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Inferior Oblique Muscle Surgery for Treatment of V-pattern Strabismus and Dissociated Vertical Deviation

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Summary: The inferior oblique muscle plays a key role in controlling eye position during changes in gaze direction, particularly in coordinating vertical and torsional movements. Its anatomy is somewhat different compared to the other extraocular muscles, making its understanding crucial for accurate diagnosis and effective surgical treatment. V-pattern strabismus with inferior oblique muscle overaction and dissociated vertical deviation, alongside trochlear nerve palsy, are among the most common indications for surgical procedures on the inferior oblique muscles. This article discusses the surgical techniques used in the treatment of V-pattern strabismus and dissociated vertical deviation and highlights the potential complications that may arise. The importance of assessing objective and subjective cyclotorsion in the diagnosis and surgical planning of these conditions is also emphasized.

Key words: strabismus, inferior oblique muscle, V-pattern strabismus, dissociated vertical deviation (DVD).

Introduction

Surgical interventions targeting the inferior oblique muscles are a critical and integral component of the comprehensive surgical management of strabismus, particularly when a vertical and/or torsional component is present, either concurrently or in isolation. The anatomy of the inferior oblique muscle differs slightly from that of the other extraocular muscles. This distinction is crucial for understanding how various surgical procedures impact ocular positioning and mobility. Most surgical techniques aim to weaken the function of the inferior oblique muscles, making them suitable for treating both primary and secondary hyperfunction of these muscles. Currently, the most commonly performed procedures include disinsertion, myectomy, graded recession, and anterior or anterior nasal transposition [1–4].

The present article provides a concise overview of the anatomy and functions of the inferior oblique muscle, outlines the primary indications for surgical intervention involving the muscle, discusses various surgical techniques – particularly those used to treat V-pattern strabismus and dissociated vertical deviation – and highlights potential intraoperative and postoperative complications.

Anatomy of the inferior oblique muscle

The inferior oblique muscle is one of six extraocular muscles responsible for eyeball mobility. The initial attachment of the inferior oblique muscle differs from that of the other extraocular muscles and the levator palpebrae superioris muscle, as it is the only one that does not arise from the common tendinous ring (annulus of Zinn). Instead, it originates from the maxilla, located posterior to the lower medial orbital rim and lateral to the nasolacrimal canal. After passing beneath the inferior rectus, the inferior oblique muscle curves superiorly, terminating approximately 8 12 mm posterior to the attachment of the lateral rectus, along its inferior border, near the macula. The inferior oblique tendon, measuring 1–2 mm in length, is the shortest tendon among the extraocular muscles. Furthermore, at the level where the inferior oblique muscle passes beneath the inferior rectus, the neurovascular bundle (NVB) enters its boundary. Due to its fibrous structure, it can serve as a potential site for new attachment of the inferior oblique muscle, particularly following its anterior transposition. The inferior oblique muscle is innervated by the inferior branch of the oculomotor nerve (cranial nerve III) and receives its blood supply from the muscular branches of the ophthalmic artery. The characteristics of the inferior oblique muscle are summarized in Table I.

Initial attachment	maxilla
Terminal attachment	8–10 mm posterior to the inferior margin of the lateral rectus attachment
Muscle length	35–37 mm
Tendon length	1–2 mm
Source of blood supply	muscular branches of the ophthalmic artery
Source of innervation	inferior branch of the oculomotor nerve (cranial nerve III)

Tab. I. Characteristics of the inferior oblique muscle.

The functions of the inferior oblique muscle include:

- excyclorotation – primary function in abduction and secondary in adduction,
- elevation – primary function in abduction and secondary in adduction,
  and
- abduction – tertiary function.

Indications for surgery on the inferior oblique muscle

The primary indications for surgery to weaken the inferior oblique muscles include:

- overactivity of the inferior oblique muscles associated with V-pattern strabismus,
- dissociated vertical deviation,
- trochlear nerve palsy.

Overactivity of the inferior oblique muscles associated with V-pattern strabismus

V-pattern strabismus is a form of horizontal strabismus with vertical dissociation, characterized by a difference of more than 15 prism diopters (D) in the deviation angle between upward and downward gaze. The etiology of V-pattern strabismus remains inconclusive. Proposed pathophysiological mechanisms include dysfunction of the inferior oblique muscles, characterized by downward displacement of the lateral rectus pulleys relative to the medial rectus pulleys, vestibular system dysfunction, and abnormal neural connections [5].

