

Effectiveness of modified inferior oblique muscle belly transposition for V-pattern exotropia combined with mild to moderate inferior oblique muscle overaction

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Abstract

• **AIM:** To investigate the effectiveness of a modified inferior oblique muscle belly transposition for treatment of V-pattern exotropia combined with mild to moderate inferior oblique muscle overaction.

• **METHODS:** Thirteen cases (23 affected eyes) of V-pattern exotropia with inferior oblique muscle overaction (+ or ++) who underwent the modified inferior oblique muscle belly transposition procedure were retrospectively reviewed. The amount of V-pattern, grade of inferior oblique overaction, degree of vertical strabismus, abnormal head posture, and the fovea-disc angle were evaluated before and after surgery.

• **RESULTS:** The V-pattern was corrected in all cases, and the amount of V-pattern reduced by 17.85 ± 5.13 prism diopter (PD) on average ($t=16.07$, $P<0.001$). The surgical cure rate for mild to moderate inferior oblique muscle overaction was 87.0% (20/23). The degree of the fovea-disc angle has a mean reduction of $5.45^\circ \pm 2.87^\circ$ ($t=3.95$, $P=0.003$) after surgery. The mean vertical deviation in 5 cases with a small-angle hypertropia (5.23 ± 3.06 PD) in the primary position reduced by 3.15 ± 1.86 PD ($t=6.10$, $P<0.001$). No serious complications were observed.

• **CONCLUSION:** The modified inferior oblique muscle belly transposition procedure can effectively treat mild to moderate inferior oblique overaction and relieve the V-pattern, which is safe and easy to perform.

• **KEYWORDS:** inferior oblique muscle belly transposition; V-pattern exotropia; inferior oblique muscle overaction

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INTRODUCTION

Inferior oblique muscle overaction (IOOA) presents as overelevation in adduction and is a common kind of eye movement abnormalities^[1]. The overaction of the inferior oblique (IO) muscle is often related to a special strabismus phenomenon called "V-pattern", defined as when the difference between the angle of horizontal deviation in the 25° upgaze and that in the 25° downgaze is more than 15 prism diopter (PD)^[2]. For patients combined with V-pattern and IOOA, it is necessary to choose an applicable procedure for weakening IO muscle safely and effectively. Recessions^[3-4], myotomies^[5-6], and myectomies^[7-8] are well-known as classic techniques of weakening the IO muscle. In 2018, Yang *et al*^[9] reported a weakening procedure without disinsertion, the inferior oblique muscle belly transposition (IOMBT) for correcting IOOA with small-angle hypertropia successfully. The emergence of new technology provides a useful addition to traditional methods and shows certain advantages in reducing risks of complications^[9]. At present, a few studies have reported this technique^[10-14]. Its indications become various gradually, such as IOOA^[9-10,12-14] diplopia^[11,13] or asymmetric superior oblique palsy^[12-13] and so on. We noticed that there were still not many reports about V-pattern strabismus^[13-14] in related researches. Further to know about the new technique, we designed a retrospective study on the IOMBT procedure. At the same time, we simplified the procedure to make it easier to perform and evaluate its effectiveness for the treatment of V-pattern exotropia with mild and moderate IOOA.

SUBJECTS AND METHODS

Ethical Approval This study received approval from the Clinical Ethics Committee of the First Affiliated Hospital of Xi'an Jiaotong University (No.XJTU1AF2020LSK-229). All the patients and their guardians had signed the informed consent.

