

# Minimal Invasive Procedures in Strabismus Surgery: A Narrative Review

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## Abstract

**Purpose:** To review the principles and different techniques of minimally invasive procedures in strabismus surgery.

**Methods:** This is a narrative review on minimally invasive procedures in strabismus surgery including general aspects and different new modifications on conventional strabismus surgery. We reviewed 24 articles published between 1993 and 2020.

**Results:** Minimal invasive procedures could be categorized into two subsets: one which minimizes conjunctival opening size and another which minimizes the muscle manipulations. Different conjunctival approaches have been introduced, such as Cul-de-sac and minimally invasive strabismus surgery incisions. Furthermore, there are different techniques for extraocular muscle weakening, strengthening, and transposition, such as mini-tenotomy, plication, mini-plication, Nishida, and modified Nishida procedures. Moreover, there are some techniques for handling strabismus in heavy eyes with high myopia and using adjustable sutures for strabismus correction.

**Conclusions:** Minimally invasive procedures in strabismus surgery consist of surgical procedures that minimize tissue disruption, speed up rehabilitation, and often ultimate better outcomes. These techniques could be replaced traditional methods to reduce conjunctival and lid swelling in the direct postoperative period.

**Keywords:** Conjunctival incisions, Minimally invasive strabismus surgery, Ophthalmology, Strabismus

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## INTRODUCTION

The history of minimal access surgery is ancient and can be traced back as long as 5000 years ago, when Babylonians and the Egyptians developed small copper knives around 3000 BC.<sup>1</sup> In 1981, Kurt Semm performed a laparoscopic appendectomy for the first time.<sup>2</sup> Minimally invasive surgery (MIS) has gained widespread acceptance, and in every surgical subspecialty, some kinds of minimal invasiveness have been applied.<sup>3</sup> The two main features of MIS are safety and lower postoperative patient morbidity. MIS significantly reduces postoperative pain, recovery time, and hospital stays and markedly improves cosmetic outcomes and overall cost-effectiveness.<sup>4</sup> MIS reduces tissue traumatism, postoperative patient discomfort,

hospital stays, and working disability.<sup>5</sup> It should be kept in mind that two significant shortcomings of MIS are steeper learning curves for most surgeons and increased costs due to investment in the equipment required and, for some techniques, the use of disposable instruments.<sup>3</sup>

In ophthalmology, many minimal techniques have been developed. One of its most famous procedures is phacoemulsification for the surgery of cataracts.<sup>6</sup> The incisions are smaller than a conventional approach and usually suture less with minimal tissue dissection and disruption. The patient has a rapid recovery. However, phacoemulsification depends on the availability of phacoemulsification machines and microsurgical instruments and shows a steeper learning

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curve for trainees. Another example in the field of oculoplastic surgery is endoscopic modifications for facial lifting.

MIS in the strabismus field has been developed to reduce the conjunctival congestion and chemosis, perimuscular tissue scarring and damage, and preservation of perilimbal episcleral vessels.<sup>7</sup> We prepared the current article to review available MIS techniques in the strabismus field.

## METHODS

We reviewed the current literature and found articles relevant to our discussion to write this narrative review.

## RESULTS

We found 24 relevant articles to our subject in the electronic database of PubMed, which were released from 1993 to 2020, with using keywords including (minimal invasive strabismus surgery), (plication), (mini plication), (heavy eye), and (MISS).

Newer approaches have been evolved in strabismus surgery into minimalizations. They can be reviewed in two aspects. In Part A, we review the evolution of new techniques for decreasing incision size, and in Part B, we review newer minimal surgical procedures.

### A. Conjunctival incision size

In the field of strabismus, for approaching extraocular muscles, there is a need for conjunctival incisions. Traditionally, many surgeons use a limbal incision [Figure 1a]. This incision is the easiest to perform for nearly all strabismus surgeries and gives the best exposure to rectus muscles.<sup>8</sup> Furthermore, it is a beneficial method in restrictive strabismus cases that needs conjunctival recession, and when there is conjunctival scarring. The disadvantages of this incision are that, dependent on surgical types, one or more quadrants adjacent to the limbus are dissected, so protracted postoperative redness, discomfort, and reactive ptosis are common. Furthermore, sometimes edematous tenon's capsule tissue may protrude over the cornea, inducing severe corneal complications such as dellen and ulcer.

