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Research article

Clinical outcomes of inferior oblique myectomy in age categorized patients with unilateral superior oblique palsy

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ABSTRACT

Background: Unilateral superior oblique palsy (SOP) is the most common isolated cranial nerve palsy. This report looks at the results and safety of inferior oblique (IO) myectomy for SOP.
Methods: A retrospective chart review of patients with fusional ability who underwent IO myectomy for unilateral SOP over a 15-year period, at one of our university-associated health care centers. Primary outcomes were: distance hypertropia and excyclotropia in primary position, inferior oblique overaction (IOOA) and the correlation between the age at surgery and the residual distance hypertropia.
Results: A total of 73 patients with unilateral SOP who underwent IO myectomy were included in the analysis. Mean pre-operative values were: distance hypertropia: 15.41 ± 6.8 Prism Diopters (range 4–30 PD), IOOA: +2.2 ± 0.7 (range 0–3.5) and excyclotropia: +5.34 ± 3.6° (range 0–12°). Mean post-operative values were: distance hypertropia: 3.7 ± 3.4PD [0-14PD], IOOA: −0.1 ± 0.8 [(-2)-2] and excyclotropia: +1.1 ± 2.3°[(-5)-10]. The younger age group (0–20 years old) had a trend toward smaller preoperative distance hypertropia ($P = 0.051$), and a significantly smaller distance hypertropia post-operatively ($p = 0.007$). There was no case of ocular complication.
Conclusions: On average, IO myectomy results in a 11.7PD reduction of the distance hypertropia, and 4° reduction of excyclotropia, with an effective reduction of IOOA. While these results are comparable to other surgical methods reported in the literature, they underline an efficacy without the risks of complications such as anti-elevation syndrome and possible scleral perforation. The younger age group had a trend toward smaller preoperative deviation, and better outcomes compared to the older age group.

1. Introduction

Unilateral superior oblique palsy (SOP) is the most common isolated cranial nerve palsy and can be congenital or acquired [1,2]. It can cause diplopia, abnormal head posture with neck discomfort, facial asymmetry and asthenopia [2,3].

The most common surgical approach for symptomatic patients is weakening of the ipsilateral antagonist inferior oblique (IO) muscle [2–4], such as myectomy, recessions of various amounts, anterior transposition, or, in recurring cases, denervation-extirpation [2,5,6]; in cases with large vertical deviation, this can be combined with contralateral inferior rectus recession or ipsilateral superior

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rectus recession [2,6]. .IO weakening procedures are described as self-titrating or self-graded with preoperative hyper deviation strongly correlated with the amount of correction achieved by the same amount of weakening [7,8].

Technics of recession and anteriorization of the IO involve suturing the sclera, sometimes close to the macular area with potential local harm, in addition to possible scleral perforation [4]. For example, Turan-Vural et al. found elevated macular thickness on optical coherence tomography (OCT) after IO recession procedures compared to regular horizontal strabismus surgeries that caused no change in macular thickness [4].

In this study, we report clinical outcomes of a standard IO myectomy procedure over a 15 years period.

2. Materials and methods

A retrospective chart review of all patients with a diagnosis of SOP, who had a standard IO myectomy carried out, with the approval of our institutional ethics research board [IWK Institutional Review Board, approval number 1005396]. Due to the retrospective nature of our study, informed consent has been waived by the institutional ethics committee. The surgeries were performed by one experienced surgeon (RLR), at the IWK Health Center or the Victoria General Hospital, Halifax, NS, Canada, between July 1998 and June 2013.

The confirmation of a diagnosis of SOP was reached on all patients through a full orthoptic work-up including both sensory and motor evaluation and a Bielschowsky three step test.

The inclusion criteria were patients with unilateral SOP that underwent IO standardized myectomy within a 15 years period. The preoperative and postoperative examinations had to yield at a minimum: alternate prism cover test measurements of the vertical deviation in primary position, double Maddox rod measurements in primary position for torsion and inferior oblique overaction (IOOA) assessment during eye movements. The scale used for IOOA before the surgery, or IOUA (inferior oblique underaction) after the surgery was from −4 to +4 with normal being 0 while assessing the elevation of the eye in adduction compared to the other eye and using the 6 o'clock limbal point as the reference point (each unit was equivalent to 1 mm difference between the eyes). Due to the torsion of many patients, a sensory assessment was carried out on synoptophore to confirm sensory fusion.