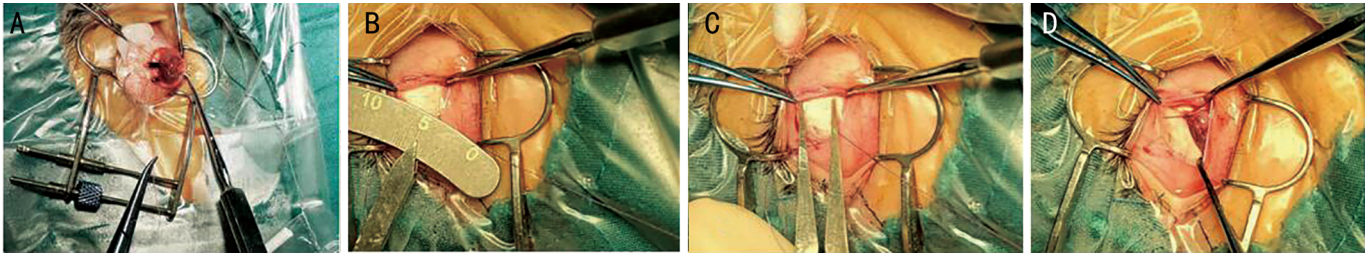


Figure 1 The operative procedure of inferior oblique muscle belly transposition A: Complete hooking of the inferior oblique and suturing at the superior edge of inferior oblique with loop suture technique; B, C: Marking the position in 5 mm posterior to the temporal insertion of the inferior rectus; D: Single-stitch suture fixation of the inferior oblique muscle belly on the sclera.

Cases with V-pattern exotropia with IOOA diagnosed in the First Affiliated Hospital of Xi'an Jiaotong University from March 2020 to October 2021 were retrospectively collected. The patients with the following criteria were excluded: 1) restrictive, paralytic, and sensory strabismus factors; 2) endocrine and autoimmune system diseases; 3) cranial developmental abnormalities such as premature closure of cranial suture. Finally, a total of 13 eligible study subjects (10 bilateral and three monocular) met the inclusion criteria: 1) the degree of horizontal strabismus >-15 PD and vertical strabismus <10 PD; 2) the angle of deviation in 25° upgaze was greater than that in the 25° downgaze at least 15 PD (V-pattern); 3) combined with IOOA “+” or “++” (graded by the Wright’s scale); 4) cooperated with follow-up for 6mo. The study subjects included seven males and six females at age of 5 to 33 years old (16.2 ± 9.0 mean age). IOOA was found in 23 eyes (IOOA ++ in 19 eyes, IOOA + in 4 eyes).

General anesthesia was given to patients under 14 years of age, and subconjunctival anesthesia was given to patients over 14 years of age. The modified IOMBT procedure was performed as follows: we made a fornix incision in the inferiortemporal area of the operated eye, and completely hooked the IO muscle. A single-armed 6-0 absorbable suture (ETHICON VICRYL, obtained by cutting the 6-0 double-armed suture) inserted through the muscle belly at 10–11 mm from the temporal insertion of IO muscle, and looped at the superior edge of the IO muscle (Figure 1A). The position in 5 mm posterior to the temporal insertion of the inferior rectus was marked (Figure 1B, 1C). The belly of IO muscle was fixed to the sclera at this marked point with a single stitch (Figure 1D). All procedures were performed by the same surgeon group.

In the completed refractive correction state, pre-operative and post-operative strabismus-related examinations were performed on every one patient, including eye movements, the grade of IOOA, the angle of deviation (examined by prism alternating cover test), abnormal head posture and the nine-eye position (photoed by 9gaze app.). Except for angles in the primary position at the distance of 33 cm and 5 m, the angle of deviation in upgaze and downgaze also were measured. The difference

between them means the amount of V-pattern with 15 PD at least. The fovea-disc angle (FDA) in the preoperative and postoperative fundus pictures (Canon, Japan) was measured with Image J software (Figure 2). The above examinations were all repeated by regular examiners. Differences in the preoperative and postoperative mean values were assessed for statistical significance by paired *t*-test using SPSS 21.0.