Another aspect of the localization of the conjunctival incisions is the importance of the limbus. Corneal epithelium integrity and transparency depend on the limbal epithelial stem cell population located in the basal cell compartment of the

limbus.<sup>9</sup> These perilimbal episcleral vessels and stem cells are prone to surgical damage, as we saw in intra and extracapsular cataract extraction cases, and may be permanently traumatized after surgery.<sup>9</sup> So, approaches to locate the conjunctival incisions away from the limbus have been developed to prevent limbus damage. Furthermore, avoiding a limbal opening will decrease postoperative visibility of the surgical procedure, patient discomfort, and working disability.

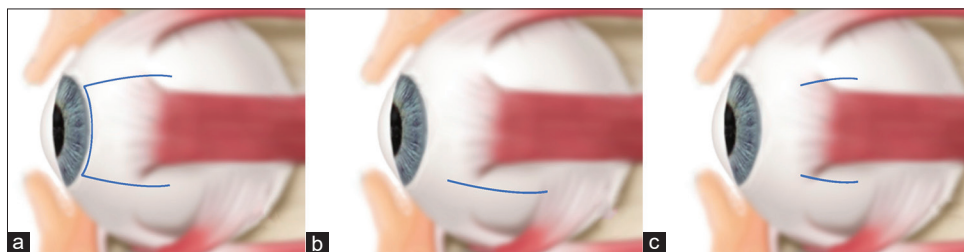
### *Cul-de-sac incision*

In order to hide the incisions behind the eyelids, parks introduced the Cul-de-sac incision [Figure 1b]. With this type of incision, the patient will experience a more comfortable postoperative period. Nevertheless, it has some limitations. It is difficult to perform in inelastic conjunctiva, in older patients or with thyroid disease, when there is a lot of tenon's tissue (young children), and in repeated surgeries because visualization of scars is difficult.<sup>8</sup>

### *Minimally invasive strabismus surgery*

A newer approach to conventional strabismus surgery has been developed to reduce the incision size and place them far from the limbus to decrease postoperative complications. For the first time, Gobin and Bierlaagh described two small radial openings next to the rectus muscle insertions without providing data about patients operated with such a technique [Figure 1c].<sup>10</sup> Mojon started in 2003 refining this technique and introduced the term minimally invasive strabismus surgery (MISS) for a muscle approach through small, parainsertional conjunctival openings in 2007.<sup>11</sup> The primary goals of MISS are reducing the conjunctival opening size and tissue disruption, and placing openings as far away from the limbus as possible to minimize postoperative discomfort.<sup>12</sup> It has been shown that the patient's recovery is faster because the discomfort during the postoperative period is reduced, conjunctival swelling is minimized, visibility of surgery is reduced, and corneal complications can be entirely avoided. The location of MISS incisions enables the patient to wear a contact lens earlier.<sup>13</sup>

Suitable instruments are necessary for all types of minimal eye surgeries. For MISS, microscope use is advised because of the advantages of coaxial illumination and better magnification than loupes. MISS has been developed and performed for all types of strabismus surgery, including rectus muscle transposition (RMT), rectus muscle repeat surgery, oblique muscle recessions, and adjustable sutures.<sup>14</sup>



**Figure 1:** Three types of conjunctiva incisions. (a) Limbal incision, (b) Cul-de-sac incision, (c) Minimally invasive strabismus surgery incision. The blue lines shows the place of incisions.

