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Assessment of combined transposition of the inferior oblique muscle belly without disinsertion and contralateral inferior oblique recession for treating asymmetric inferior oblique muscle overaction (IOOA)

Xiaolin Yin[1], Lei Jin[2], Qian Li[1], Te Fu[1] and Longge Sun[1*]

Abstract

Background This study aimed to investigate the efficacy of inferior oblique belly transposition (IOBT) combined with contralateral inferior oblique recession in treating bilateral asymmetric inferior oblique overaction (IOOA).

Methods A retrospective study was conducted on 23 patients with asymmetric IOOA. IOBT was performed on the less affected eye of the patient, while the contralateral inferior oblique recession was conducted on the more affected eye. Pre- and post-operative changes in the vertical deviation, V-value, fovea-disc angle (FDA), and inferior oblique muscle function were compared. Follow-up duration ranged from 3 to 8 months.

Results The V-pattern was corrected in all cases, and the V-value improved from 14.57 ± 4.50 preoperatively to 4.09 ± 2.17 postoperatively (t = 12.640, $P < 0.001$). The preoperative vertical deviation (5 m) significantly decreased from 8.04 ± 3.08 to 1.57 ± 1.90 postoperatively (t = 8.713, $P < 0.001$). Similarly, the lesser side FDA reduced from 11.39° ± 2.39° before surgery to 6.62° ± 1.11° after surgery (t = 11.132, $P < 0.001$). On the greater side, the FDA also showed significant improvement, reducing from 14.39° ± 2.45° preoperatively to 7.43° ± 1.23° postoperatively (t = 11.231, $P < 0.001$). No patients experienced anti-elevation syndrome (AES) or complications such as reverse head tilt postoperatively.

Conclusion IOBT combined with contralateral inferior oblique recession could effectively treat asymmetric IOOA in patients with ocular asymmetry.

Keywords Inferior oblique belly transposition, V-pattern exotropia, Inferior oblique muscle overaction

*Correspondence:
Longge Sun
lucykerin@163.com
[1]Department of Ophthalmology, The Second People's Hospital of Jinan, No. 148 Jingyi Road, Jinan 250000, China
[2]Department of Ophthalmology, Shandong Provincial Police General Hospital, Jinan 250000, China

Background

Inferior oblique overaction (IOOA) is a common abnormality in ocular motility, classified into primary and secondary IOOA. This condition typically presents bilaterally and asymmetrically and is characterized by vertical strabismus in the primary gaze. Investigations have revealed that in individuals undergoing unilateral inferior oblique weakening surgery, the incidence of contralateral IOOA is 36.1% [1]. When accompanied by horizontal deviation, a V pattern is frequently observed. Selecting the appropriate surgical approach is crucial to achieving the safe and effective weakening of the IOOA muscle. Managing surgical correction for mild to moderate vertical strabismus accompanied by mild IOOA poses challenges due to the risk of overcorrection postoperatively.

Due to its extensive contact with the sclera, spanning up to 15 mm in length, the inferior oblique muscle is particularly susceptible to functional hyperactivity [2]. Commonly employed procedures include myotomy, myectomy, recession, and anterior transposition, each offering varying degrees of improvement in IOOA. Treatment for bilateral asymmetric IOOA currently lacks standardized clinical guidelines and largely relies on the experience and preferences of surgeons. Some surgeons opt for symmetrical bilateral weakening surgeries [3, 4]. However, in cases of bilateral asymmetric IOOA accompanied by small-angle vertical deviations, symmetrical surgeries can lead to over-weakening of the less affected eye and residual IOOA on the more affected side. Tailoring the surgical procedure to the severity of IOOA enables more precise control over the intervention [5–8], leading to improved outcomes. However, for patients with mild to moderate IOOA, traditional surgical techniques frequently used in the past carry a higher risk of overcorrection or the development of secondary A-pattern deviation [9].

In 2015, Tomarchio S [10] has introduced a novel surgical approach termed the "equatorial scleral anchor" procedure, where the inferior oblique muscle is sutured 11 mm from its insertion point at the Gobin point, without detaching the muscle belly. The aforementioned technique, recognized as the anteroposition of the inferior oblique muscle with bulbar insertion to the equator, has showcased favorable outcomes in addressing mild to moderate instances of IOOA, obviating the necessity for muscle belly dissection.

This study presented a novel combined surgical approach for treating asymmetric IOOA in both eyes. It aimed to investigate the efficacy of inferior oblique belly transposition combined with contralateral inferior oblique recession in treating bilateral asymmetric inferior oblique overaction.