Inferior oblique muscle overaction (IOOA) in V-pattern strabismus is associated with convergent strabismus in approximately 70% and divergent strabismus in 30% of cases. IOOA is characterized by excessive elevation of the eyes in adduction (Fig. 1), warranting surgical intervention to reduce vertical deviation through weakening of the inferior oblique muscles [6, 7].

Dissociated vertical deviation

Dissociated vertical deviation (DVD) is a unilateral or bilateral eye movement disorder of unknown etiology, characterized by a slow upward drift of the non-fixating eye while the other eye maintains fixation on an object [8]. It most commonly occurs in patients with infantile convergent strabismus and is frequently accompanied by excessive eye elevation in adduction. Therefore, the planning of surgical treatment for DVD depends on the presence or absence of inferior oblique muscle overactivity. In the former case, similar to V-pattern strabismus with associated inferior oblique muscle overactivity, procedures that weaken the inferior oblique muscles, such as recession or anterior transposition, are employed. In the latter case, the treatment typically involves recession of the superior rectus or the use of sutures to fixate the superior rectus to the sclera (posterior fixation suture) [8–11].

Types of procedures involving the inferior oblique muscle

Numerous surgical techniques have been described for weakening the inferior oblique muscles, including myectomy, disinsertion, extirpation, recession, and anterior or anterior nasal transposition [1–4].

Disinsertion and myectomy

Disinsertion and myectomy are relatively old surgical methods. Disinsertion refers to the severing of a muscle from its attachment, followed by its release within Tenon's capsule. Myectomy differs in that after severing the muscle at its original attachment a portion of the muscle is excised [12].

The main advantage of these procedures is their convenience, as they are quicker and easier to perform compared to recession. Additionally, the risk of complications during surgery is reduced, as these procedures do not involve suturing the muscle to the sclera, which lowers the likelihood of scleral perforation. Clear disadvantages of these methods are the unpredictability and variability of postoperative outcomes, as well as the risk of recurrence of overactivity. Numerous studies in the literature highlight the high efficacy of disinsertion and myectomy in treating inferior oblique muscle overaction, emphasizing their ease of execution, lower risk of bleeding, and comparable success rates to other techniques [13, 14].

Currently, most strabismus specialists prefer graded recession of the inferior oblique muscle over disinsertion or myectomy. This approach offers a more predictable surgical outcome and eliminates the risk of uncontrolled inferior oblique muscle adhesion to the sclera.

Graded recession

Graded inferior oblique recession is a method involving retraction of the inferior oblique muscle by 8, 10, 12, or 14 mm, depending on the severity of its overaction. This approach enables more precise correction while minimizing the risk of both undercorrection and overcorrection [15]. This highly effective method is most commonly employed in the treatment of V-pattern strabismus and unilateral trochlear nerve (cranial nerve IV) palsy [16].

Inferior transposition

Inferior oblique anterior transposition (IOAT) is a modification of muscle retraction that involves stripping and suturing the