RESULTS

The V-pattern was corrected in all cases. The amount of V-pattern on average changed from 22.00 ± 6.44 to 5.08 ± 3.82 PD, which had a mean decrease of 17.85 ± 5.13 PD *via* surgeries ($t=16.07$, $P<0.001$). In the 23 eyes with mild or moderate IOOA, IOOA+ in four eyes and IOOA++ in 16 eyes were completely corrected after surgeries, with a cure percentage of 87%. While IOOA++ in 3 eyes were improved to IOOA+. The mean angle of FDA was $12.26^\circ\pm 2.58^\circ$ on baseline and $6.38^\circ\pm 3.05^\circ$ after half a year ($t=3.95$, $P=0.003$), reducing by $5.45^\circ\pm 2.87^\circ$ in FDA on average. In five cases combined with vertical strabismus (5.23 ± 3.06 PD) at primary position, the mean degree of vertical deviation was improved to 2.08 ± 1.85 PD ($t=6.10$, $P<0.001$), which decreased by 3.15 ± 1.86 PD on average. In the three cases with abnormal head posture, chin uplift had relieved immediately after surgeries. During the surgeries, macula damage, active bleeding, punctures in the ocular wall and other accidents didn’t occur as we estimated. In our study, we didn’t observe those postoperative complications, such as overcorrection of IO muscle weakening, secondary A-pattern, limitation of movement, delayed hemorrhage, muscle slippage or other serious problems in any case.

We give a case example to show the use of modified IOMBT procedure. A young girl with bilateral IOOA++ and typical V-pattern had exotropia. She had no abnormal head posture and her nine-gaze positions before treatment were exhibited in Figure 3A. Except for the conventional procedures of the horizontal muscles, she also received a modified IOMBT procedure in two eyes. After surgeries, both eyes were normal position at the primary position. Both the previous IOOA and V-pattern were significantly relieved, and ocular alignment was more coordinated (Figure 3B).