Methods

A retrospective analysis was conducted on patients with asymmetric IOOA who underwent combined IOBT and contralateral inferior oblique recession surgeries at the Second People's Hospital of Jinan from June 2019 to September 2023. The inclusion criteria were as follows: (1) age ≥ 5 years with the ability to cooperate during ophthalmic examinations; (2) bilateral and asymmetrical IOOA, with the severity of +3 to +4 in the more affected eye and +1 to +2 in the less affected eye, along with a vertical deviation of ≥ 5 prism diopters (PD) in the primary gaze; and (3) a postoperative follow-up period of at least 3 months. Exclusion criteria encompassed patients with ocular trauma, posterior staphyloma syndrome, dissociated vertical deviation (DVD), amblyopia, or a history of previous ocular surgery. Informed consent was obtained from all patients or their guardians, adhering to the principles of the Declaration of Helsinki.

The criteria for cure were defined as the absence of inferior oblique overactivity or insufficiency, a V-pattern exotropia with a V-value of < 10 PD, and horizontal deviation (base-in) of < 10 PD in the primary gaze at distance [11]. The fovea-disc angle (FDA) in the preoperative and postoperative fundus pictures was measured with drawing software. We draw a horizontal line starting from the center of the optic disc, and draw a line connecting the center of the optic disc and the fovea of the macula, and measure the Angle.

Examination methods

Routine ophthalmic examinations, including visual acuity, refractive error assessment, intraocular pressure measurement, slit-lamp examination, and fundus evaluation, were performed to rule out any organic ocular pathologies. Patients with refractive errors were provided with appropriate correction. The alternate prism cover tests were used to evaluate horizontal and vertical deviations at both distance (5 m) and near (33 m) fixation points. Horizontal deviations were further evaluated in 25° upgaze and 25° downgaze at distance fixation, with the difference between these measurements calculated to determine the V-value. A difference exceeding 15 PD was defined as a V-pattern. Eye movements were examined across nine gaze positions, and the severity of IOOA was assessed using Wright's grading scale [12].

Surgical procedure

All patients underwent surgery under general anesthesia. A parallel incision parallel to the corneal margin was made in the inferotemporal conjunctival fornix. The conjunctiva and Tenon's capsule were dissected, and the inferior oblique muscle was identified using a Stevens hook. Surrounding fascial tissues were bluntly dissected to expose the inferior oblique muscle belly. The

IOBT procedure involved pre-placing sutures using 5 – 0 non-absorbable thread at a point 10 to 12 mm from the insertion of the inferior oblique muscle. These sutures were then anchored to the superficial sclera, positioned 5 mm posterior to the temporal end of the inferior rectus muscle (Figs. 1 and 2). In patients undergoing inferior oblique recession, the transpose point on the sclera was determined based on the degree of IOOA; for + 3, the muscle was repositioned to the temporal end of the inferior rectus muscle, 3 mm posterior and 2 mm lateral to the insertion, and for + 4, it was relocated adjacent to the temporal end of the inferior rectus muscle. Surgical plans were tailored for patients with horizontal deviations based on preoperative horizontal deviations, and simultaneous horizontal strabismus correction was performed. Conjunctival closure was achieved with interrupted 7 – 0 absorbable sutures.

Figure legends.

Statistical analysis

Statistical analysis was performed using SPSS version 27.0 software. Changes in the pre- and post-operative vertical deviation, V-value, and fovea-disc angle (FDA) followed a normal distribution. Pairwise sample t-tests were conducted, with statistical significance set at $P < 0.05$. The degree of IOOA in both eyes pre- and post-operatively was analyzed using the Wilcoxon signed-rank test, with statistical significance set at $P < 0.05$.

Results

A total of 23 patients met the inclusion criteria, comprising 15 males and 8 females, aged between 5 and 15 years (mean age: 8.78 ± 2.89 years). Among the cases, 16 presented with V-pattern exotropia accompanied by horizontal deviations, while seven exhibited IOOA. In Table 1, it is shown that out of the 23 cases, 21 (91.3%) were successfully cured. The V-pattern was successfully corrected in all 16 cases of V-pattern exotropia, with the V-value significantly reduced from 14.57 ± 4.50 preoperatively to 4.09 ± 2.17 postoperatively (t = 12.640, $P < 0.001$). Additionally, Table 1 demonstrates a notable improvement in pre-existing primary gaze vertical deviation (5 m), with values decreasing from 8.04 ± 3.08 preoperatively to 1.57 ± 1.90 postoperatively, indicating statistical significance (t = 8.713, $P < 0.001$), and the lesser side FDA reduced from 11.39°±2.39° preoperatively to 6.62°±1.11° postoperatively (t = 11.132, $P < 0.001$). The greater side FDA reduced from 14.39°±2.45° preoperatively to 7.43°±1.23° postoperatively (t = 11.231 $P < 0.001$). Significant postoperative improvement was observed in cases with lesser overacting IOOA, with statistical significance (z = -4.332, $P < 0.001$). Similarly, cases with greater overacting IOOA also demonstrated substantial improvement (z = -4.630, $P < 0.001$). Improvement in binocular IOOA difference was also significant postoperatively (z=-4.330, $P < 0.001$). Among the 14 patients with compensatory head positions preoperatively, all showed significant improvement postoperatively with the absence of compensatory head positions, with statistical significance (z = 3.357, $P < 0.001$). None of the patients experienced anti-elevation syndrome (AES) or complications such as reverse head tilt.