Exclusion criteria included any other significant eye morbidity and any other concurrent surgery on vertical muscle.

IO myectomy was offered to patients with SOP and significant clinical symptoms such as diplopia and asthenopia. IO myectomy alone was done for patients with up to 25 Prism diopters (PD) vertical deviation. In patients with more than 25 Prism diopters (PD) vertical deviation, another vertical muscle was added, and these cases were excluded from the study.

The standard myectomy was done through a fornix-based incision. The IO muscle was identified in the inferior lateral quadrant and cleaned from its surrounding fascia. Two clamps were placed 6 mm apart on the IO between the inferior edge of the lateral rectus and the temporal edge of the inferior rectus muscle, with an average resulting resection of 2 mm of unstretched muscle. Both ends of the remaining muscle stumps were cauterized. There was no case of visible fat herniation in the series nor was the tenon sutured over the stumps.

The primary outcomes were postoperative primary position distance hypertropia and excyclotropia, postoperative IOOA at the second follow-up visit after the surgery, and the correlation between the age at surgery and the residual distance hypertropia.

2.1. Statistical analysis

Clinical data from retrospective chart review were compiled anonymously in Microsoft Excel (v. 16.73, 2023). The final spreadsheet was then transferred to the statistical software Stata (v 16.1, StataCorp, College Station, Texas 77845 USA). Scatter plots were generated from elected continuous variables and linear regression applied with no origin constrain; R-square was used as index of variability. For each scattergram, frequency histograms were added for both variables to help determine the global distribution of clinical cases. In case of age, the frequency histograms were segregated by arbitrary age groups (four groups of 20 years range). T test was used for comparison of residual hypertropia among the different age groups, and the bonferroni correction for multiple comparisons was used, for choosing the 20 years old as an arbitrary cut point. P value of less than 0.5 was considered statistically significant.

3. Results

A total of 73 patients were included. They were aged from 6.4 to 79.8 years old with a mean age of 37.5 ± 17.7. The second follow-up visit was approximately 2–3 months after the surgery (mean 110.28 ± 156.32 days). Part of the patients had a longer follow up, with an average maximal follow-up of 332.7 ± 482.7 days.

Table 1
Preoperative Measurements and Surgical Outcomes.

	Distance Hypertropia (PD)	Excyclotropia (°)	IOOA
Pre-operatively	15.41 ± 6.8	+5.34 ± 3.6	+2.2 ± 0.7
2–3 months P.O	3.7 ± 3.4	+1.1 ± 2.3	−0.1 ± 0.8
Maximal follow-up P.O	2.2 ± 2.3	+1.0 ± 2.4	−0.2 ± 0.9

HT- Hypertropia, PD- Prism diopters, IOOA- Inferior oblique overaction, P.O.- post-operatively.

3.1. Distance hypertropia

The mean preoperative distance hypertropia was 15.41 ± 6.8 Prism Diopters (PD) (range 4-30PD), and the mean postoperative distance hypertropia was 3.7 ± 3.4PD (range 0-14PD) approximately 2–3 months after the surgery. After a maximal follow up, the distance hypertropia was 2.2 ± 2.3 PD (range −1 – +8 PD) (Table 1). We found correlation between the preoperative distance hypertropia and the amount of correction obtained ($r^2 = 0.74$, Fig. 1).

3.2. Excyclotropia

The patients presented a mean preoperative excyclotropia of +5.34 ± 3.6° (range 0–12°), and the mean postoperative excyclotropia was +1.1 ± 2.3°(range(-5)-10), approximately 2–3 months after the surgery. Maximal follow up mean excyclotropia was +1.0 ± 2.4°[(−3)-6], Table 1.

3.3. Inferior oblique overactions (IOOA)

The mean preoperative IOOA was +2.2 ± 0.7 (range 0–3.5), and the mean postoperative IOOA was −0.1 ± 0.8(range (−2)-2), approximately 2–3 months after the surgery. Maximal follow up IOOA was −0.2 ± 0.9[range (−2)-3], Table 1.

3.4. Correlation between age and residual distance hypertropia

No correlation was found between the preoperative or postoperative distance hypertropia and age ($r^2 = 0.009$, $r^2 = 0.005$, respectively, Fig. 2). However, as illustrated in the scattergram in Fig. 2, the young age group (0–20 years old) had a smaller residual distance hypertropia, with all cases up to 5PD of distance hypertropia, whereas in all the other age groups the values were widely scattered with values as high as 14PD of residual distance hypertropia.