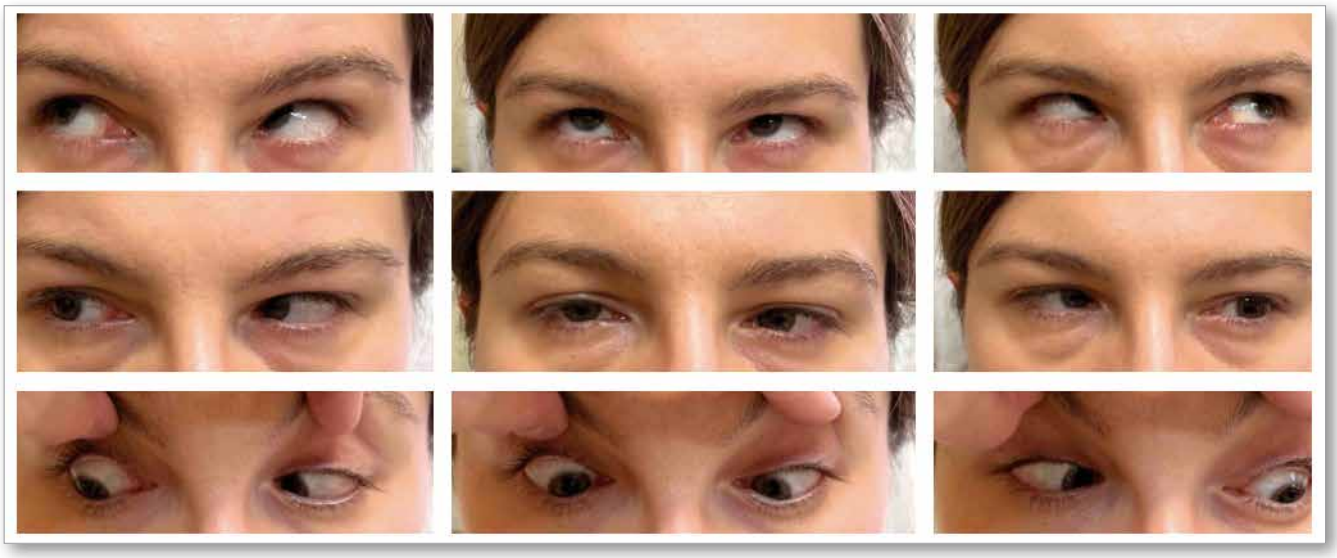

Fig. 1. V-pattern horizontal strabismus with inferior oblique muscle overaction (authors' own material).

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inferior oblique muscle anteriorly, near the temporal edge of the inferior rectus attachment. The technique, which aims to enhance the effect of the recession, was first described by Gobin in 1964 [17] for the treatment of V-pattern strabismus with inferior oblique muscle overaction, but has also been successfully applied in the management of dissociated vertical deviation [18]. The disadvantages of this procedure include the risk of palpebral fissure narrowing [19], hypotropia, and postoperative limitation of eye elevation, as discussed later in the article, particularly in cases of unilateral surgery.

Inferior nasal transposition

Inferior oblique anterior nasal transposition (IOANT) is a relatively new surgical technique in which the inferior oblique muscle is sutured to the sclera at the nasal border of the inferior rectus (Fig. 2). As a procedure significantly weakening the inferior oblique muscle, it eliminates its function as an elevator and external rotator of the eye, converting it into a muscle that depresses and internally rotates the eye during adduction. The technique has been described in the treatment of severe overaction of the inferior oblique muscles with objective excyclotorsion, as well as in DVD, superior oblique muscle palsy, and IV cranial nerve palsy with a large vertical deviation angle [20–22].

Fig. 2. Inferior oblique anterior nasal transposition (authors' own material).

Before any procedure involving an intervention on the inferior oblique muscles, a forced duction test should be performed to assess muscle tension during inward torsional rotation. The muscle is accessed via a fornix or linear incision along the corneal limbus in the inferior temporal quadrant. If simultaneous retraction of the lateral rectus is planned, the existing incision can be used without enlargement. Muscle isolation should be performed under direct visual guidance, with careful attention to avoid capturing excess tissue or orbital fat. The inferior oblique muscle isolated during the surgical procedure is shown in Figure 3. It also needs to be ensured that all muscle bellies and strands are properly isolated.

Importance of both subjective and objective assessment of cyclotorsion in planning inferior oblique muscle procedures

A crucial aspect in diagnosing and planning surgery on the inferior oblique muscles is the assessment of objective and subjective cyclotorsion. The purpose is to detect or confirm excyclotorsion, an excessive outward rotation of the eye that impedes fusion and contributes to diplopia. Bilateral excyclotorsion visualized on

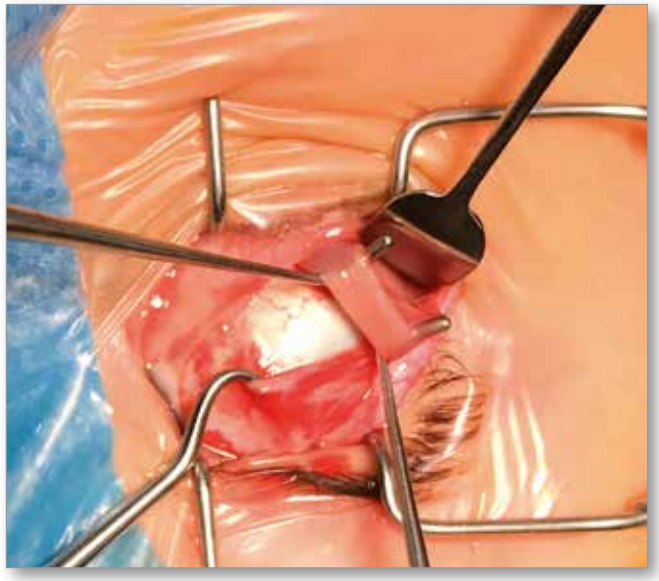

Fig. 3. The inferior oblique muscle isolated during the surgical procedure (authors' own material).

the fundus photograph captured with a fundus camera is shown in Figure 4. Measurement of objective cyclotorsion helps differentiate true from apparent excessive eye elevation in adduction, as the impression of inferior oblique muscle overaction may also occur in cases of mechanically induced strabismus or pulley anomalies. In true inferior oblique muscle dysfunction, excyclotorsion is observed at the fundus of the eye [23–25].