Discussion

Yang et al. have developed a novel technique that demonstrates significant efficacy in mitigating mild to moderate inferior oblique overaction. Additionally, this method effectively alleviates head tilt symptoms associated with vertical deviation. [12]. These reports indicate that IOBT effectively improves mild to moderate IOOA without compromising postoperative muscle function. Research involving IOBT has not observed complications such as adherence syndrome, AES, or overcorrection, indicating a high level of safety [13–16].

Therefore, in this study, we gathered patients exhibiting significant disparities in bilateral asymmetric secondary IOOA. We tailored the weakening procedures according to the severity of IOOA in each eye. For milder IOOA (grades + 1 to + 2), the IOBT procedure was performed, whereas graded recession surgery was employed for more severe IOOA (grades + 3 to + 4). The transposition point of the inferior oblique insertion on the sclera was determined based on the IOOA grade. For grade + 3, the transposition point was positioned at the temporal end of the inferior rectus muscle, 3 mm posterior and 2 mm lateral to the inferior rectus insertion. For grade + 4, the transposition point was located at the temporal end of the inferior rectus muscle.

The IOBT procedure involved pre-placing sutures using 5 – 0 non-absorbable thread at a distance of 10 to 12 mm from the inferior oblique muscle insertion point, which was then secured on the superficial sclera 5 mm posterior to the temporal end of the inferior rectus muscle, corresponding to approximately 12–14 mm from the inferior oblique muscle insertion. By anchoring the inferior oblique muscle belly at the temporal end of the inferior rectus muscle, with a slight degree of anteriorization. its action on the temporal side of the globe was restricted, resulting in a posterior fixation effect akin to other extraocular muscles. This slightly attenuated the action of the inferior oblique muscle. The standard approach was employed for the correction of horizontal strabismus.

Our investigation revealed a significant improvement in both the original in situ vertical strabismus and V values following combined surgery. Using modified IOBT for V-pattern exotropia combined with mild to moderate IOOA, Hao et al. [14] have reported a reduction in V-values postoperatively, alongside a decrease in vertical