When we compared the younger age group (0–20 years old, range 6.4–19.7 years old) to patients older than 20 years old (range 20.4–79.8), we found that preoperatively there was a trend toward lower distance hypertropia in the younger age group ($P = 0.051$), and post-operatively, the younger age group had significantly lower residual distance hypertropia compared to the older group($P = 0.007$), (Fig. 2, Table 2). We applied the Bonferroni correction for multiple comparisons, for choosing the 20 years old as an arbitrary cut point.

4. Discussion

In our study, IO myectomy results in a 11.7PD reduction of the distance hypertropia, 4° reduction of excyclotropia in primary position and a 2.3 reduction of IO overaction in SOP cases with fusion (Table 1).

Farid et al. compared the results of three different IO weakening procedures among patients with unilateral SOP [2]. In the IO

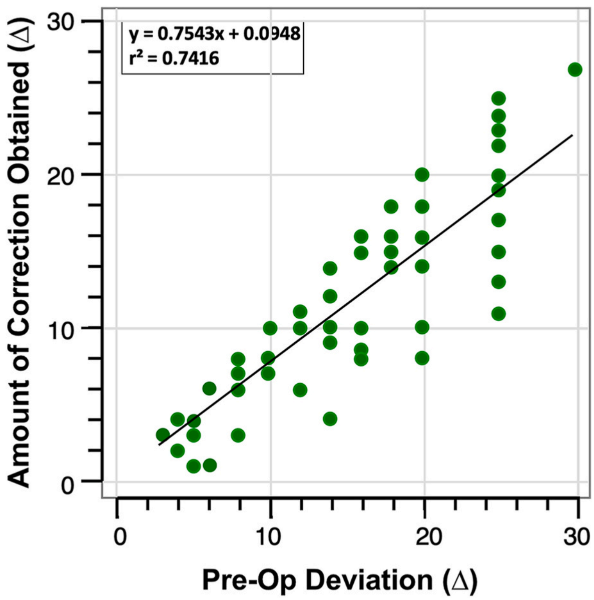

Fig. 1. The correlation between the pre-op deviation and the amount of correction obtained. This scattergram illustrate correlation between the preoperative distance hypertropia and the amount of correction obtained with surgery ($r^2 = 0.74$).

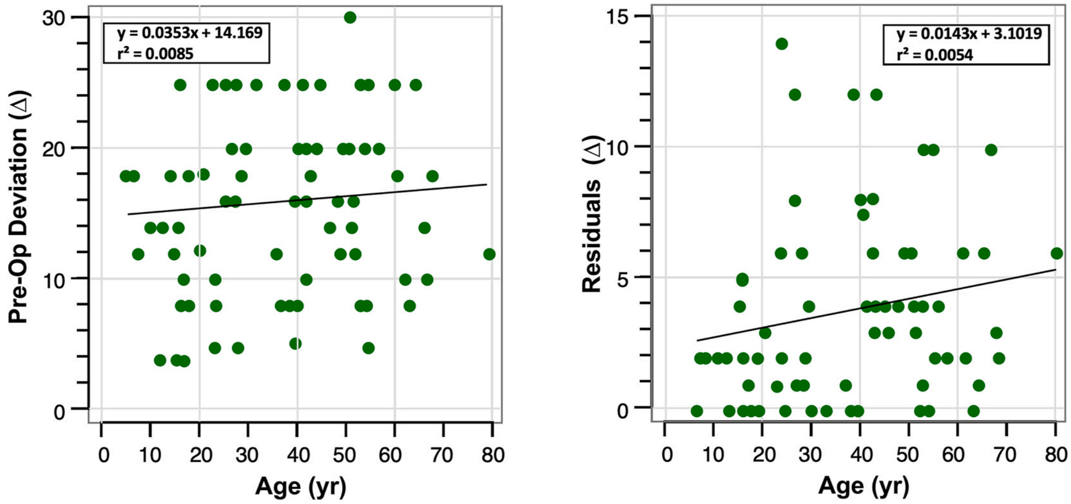

Fig. 2. The correlation between age and the pre-op and post-op deviations. Scattergrams illustrating no correlations between preoperative or postoperative distance hypertropia and age ($r^2 = 0.009$, $r^2 = 0.005$, respectively). After breaking down the distribution of success as function of age, it appears that the rate of success is higher in individuals younger than 20 years old, with post-operatively significantly lower residual distance hypertropia compared to the older group (P = 0.007).