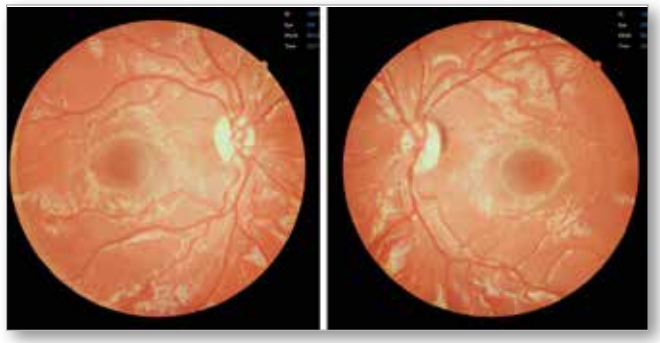

Fig. 4. A fundus photograph showing bilateral excyclotorsion (authors' own material).

Subjective cyclotorsion is assessed using the synoptophore test, the Maddox double rod test, and the Harms screen test. The gold standard in the evaluation of subjective cyclotorsion is the disc-foveal angle measurement.

Possible complications of inferior oblique muscle surgery

Surgery on the oblique muscle carries a risk of complications, which may arise from factors such as inadequate muscle preparation, improper placement of the new attachment, or insufficient care during the procedure. These complications highlight the importance of the operator's precision, experience, and thorough knowledge of the anatomical structures involved. The most common complications include bleeding, transient pupillary dilation, and postoperative limited elevation in adduction.

Bleeding

Bleeding can occur as a result of damage to the perimuscular vessels or the inferior vortex veins, which are located in close

proximity to the inferior oblique muscle. Intraoperative damage to the vortex vein may occur during the isolation of the inferior oblique muscle or while suturing the muscle to the sclera near its insertion point. In rare cases, bleeding during or after the procedure may lead to the formation of a retrobulbar hematoma, a very dangerous and potentially sight-threatening complication that requires immediate intervention [26, 27].

Pupillary dilation

Pupillary dilation may occur after any of the procedures described above [28, 29]. It results from excessive traction on the inferior oblique muscle during the procedure, leading to paralysis of the parasympathetic fibers in the neurovascular bundle, causing partial oculomotor nerve (cranial nerve III) palsy. Most case reports in the literature indicate near-complete regeneration of the pupil within a few months following surgery. However, there are reports of this complication persisting over time [30]. It can be prevented by exercising caution during the isolation and manipulation of the inferior oblique muscle. Postoperative pupillary dilation on the right is shown in Figure 5.

Fig. 5. Postoperative right-sided pupil dilation (authors' own material).

Postoperative anti-elevation syndrome

Postoperative anti-elevation syndrome is another possible complication of inferior oblique muscle surgery. It may arise from excessive anteriorization of the inferior oblique muscle (positioned more than 1 mm anterior to the inferior rectus attachment) or, less commonly, from suturing the inferior oblique muscle near the temporal edge of the inferior rectus attachment [31, 32]. Postoperative anti-elevation syndrome in adduction is shown in Figure 6.

Fig. 6. Postoperative anti-elevation syndrome (authors' own material).