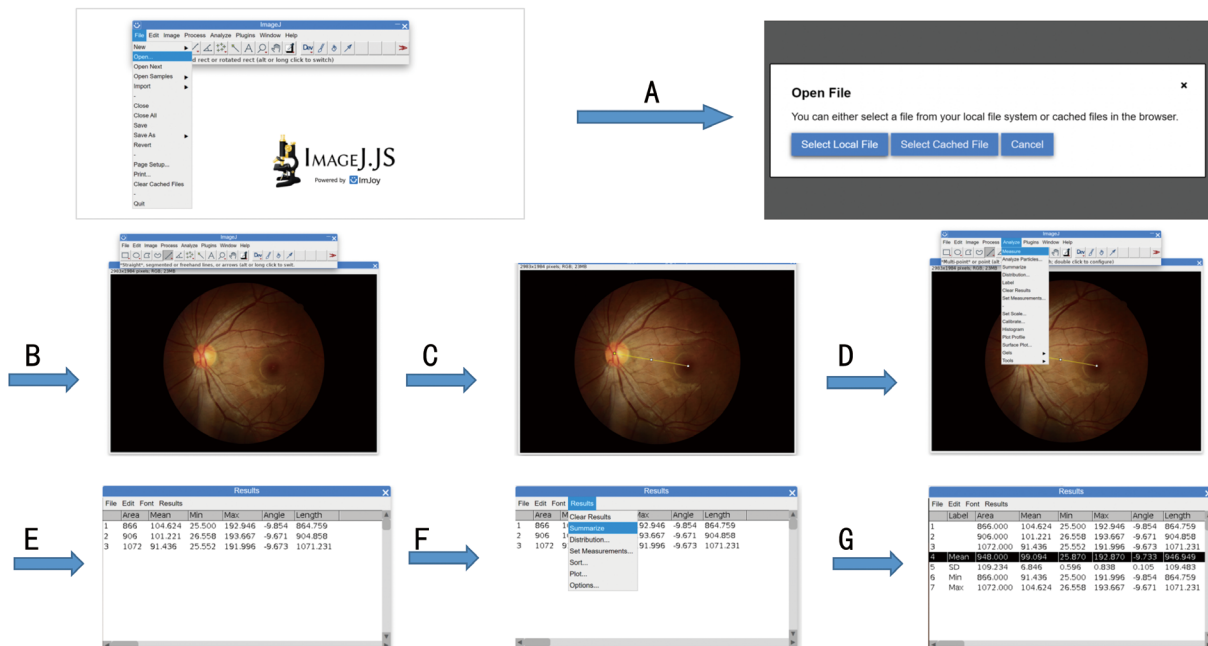


Figure 2 The measurement of FDA A: Turn on the “Image J”, and click the button “open” in the toolbar; B: A pop-up will help us to choose a fundus picture to open in the analysis interface; C: Click the icon “straight” and we can use the tool to mark the center of the optic disk and the fovea of macula as two points in a straight line; D: Click the button “Analyze” and choose “Measure” in the drop-down lists or click the shortcut key “M”, the default program will be started to calculate the angle between the marked line and the horizontal axis; E: The results are shown in a pop-up window, and the “Angle” column displays the value of FDA and measure three times in succession; F: Click the button “result” in the pop-up window and choose “Summarize” in the drop-down lists to analyze the data further; G: We can get the mean value of FDA as the valid data of one eye in the pop-up window. FDA: The fovea-disk angle.

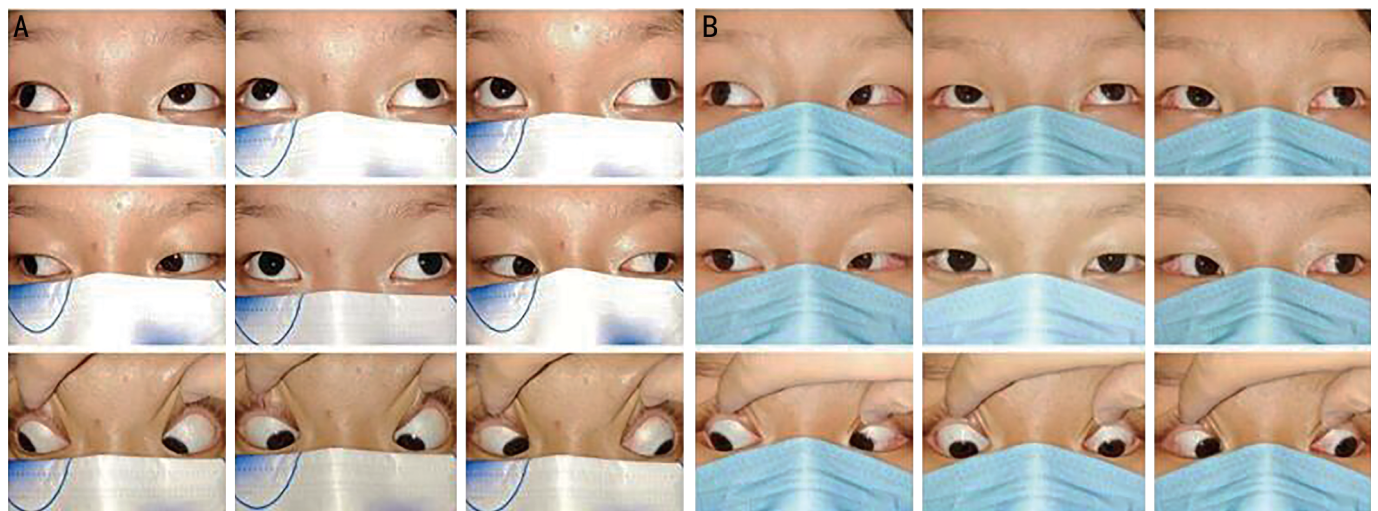


Figure 3 A case with bilateral IOOA++ and typical V-pattern exotropia A: Preoperative 9-gaze position images; B: Postoperative 9-gaze position images. IOOA: Inferior oblique muscle overaction.

DISCUSSION

V-pattern exotropia reflects a special deviation form of exotropia in the vertical direction, which is common in patients with horizontal strabismus. When the V-pattern exotropia is combined with IOOA, how to weaken the IO muscle is the key to success for effective treatment^[15]. As the common choices, recessions, myotomies or myectomies have been proven useful in cases with IOOA for a long time^[16-18]. They

are very classical^[19-20], while any operation in the IO muscle is not completely safe and needs more skilled and more careful. Because the scleral insertion of IO muscle is near the inferotemporal vorticosse vein and the macula^[21]. It means that any improper manipulation of IO muscle may result in an unacceptable outcome of vision alteration^[22]. Usually, the disinsertion or incision of the IO muscle is a necessary step for the traditional procedures in company with the damage