Table 2
Distance Hypertropia Categorized by Age Group.

Distance Hypertropia (PD)			
	0-20 y/o age group (range 6.4–19.7 y/o)	>20 y/o age group (range 20.4–79.8)	P value
Pre-operatively	12.50 ± 6.14	16.23 ± 6.76	0.051
Post-operatively	1.70 ± 1.74	4.25 ± 3.60	0.007

PD- Prism diopters, y/o-years old.

myectomy group, 24 patients were included and they had residual postoperative hypertropia in primary position of 7 PD with a reduction of 12.9 ± 3.6PD from their preoperative measurements, and a resolution of IOOA [2]. The residual hypertropia was smaller among the patients in the recession combined anteriorization group (19 patients, 2PD residual hypertropia) and the anteriorization group (22 patients, 6PD residual hypertropia) [2]. However, in those groups a significant percentage of the patients suffered from anti elevation syndrome (31 % and 13 % respectively) [2].

Another large series published by Haugen and Nepstad included 104 patients with SOP that had a standardized recession surgery [6]. They divided the patients in congenital vs acquired form [6]. In the congenital group which consisted of 69 patients, the post-operatively distance hypertropia in primary position was 2.9 ± 4.4PD with a reduction of 8.5PD from preoperative measures. In the acquired group which consisted of 35 patients the residual hypertropia was 1.6 ± 3.1PD with a reduction of 8.4PD compared to preoperative measures. They also found correlation between the preoperative vertical deviation and the amount of correction achieved in the surgery, as was found in other studies and in our study as well (Fig. 1) [7,9], further supporting the tenet that IO procedures are self-titratable or self-grading. The explanation for this is not known and various assumptions have been put forward, such as: a tighter IO muscle release will result in a greater effect, or a tighter IO muscle will retract more and will attach to the eye in a more posterior position, or that the different effect is a result of different degrees of SOP and different degrees of superior oblique residual function [7,10]. One could add to this the influence of sensory fusion, as well as the preoperative development of motor fusion amplitudes in the chronic cases. None have studied these appropriately.

Elhusseiny et al. [7], describe a large series of 94 patients who had either IO recession or IO myectomy. They considered reduction of 4PD as surgical success, which was achieved in 80 % in the IO recession group and 77 % in the IO myectomy group [7]. The IO recession group had significantly lower preoperative deviation compared to the myectomy group [7], and they had more over-correction (10 % in the recession, 4.6 % in the myectomy) [7]. The authors also found a smaller change in vertical deviation in primary gaze in the recession group compared to the myectomy group (P = 0.001) [7]. They looked at the excyclotropia in 33 patients, with reductions of 5.1 ± 1.7° in the recession group and 5.8 ± 0.3° in the myectomy group [7]. All these series fail to demonstrate the clear advantage of one technique of IO weakening over the other(s), while clearly reporting the possibility of over-correction with recession/transposition.

Another advantage of IO myectomy is its simple and consistent technique that can be compared between different settings, cases and surgeons. There is a greater risk of variability with the other weakening procedures. For example, in recessions and transpositions, the location and technique of the re-attachment point(s) to the eye vary based on measurement landmarks as well as tissue manipulation; for example, the size of the residual muscle stump at the myotomy site and the amount of the distal muscle stump reattached are but only two such examples. These do make comparison of results much more difficult.

In our study we found a trend toward smaller pre-operative deviation in patients younger than 20 years old (P = 0.051), and a significantly smaller residual hyperdeviation in those younger patients (P = 0.007, Table 2, Fig. 2). This could be the result of a larger fusional amplitude with better motor control in the younger patient, or simply better healing and elasticity of soft tissue at younger age. Tossi and Von Noorden [9] checked that correlation back in 1979 on a smaller series of 26 patients with SOP who received an IO myectomy. They didn't find a correlation between the age and the amount of correction achieved, however they had a smaller sample, with only several patients in each age group, which make it more difficult to demonstrate statistical significance [9].

The limitations of our study include it retrospective nature. Torsion measurements were conducted only subjectively using the double Maddox rod test, without objective measurements of fundus torsion.Additionally, the maximal follow up period varies between patients. All had a short average 2–3 months follow-up while some were followed for several years. We chose the 2–3 months follow-up visit for our primary outcome results. The large variability in the maximal follow-up periods is attributable to the nature of the practice used for this study: patients are referred from a large geographical area and often discharged after their initial post-op visit with instructions to return only if problems persists/return. Furthermore, we have not been able to correlate our results with the status of the superior oblique muscle due to the rare instances of imaging done on our patients [11], and we didn't have sufficient data to divide the study group to congenital versus acquired form.