Orbital fat adherence syndrome

Fat adherence syndrome is a rare but serious complication of inferior oblique muscle surgery, first described by Marshall Parks, resulting in restrictive ocular motility disorders [3]. The exact incidence of this phenomenon remains unknown; however, according to Parks, it may occur in approximately 13% of myectomy cases and 2% of inferior oblique disinsertion cases. Orbital fat adherence syndrome has also been reported as a complication following retinal detachment treatment with ocular banding or episcleral sealing [33]. This complication arises from a breach in the posterior part of Tenon's capsule, leading to the prolapse of orbital fat. The prolapsed fat may adhere to the muscle or sclera and subsequently contract, resulting in a restrictive motility disorder. It is characterized by progressive hypotropia of the affected eye, limited elevation (especially in adduction), a forced duction test, and upper eyelid retraction. Differential diagnosis should include the previously mentioned anti-elevation syndrome. Differentiating between these two complications can be challenging due to their shared characteristics. A valuable tool in differential diagnosis is definitely the forced duction test, which tends to be more markedly positive in orbital fat adherence syndrome, whereas in anti-elevation syndrome only slight resistance is observed when moving the eye in the superior temporal direction. Furthermore, orbital fat adherence syndrome is progressive and may develop later than anti-elevation syndrome, which is characterized by an earlier onset of symptoms and a stable, non-progressive deviation. The recommended treatment for this complication involves recession of the inferior oblique muscle combined with surgical revision of the muscle [34]. However, it is important to note that the restrictive motility disorders associated with this condition are difficult to eliminate, and surgical interventions often yield unsatisfactory outcomes [35].

Conclusions

In summary, V-pattern strabismus and dissociated vertical deviation with concurrent overaction of the inferior oblique muscles, along with trochlear nerve palsy, are the primary indications for inferior oblique muscle surgery. Currently, the most commonly used surgical techniques are graded recession and anterior and anterior nasal transposition, while myectomy and disinsertion are becoming increasingly rare procedures, gradually gaining historical significance. Complications of inferior oblique muscle surgery are relatively rare, with the most commonly reported including bleeding, postoperative limitation of eye elevation in adduction, orbital fat adherence, and temporary pupillary dilation. An accurate and detailed diagnostic work-up, including the assessment of objective cyclotorsion, are essential for effective planning of surgical procedures involving the inferior oblique muscles. Furthermore, a thorough understanding of anatomical relationships and caution during the procedure are essential to minimize the risk of intra- and post-operative complications discussed in the article.

References:

1. Akar S, Gökyiğit B, Yılmaz ÖF: *Graded anterior transposition of the inferior oblique muscle for V-pattern strabismus.* J AAPOS. 2012; 16(3); 286–290.
2. Stager D Jr., Dao LM, Felius J: *Uses of the Inferior Oblique Muscle in Strabismus Surgery.* Middle East Afr J Ophthalmol. 2015; 22(3): 292–297.
3. Parks MM: *Inferior oblique weakening procedures*. Int Ophthalmol Clin. 1985; 25: 107–117.
4. Farid MF, Anany M, Abdelshafy M: *Surgical outcomes of three different weakening procedures of inferior oblique muscle in the treatment of unilateral superior oblique palsy.* BMC Ophthalmol. 2020; 20, 20(1): 298.
5. Ghasia FF, Shaikh AG: *Pattern Strabismus: Where Does the Brain's Role End and the Muscle's Begin?* J Ophthalmol. 2013: 301256.
6. Hertle RW; *National Eye Institute Sponsored Classification of Eye Movement Abnormalities and Strabismus Working Group. A next step in naming and classification of eye movement disorders and strabismus.* J AAPOS. 2002; 6(4): 201–202.
7. Ozsoy E, Gunduz A, Ozturk E: *Inferior Oblique Muscle Overaction: Clinical Features and Surgical Management.* J Ophthalmol. 2019; 17: 9713189.
8. Strominger MB, Rogers GL, Wagner RS: *Dissociated vertical deviation and inferior oblique overaction.* J Pediatr Ophthalmol Strabismus. 2009; 46(3): 132–136.
9. Nelson LB: *Anterior transposition of the inferior oblique for dissociated vertical deviation.* J Pediatr Ophthalmol Strabismus. 2007; 44(3):152.
10. Wong CY, Ng JS, Goh TY: *Combined resection and anterior transposition of the inferior oblique muscle for the treatment of moderate to large dissociated vertical deviation associated with inferior oblique muscle overaction.* J Pediatr Ophthalmol Strabismus. 2003; 40(4): 194–195.

11. Pineles SL, Velez G, Velez FG: *Asymmetric inferior oblique anterior transposition for incomitant asymmetric dissociated vertical deviation.* Graefes Arch Clin Exp Ophthalmol. 2013; 251(11): 2639–2642.

12. Toosi SH, von Noorden GK: *Effect of isolated inferior oblique muscle myectomy in the management of superior oblique muscle palsy.* Am J Ophthalmol. 1979; 88(3): 602–608.