## B. Minimal invasive procedures

### Weakening procedures

The standard rectus muscle weakening procedure is muscle recession. A minimally invasive surgical procedure, named mini-tenotomy, was developed by Kenneth W. Wright in 2009 for treating small angle horizontal or vertical deviation [Figure 2]. This procedure is usually considered for the treatment of vertical deviations of <6 prism diopter (PD), and horizontal deviations of <16 PD. It can be performed under topical anesthesia and, sometimes, in an office setting, a central 3–4 mm tenotomy releases approximately one-third of the insertion through the conjunctiva.<sup>15</sup> Using MISS, the procedure is performed using two paraincisional openings.<sup>12</sup>

### Strengthening: plication and mini-plication

One of the most historical strengthening procedures in strabismus is muscle resection. It requires disinsertion and clamping of the muscle and permanently disrupts the anterior ciliary blood supply. Also, especially in the medial rectus, there is a risk of losing the muscle.<sup>16</sup>

Plication is considered an alternative for strengthening the horizontal rectus muscles. In plication, the muscle is not cut, and the surgical trauma is decreased, so it minimizes postoperative discomfort and inflammation. This procedure can be performed by small incisions that improve the postoperative cosmetic outcome. MISS performs a plication similarly to a recession using two small, paraincisional openings, as described by Mojon.<sup>12</sup> Less perimuscular soft tissue inflammation and distortion, makes it an option in conditions with more chance of inflammation, such as thyroid ophthalmopathy.<sup>17</sup> In a systematic review and meta-analysis that compared plication with standard resection, plication showed to be an alternative to resection in strabismus surgery, with similar results.<sup>18</sup>

Another minimally invasive procedure is the mini-plication described by Wright and Thompson [Figure 3]. It can be used

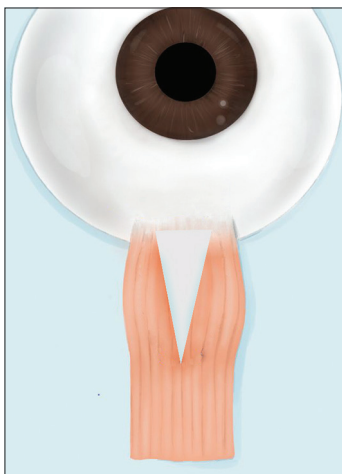
for small-angle deviations in the range of 8–10 PD, which are too small angles for traditional surgery.<sup>16</sup> The approximate dose–response of the procedure is  $5\Delta$ – $7\Delta$  correction in patients without previous surgery and those with a recession of the antagonist the effect size is nearly  $9\Delta$ .<sup>19</sup> It has all the advantages of plication. Compared with plication or resection, the risk of overcorrections is reduced, and mini plication can be used progressively with mini tenotomy to eliminate the diplopia in patients with annoying diplopia.<sup>20</sup>

### Minimal invasive transposition procedures

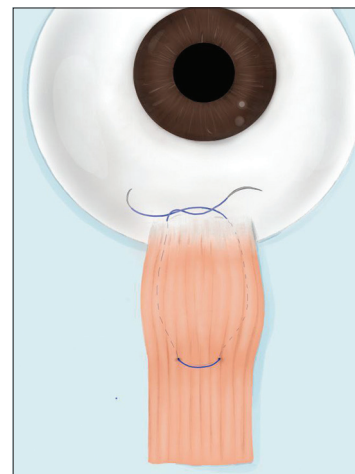
When a rectus muscle has complete nerve palsy, such as complete sixth nerve palsy, a standard recession/resection surgery cannot be applied, and there is a need for a RMT procedure. Over the past several decades, many techniques and modifications for RMT have been proposed. In classic RMT, the whole or half of two adjacent muscle tendons are transferred to the affected rectus muscle insertion.<sup>21</sup> RMT surgery can be performed with simultaneous chemodeneration or recession of the antagonist medial rectus muscle.<sup>22</sup> MISS also allows performing RMT.

In 2003, for the first time, Nishida *et al.* reported a new muscle transposition procedure for complete abducens palsy in which only the vertical muscle halves after splitting were secured with anchoring sutures to the sclera instead of vertical muscle tenotomy as in the conventional Hummelsheim's procedure.<sup>23</sup> In 2005, they simplified their previous approach to reduce operative damage further and developed a second new procedure without tenotomy or muscle splitting. In three patients, they anchored only the temporal muscle margins to the sclera by 6-0 polypropylene sutures without any tenotomy or muscle splitting.<sup>24</sup> In 2013, Muraki *et al.* reported the postoperative results of this second new muscle transposition procedure on nine patients with complete sixth nerve palsy.<sup>25</sup>