of its own structural integrity and the latent risks of injuring the macula or bleeding. And since muscle cut-ends need hemostasis, the use of cauterizers and electrocoagulators may bring new dangers. Two cases of macular damage were ever reported to occur during the IO myectomy by the cutting diathermy^[23]. Turan-Vural *et al*^[24] found the macular thickness changed after IO muscle recession and suggested that more gentle and careful surgeries could prevent macular trauma. The hang-back recession technique^[25], a modified recession method, as well as myotomies makes the cutoff point far away from the dangerous area but still couldn't avoid the potential risk of hemorrhage and does comparatively more complex sutures. Arès and Superstein^[26] ever reported a case of delayed retrobulbar hemorrhage occurred in the inferolateral orbit near after the IO myotomies, and they attributed bleeding to inadequate cautery of the IO muscle. In recent years, the similar case still happened by accident^[27]. In addition, the cut-ends of IO muscle adhere to the sclera randomly and it may bring more challenges in secondary surgeries. Although the awful complications are not common, safety can never be overemphasized. Doctors never give up trying to find safer, simpler, and resultful alternatives endlessly. Avoiding the disinsertion, several new weakening techniques were described by Tomarchio *et al*^[28], García de Oteyza *et al*^[23], and Yang *et al*^[9]. The IOMBT is one of the representatives. What they have in common is that the IO muscle is fixed at a certain point on the sclera without cutting the muscle or tendon, while preserving the integrity of the muscle. Patients might benefit from minimizing the IO muscle trauma, which make it possible for less bleeding, a more comfortable experience, and faster recovery^[26]. The techniques can give us more options for surgical procedures with the same symptoms.

In our study, we used the treatment strategy based on the IOMBT technique that performed a gentle functional improvement of IOOA by transposing the IO muscle belly to the location in 5 mm posterior to the temporal insertion of the inferior rectus^[9]. In the standard procedures on IOMBT, it was used to make two double-loop sutures on the bilateral edges of the IO muscle and finally fix the belly with two stitches. But potential risks exist when any suture goes through the sclera every time, for example, piercing the eye wall and injuring retina^[29]. In our procedure, the belly of IO was looped the upper edge of the IO and fixed by one stitch at the same point. We try to simplify the process by less suture to make the operation easier and safer. No tendons detached, no muscle apart, and just a convenient suture may be more friendly to the tyro. Furthermore, additional precautions may be needed to reduce the accidental slippage of the muscle. In the author's experience, this can be done with a laminar suture of the IO muscle to half the muscle thickness. For suture fixation of the

muscle with a tight knot and a clear depth of the suture through the lamellar sclera. It has been confirmed that the standard IOMBT was useful for the overaction of IO muscle^[9-10]. We found IOOA in all cases were improved after the simplified procedure, and the cure rate was 87.0%, comparable to previously reported rates (71.0%^[12] to 86.7%^[13]). Our study also demonstrated that the modified procedure also achieved a good effect on treating V-pattern exotropia. The mean amount of V-pattern was reduced by 17.85±5.13 PD and the difference between the preoperative and postoperative value of V-pattern was significant ($t=16.07$, $P<0.001$). Analogously, Su *et al*^[13] reported a mean reduction of 16.4±2.5 PD, and Si *et al*^[14] described a similar reduction of 16.5±1.1 PD in V-pattern *via* the standard IOMBT surgery. Some features of the standard procedure got retained in the simplified procedure.

