This approach of awareness and risk understanding may be more useful for patient satisfaction.

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Conflicts of interest
There are no conflicts of interest.

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