In Nishida's procedure, there is no need for tenotomy and splitting the vertical muscles. Just the temporal one-third of the vertical recti, 10 mm behind their insertion, are secured onto the



**Figure 2:** Central tenotomy procedure. The blue line represent the site of suturing.



**Figure 3:** Central plication procedure. The blue triangle represent the site of tenotomy.

supratemporal or infratemporal sclera, 12 mm behind limbus. It involves making radial conjunctival incision in superotemporal and inferotemporal quadrants, and it could be done with Cul-de-sac or MISS incisions.<sup>26</sup> The surgical correction by muscle transposition alone ranges from 24 to 36 PD, and that by muscle transposition and recession of the medial rectus muscle increases up to 62 PD. The most important feature of this procedure compared with the other procedures is that this technique is surgically more straightforward and minimal, with less damage to the ocular fascia.<sup>25,26</sup> This modification of vertical rectus transposition (belly transposition) has been applied for different types of paralytic strabismus. Kiarudi *et al.* reported a case of unilateral hypoplastic medial rectus in a 37-year-old male with large angle exotropia and complete adduction limitation treated by a modification of the Nishida technique, in which the vector of superior and inferior recti was transposed medially by inserting nonabsorbable sutures at nasal margins of muscles secured to sclera 8 mm posterior to medial rectus site without any tenotomy or splitting. The deviation was decreased to <10 PD exotropia in the primary position. The adduction was improved from -6 to -4.<sup>27</sup> In another report, Murthy and Pappuru, used Modified Nishida's procedure in three cases of monocular elevation deficiency (MED) and transposed the horizontal rectus forces superiorly. The correction obtained with modified Nishida's procedure in MED is 30Δ and increases up to 40Δ in conjunction with inferior rectus recession.<sup>28</sup>

### Procedures for heavy eye

Strabismus associated with high myopia is a particular form of strabismus characterized by progressive acquired esotropia and hypotropia in patients with pathologic myopia. The extreme form of this ocular motility disorder is called "myopic strabismus fixus". With the aid of high-resolution quasi-coronal magnetic resonance imaging, it is proposed that the pathogenesis is a supratemporal protrusion of the elongated myopic globe through the muscle cone, displacing superior and lateral rectus muscles.<sup>29</sup> Yamaguchi *et al.*, for the first time, proposed a minimal strabismus surgery of uniting muscle bellies of the superior rectus and lateral rectus muscles (suture loop myopexy) to restore the dislocated globe into the muscle cone with a favorable outcome compared with traditional horizontal rectus muscle surgery.<sup>30</sup> In this procedure, medial rectus recession is performed when the forced duction test shows severe contracture of the medial rectus or when loop myopexy is difficult to perform due to this restriction. In the classic technique, muscle union is performed by one nonabsorbable suture passing about 14 mm posterior to the insertion of both muscles. However, adding 2 extra sutures 2 mm anterior and posterior to the first suture has shown to be more effective.<sup>31</sup> Although some surgeons have secured myopexy sutures to the sclera, no significant difference in the outcome of scleral fixation group and nonscleral fixation group has been shown.<sup>32</sup> Now, most surgeons prefer a surgical technical without sclera fixations.<sup>33</sup> Avoiding the scleral suture is an advantage, especially for high myopic eyes with scleral

thinning. Yokoyama-based procedures concomitant with medial rectus recession can be corrected up to 85Δ of esotropia.<sup>29</sup>

## DISCUSSION

Reviewing the abovementioned procedures, we can consider the advantages of MISS as reducing the conjunctival congestion and chemosis, decreasing perimuscular tissue scarring, and preserving perilimbal episcleral vessels. On the other hand, these techniques may be challenging, and the surgery time becomes longer, especially for unfamiliar surgeons. Also, we face a lack of evidence in this field.

In conclusion, like any field of surgery, there has been a progression to minimalization in strabismus surgery. These evolutions can be evaluated in two aspects. On one side, there have been new approaches and techniques for decreasing conjunctival incision size; on another side, newer, less invasive, and minimal surgical procedures have been introduced. These efforts minimize tissue disruption and dissection, and lessen patient recovery time without compromising the outcome.

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### Conflicts of interest

There are no conflicts of interest.

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