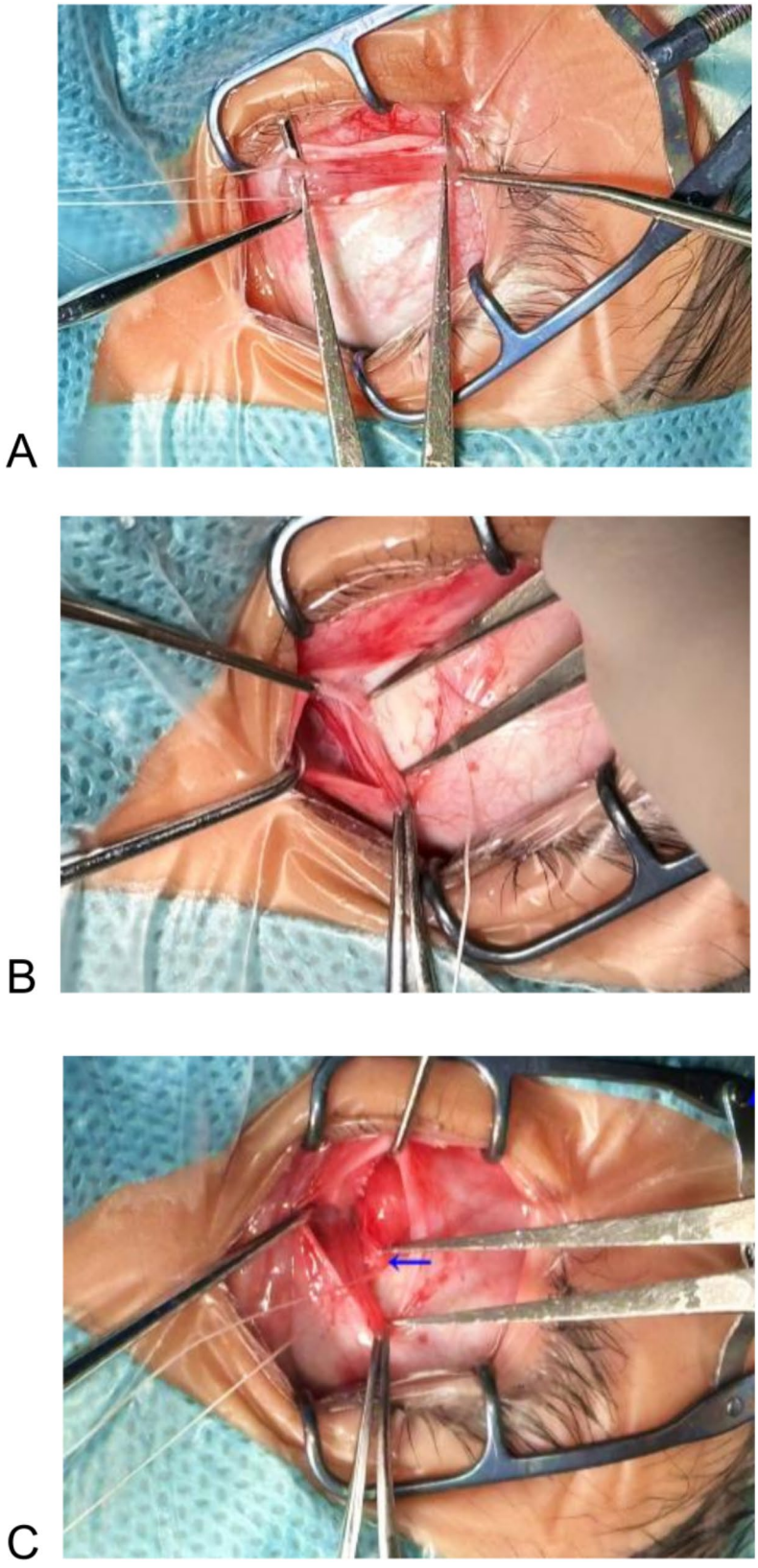

Fig. 1 Photographs illustrating the inferior oblique button tuck (IOBT) procedure (right eye, surgeon's view). (**A**) A 5 – 0 non-absorbable suture is preplaced in the muscle belly, positioned 11 mm from the muscle insertion. (**B**) The belly of the inferior oblique muscle is secured to the sclera, 5 mm posterior to the temporal insertion of the inferior rectus muscle. (**C**) The suture (arrow) is fixed 5 mm posterior to the temporal side of the inferior rectus muscle

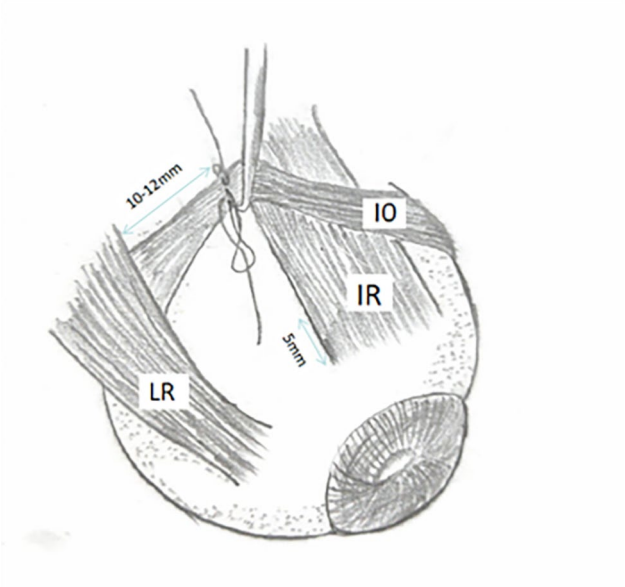

Fig. 2 Schematic diagram of the right eye illustrating the IOBT procedure. The IOBT involved pre-placing sutures using 5 – 0 non-absorbable thread at a point 10–12 mm from the insertion of the inferior oblique muscle. The sutures were then anchored to the superficial sclera, 5 mm posterior to the temporal end of the inferior rectus muscle

deviation at the primary position postoperatively. These findings align with our results, where both V-values and vertical deviations were effectively improved. Similarly, Si et al. [16] have treated 30 patients with asymmetric IOOA using a combination of IOBT and myectomy. Their study has demonstrated a reduction in vertical deviation, both showing significant improvement consistent with our findings.