To conclude, while our results on IO myectomy are comparable to other surgical methods reported in the literature, they underline an efficacy without the risks of complications such as anti-elevation syndrome [2] and possible scleral perforation. The younger age group had a trend toward smaller preoperative vertical deviation, and better surgical outcomes compared to the older age group. To further our knowledge, future analysis of this and other IO weakening surgeries on SOP, will require a careful comparison of chronicity, sensory and motor fusional abilities, as well as strict standardizations of surgical methods, all lacking in the literature presently.

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Data availability statement

The data that has been used is confidential.

Ethics declarations

This study was reviewed and approved by the IWK Institutional review board, with the approval number: 1005396.
Informed consent was not required for this study because of its retrospective nature.

CRediT authorship contribution statement

Michal Blau-Most: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Francois Tremblay:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis. **G Robert La Roche:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

No conflict of interest.

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References

[1] J.L. Demer, R.A. Clark, Masquerading superior oblique palsy, Am. J. Ophthalmol. 242 (2022) 197–208, https://doi.org/10.1016/j.ajo.2022.05.017.
[2] M.F. Farid, M. Anany, M. Abdelshafy, Surgical outcomes of three different weakening procedures of inferior oblique muscle in the treatment of unilateral superior oblique palsy, BMC Ophthalmol. 20 (1) (2020) 1–6, https://doi.org/10.1186/s12886-020-01568-w.
[3] E.H. Cha, S gyu Ha, Shu Y. Suh, S.H. Kim, Clinical features of excyclotorsion in the non-paretic eye of patients with congenital unilateral superior oblique palsy, BMC Ophthalmol. 22 (1) (2022) 1–5, https://doi.org/10.1186/s12886-022-02339-5.
[4] E. Turan-Vural, C. Unlu, G. Erdogan, A. Aykut, H. Bayramlar, F. Atmaca, Evaluation of macular thickness change after inferior oblique muscle recession surgery, Indian J. Ophthalmol. 62 (6) (2014) 715–718, https://doi.org/10.4103/0301-4738.136230.
[5] M.A. Del Monte, M.M. Parks, Denervation and extirpation of the inferior oblique: an improved weakening procedure for marked overaction, Ophthalmology 90 (10) (1983) 1178–1185, https://doi.org/10.1016/S0161-6420(83)34409-2.
[6] O.H. Haugen, L. Nepstad, A standardized recession of the inferior oblique extraocular muscle – a safe and self-grading surgical procedure for trochlear nerve palsy: a 10-year material, Acta Ophthalmol. 97 (5) (2019) 491–496, https://doi.org/10.1111/aos.13988.
[7] A.M. Elhusseiny, C. Gore, A. Ali, M. Sadiq, L.R. Dagi, M. Kazlas, D.G. Hunter, Self-grading effect of inferior oblique myectomy and recession, J AAPOS 24 (4) (2020) 218.e1–218.e6, https://doi.org/10.1016/j.jaapos.2020.04.014.

[8] A.M. Reza, S. Samira, M. Arash, Surgical outcome of single inferior oblique myectomy in small and large hypertropia of unilateral superior oblique palsy, J. Pediatr. Ophthalmol. Strabismus 56 (1) (2019) 23–27, https://doi.org/10.3928/01913913-20180925-03.
[9] S.H. Toosi, G.K. von Noorden, Effect of isolated inferior oblique muscle myectomy in the management of superior oblique muscle palsy, Am. J. Ophthalmol. 88 (3 PART 2) (1979) 602–608, https://doi.org/10.1016/0002-9394(79)90522-1.
[10] R.S. Bahl, A. Marcotty, P.J. Rychwalski, E.I. Traboulsi, Comparison of inferior oblique myectomy to recession for the treatment of superior oblique palsy, Br. J. Ophthalmol. 97 (2) (2013) 184–188, https://doi.org/10.1136/bjophthalmol-2012-301485.
[11] Y. Moon, B.J. Lee, Effect of inferior oblique myectomy on ocular torsion according to the absence of the trochlear nerve in unilateral congenital superior oblique palsy, PLoS One 18 (3) (2023) e0283555, https://doi.org/10.1371/journal.pone.0283555.