Researchers in a population-based survey, the Beijing Eye Study 2011, claimed that the normal FDA involved with 6043 eyes was 7.76°±3.63° on average and the median value is 7.65°^[30]. In our study, the mean FDA decreased from 12.26°±2.58° on baseline to 6.38°±3.05° after surgeries ($P=0.003$). We could see our terminal FDA was near the normal average value. From another point of view, it was also confirmed that effect of IOOA was improved by surgery partially. The postoperative reduction in FDA was 5.45°±2.87°, which indicated that IOMBT slightly improved external rotation, but different from the data in the earlier reports. The change of FDA waved in a range of about 10° from 1.83°±3.02° to 6.5°±2.3°^[12-14]. Perhaps the differences came from the selection bias on small samples for different indications. Besides, nonuniform measurement methods couldn't be excluded completely. In the current articles about the IOMBT, various graphic software was used for measuring the FDA. And the detailed flow was not described in these reports so that we couldn't compare measurement methods directly. Because the FDA is defined as the angle between the disc-fovea line and the horizontal line passing through the disc center. The common approach to measuring the FDA is that operators locate three points in the angle or connect the two characteristic points with the disc horizontal line by the "Angle" tools^[31]. In fact, the manual measurement error of FDA is hard to avoid^[32] with a reported error of 2.0°±1.8° on average^[33]. So we took advantage of the built-in horizontal line function on the "Straight" program in Image J to simplify the process and reduce the measuring-error by less manually markers. All we need to do was just line the fovea and center of the disc and click the button "M". In the future, perhaps artificial intelligence technologies which can recognize the angle's construction automatically would further optimize the operation of this indicator and improve the accuracy of measurement.

We found a mean reduction of 3.15 ± 1.86 PD in vertical deviation among 5 patients with hypertropia, more similar to the results of Yang *et al*'s^[9] (from 3.30 ± 0.48 PD down to 0.10 ± 0.32 PD) and Su *et al*'s^[13] (4.2 ± 0.4 PD) studies that IOMBT procedure could correct a small-angle hypertropia within 5 PD, and different from Zhu *et al*'s^[12] study that IOMBT showed a powerful decrease of 5.86 ± 2.24 PD. According to those reports, hypertropia in the primary position was reduced by the minimum deviation in our study. This discrepancy might be due to the small sample sizes of existing studies. In addition, we couldn't sure whether the attenuation was related with our simplified operation or not. In Demer's point, the gaze-related inflection of IO muscle depends on the pulley which is the functional origin near the temporal border with the inferior rectus. When eyes turn from infraduction to supraduction, the IO muscle will move anteriorly at the point of inferior rectus crossing^[34]. Belly transposition sparing the IO muscle insertion might depress the anterior movement of IO muscle and change the new effective origin, partially similar to the mechanism of posterior fixation, or a little-dose recession^[9,14]. In our study, the simplified procedure kept the same anchor in the sclera as the standard IOMBT. In theory, depression of overaction for IO muscle by increasing the distance between the insertion and the cross point where the IO muscle naturally passes by the inferior rectus' temporal edge and pushing it closer to its origin with a loosening effect of proximal IO for improving the primary hypertropia^[9]. So the influence factor perhaps corresponds to a unbalance effect on the different parts of IO bundles, due to the simplified suture method. Single-border suture of IO might make less limitation to inferior muscle bundle than superior muscle bundle, weakening the whole effect of the procedure. Moreover, Zhu *et al*'^[12] claimed the IOMBT was self-grading in vertical deviation correction just like IO muscle recession^[35]. Their study indeed involved more cases with hypertropia more than 5 PD. In this view, the difference between our trials could make sense. The above hypotheses still need magnetic resonance imaging and other evidence based on larger samples to be confirmed. And we will concern and research in the field continuously.

In the study, no hemorrhage and serious ocular damage occurred during the IOMBT operation. No postoperative complications like the adherence syndrome, anti-elevation syndrome, overcorrection, and other accidents were observed, demonstrating the safety of IOMBT in agreement with previous studies^[9,12-14]. Overall, the modified procedure retains the advantages of the IOMBT procedure while being easier to perform, potentially shortening the pulling muscle and surgery time, and reducing the risk of ocular penetration with multiple sutures.

Because this new technique develops for a relatively short time, we still face some points to improve including the previously mentioned. In future, the sample size should be expanded to further compare our method with conventional IOMBT based on continuous follow-up. In conclusion, modified IOMBT can effectively attenuate mild to moderate IO muscle overreaction and relieve V-pattern. Moreover, this approach is easy to implement and is a safe addition to the IO muscle weakening procedures.

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