In our study, the function of the inferior oblique in the lesser overacting IOOA returned to normal in all cases, while 21 out of 23 severe eyes (91.3%) achieved complete restoration, with only two cases (8.7%) exhibiting residual IOOA graded at +1. Yang et al. [2] have also demonstrated the effectiveness of IOBT in treating IOOA accompanied by small-angle vertical deviation. Among 10 patients, nine (90%) exhibit complete relief from overactivity in the downward position, while one case (10%) shows improvement from +3 to +1, aligning closely with our findings, indicating significant improvement in inferior oblique muscle strength. The correction of horizontal strabismus through inferior oblique weakening surgery remains controversial. The impact of inferior oblique weakening procedures on horizontal strabismus remains a topic of debate.

In our study, rectus muscle surgeries were performed following standard protocols, yielding satisfactory postoperative outcomes without accounting for the influence of inferior oblique weakening procedures on horizontal deviation. Based on these results, we suggested that in patients with IOOA, considering the effect of IO weakening procedures might be unnecessary when addressing horizontal deviation. Our study revealed a statistically significant decrease in FDA. In our study, the lesser side FDA decreased significantly. Similarly, the greater side FDA was reduced, demonstrating the effectiveness of combined surgery in improving FDA. For comparison, a population-based study conducted in Beijing in 2011 has reported a mean FDA of 7.76° ± 3.63° across 6,043 eyes, with a median value of 7.76° ± 3.63° [17]. Consistent with the findings of Hao et al. [14], inferior oblique muscle posterior fixation surgery notably improved FDA, bringing postoperative FDA values close to the normal range. The FDA of both eyes was close to the physiological value after operation.

Our study revealed that none of the patients experienced AES following combined surgery, a significantly lower rate compared to inferior oblique muscle recession combined with inferior oblique anterior transposition (IORAT) (six cases, 31% postoperatively), which showed a markedly higher incidence of AES than anteriorization alone (IOAT) (three cases, 13%) and inferior oblique myectomy (IOM) (one case, 4%) [18]. This indicated that the efficacy of IOBT combined with contralateral inferior oblique muscle recession in treating asymmetric IOOA is notable.

Table 1 Comparison of VD, HD, V value, FDA value, IOA, compensatory head position between the two groups

	Distance	preop. (PD, x ± s)	postop. (PD, x ± s)	t	Z	*P*
VD (PD)	5 m	8.04 ± 3.08	1.57 ± 1.90	8.713		*P* < 0.001
HD (PD)	5 m	23.26 ± 13.43	2. 47 ± 2.84	6.672		*P* < 0.001
	33 cm	30.96 ± 15.99	6. 39 ± 2.59	6.759		*P* < 0.001
V-value	5 m	14.57 ± 4.50	4. 09 ± 2. 17	12.640		*P* < 0.001
the lesser overacting IOOA [level, M (P75, P25)]		(1) 00(1. 00, (2) 00)	0. 00(0. 00, 0. 00)		-4.332	*P* < 0.001
the greater overacting IOOA [level, M (P75, P25)]		3. 00(3. 00, 4.00)	0. 00(0. 00, 0. 00)		-4.630	*P* < 0.001
Binocular IOOA difference [level, M (P75, P25)]		2. 00(1. 00, 2. 00)	0. 00(0. 00, 0. 00)		-4.320	*P* < 0.001
mild side FDA		11.39°±2.39°	6.62°±1.11°	11.132		*P* < 0.001
severe side FDA		14.39°±2.45°	7.43°±1.23°	11.231		*P* < 0.001
Compensatory head position		14	0		3.357	*P* < 0.001

While our study was retrospective and based on a relatively small sample size, it introduced a novel approach in the treatment of bilateral asymmetric IOOA through IOBT combined with contralateral inferior oblique muscle recession. The approach demonstrated promising outcomes, warranting further investigation. Our next step involves conducting a prospective study with an increased sample size to further validate the conclusions drawn from this research.

In summary, the efficacy of inferior oblique muscle posterior fixation combined with posterior transposition in treating bilateral asymmetric inferior oblique muscle overaction is affirmed. Postoperatively, ocular movements tend towards symmetry and coordination, with improved correction of primary position vertical strabismus and favorable head posture. Additionally, there is a low incidence of postoperative overcorrection and AES.

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Author contributions
Conception and design: Xiaolin Yin, Te FuAnalysis and interpretation: Xiaolin Yin, Qian Li, Te FuData collection: Xiaolin Yin, Lei JinAll authors have read and approved the final manuscript.

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Data availability
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of Jinan Second People's Hospital, and all procedures adhered to the principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants and their parents or guardians prior to participation, confirming their understanding and agreement with the study procedures.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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