13. Aghdam KA, Asadi R, Sanjari MS, et al.: *Comparing Two Inferior Oblique Weakening Procedures: Disinsertion versus Myectomy*. J Ophthalmic Vis Res. 2021; 29, 16(2): 212–218.

14. Mulvihill A, Murphy M, Lee JP: *Disinsertion of the inferior oblique muscle for treatment of superior oblique paresis*. J Pediatr Ophthalmol Strabismus. 2000; 37(5): 279–282.

15. Sokeer SH, Ali AL, Arafa ES, et al.: *Evaluation of graded recession of inferior oblique muscle for correction of different grades of V-pattern strabismus*. BMC Ophthalmol. 2023; 16, 23(1): 462.

16. Muchnick RS, McCullough DH, Strominger MB: *Comparison of anterior transposition and recession of the inferior oblique muscle in unilateral superior oblique paresis*. J AAPOS. 1998; 2(6): 340–343.

17. Gobin MH: *Anteroposion of the inferior oblique muscle in V-esotropia.* Ophthalmologica. 1964; 148: 325–341.

18. Elliott RL, Nankin SJ: *Anterior transposition of the inferior oblique.* J Pediatr Ophthalmol Strabismus. 1981; 18: 35–38.

19. Kushner BJ: *The effect of anterior transposition of the inferior oblique muscle on the palpebral fissure*. Arch Ophthalmol. 2000; 118(11): 1542––1546.

20. Saxena R, Sharma M, Singh D, et al.: *Anterior and nasal transposition of inferior oblique muscle in cases of superior oblique palsy.* J AAPOS. 2017; 21(4): 282–285.

21. Saunte JP, Tobias Torp-Pedersen T, Claes Lønkvist C: *Does it work? the inferior oblique anterior nasal transposition (IOANT) – procedure with short tag noose adjustable sutures in treating 4th nerve palsy with large angle deviation.* J AAPOS. 2019; 23(4): 52.

22. Torp-Pedersen T, Lønkvist C, Saunte JP: *Effect of anterior and nasal transposition of the inferior oblique muscle.* J AAPOS. 2021; 25(4): 70.

23. Cho SY, Lee SY, Lee YC: *Clinical Evaluation of Excyclotorsion in Patients with Primary Inferior Oblique Overaction*. J KOS. 2012; 53.

24. Lee D, Kim WJ, Kim MM: *Comparison of excyclotorsion following graded inferior oblique recession for primary versus secondary inferior oblique overaction.* Int J Ophthalmol. 2020; 18, 13(8): 1281–1286.

25. Sethi A, Dhiman R, Mahalingam K, et al.: *Evaluation of change in objective cyclotorsion after various inferior oblique-weakening procedures*. J AAPOS. 2023; 27(6): 345.

26. Al Thiabi SM: *Unilateral retrobulbar hemorrhage immediately after bilateral strabismus surgery.* Saudi J Ophthalmol. 2019; 33(4): 417–419.

27. Arès C, Superstein R: *Retrobulbar hemorrhage following strabismus surgery.* J AAPOS. 2006; 10(6): 594–595.

28. Bladen JC, Moosajee M, Angunawela R, et al.: *Transient internal ophthalmoplegia after inferior oblique myectomy.* J AAPOS. 2009; 13(6): 596–597.

29. Stevanovic M, Barry GP: *Transient internal ophthalmoplegia with anisocoria and loss of accommodation after inferior oblique recession in a 5-year-old.* Can J Ophthalmol. 2021; 56(2): 55–56.

30. Kim WJ, Kim MM: *Permanent tonic pupil following inferior oblique myectomy.* J AAPOS. 2015; 19(2): 193–194.

31. Kushner BJ: *Restriction of elevation in abduction after inferior oblique anteriorization.* J AAPOS. 1997; 1(1): 55–62.

32. Mims JL, Wood RC: *Antielevation syndrome after bilateral anterior transposition of the inferior oblique muscles: incidence and prevention.* J AAPOS. 1999; 3: 333–336.

33. Wright KW: *The fat adherence syndrome and strabismus after retina surgery.* Ophthalmology. 1986; 93(3): 411–415.

34. Merino P, Blanco I, Liaño PG: *Fat adherence syndrome following inferior oblique surgery: Treatment and outcomes*. J Optom. 2016; 9(4): 240–245.

35. Burton B, Dawson E, Lee J: *Adherence syndrome following inferior oblique surgery: management and outcome of 14 cases*. Strabismus. 2004; 12(3): 169–174.

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