International Journal of Multiphysics
Volume 18, No. 3, 2024
ISSN: 1750-9548

An Overview on Refractive Accommodative Esotropia

Ahmed A. Elsharkawy, Emad M. ElHady, Yasmine A. Diaaeldien, Manar A. Ghali

Ophthalmology Department, Faculty of Medicine - Zagazig University, Zagazig, Egypt

Corresponding author: Ahmed Abdalla Hassen Elsharkawy

Email: aah_209@yahoo.com

Abstract:

Accommodative esotropia (ET) is the most common form of childhood ET. The prevalence of accommodative ET has been estimated to be 1%–2% in the Western population. The convergent misalignment of visual axes has been attributed to hyperopia associated with an abnormal fusional divergence. Accommodative ET initially presents as intermittent esodeviation between 1½ and 4 years of age. It has a favorable prognosis if appropriate treatment is initiated early. Optical correction of hypermetropia is usually successful in reestablishing ocular alignment. There has always been a concern regarding striking a balance between achieving bifoveal fixation and avoiding interference with emmetropization by prescribing full hypermetropic refractive correction when treating accommodative ET in young children. The management of accommodative ET includes (1) identifying risk factors for the development of accommodative ET, (2) providing optimal refractive correction without interfering with the process of emmetropization, and (3) weaning of glasses when possible.

Keywords: Refractive, Accommodative Esotropia, **Fenestration.**

Introduction:

Strabismus, colloquially known as "crossed eyes" is a visual disorder characterized by the misalignment of the eyes. This misalignment prevents both eyes from focusing on the same point simultaneously, leading to impaired binocular vision and depth perception. Strabismus can present in various forms, including esotropia (inward deviation), exotropia (outward deviation), hypertropia (upward deviation), and hypotropia (downward deviation). **(1)**

The onset of strabismus can occur at any age, but it typically emerges in early childhood. It may arise from abnormalities in the muscles that control eye movement, disruptions in the nerve pathways responsible for coordinating eye movements, or refractive errors such as nearsightedness or farsightedness. Left untreated, unilateral strabismus can result in amblyopia (lazy eye), wherein the brain suppresses input from the misaligned eye, potentially causing permanent vision impairment. **(2-4)**

Accommodative esotropia

Accommodative esotropia is a convergent strabismus caused by stimulation of the accommodation reflex. It is the most common eye deviation in the pediatric age group accounting for 50% of all esotropia cases. It is divided into 3 different types:

- Refractive.
- Non-refractive.
- Partially Accommodative. **(2)**

All types are sharing some features as:

- They affect children with ages ranging from 6 months to 7 years with average age of 2.5 years.
- They begin as an intermittent deviation precipitated by trauma or illness and become constant later.
- May be inherited
- Sometimes, they are accompanied by amblyopia or even diplopia in older children. **(2)**

I. Refractive Accommodative Esotropia

It is caused by interaction between different factors as uncorrected hyperopia, poor fusional divergence and accommodative convergence. To achieve a clear retinal image, accommodative reflex leads to convergence specially when there is small amplitude of fusional divergence. Anisometropia can induce more convergence despite the low level of hyperopia. **(3)**

Clinical picture:

Refractive esotropia starts as an intermittent strabismus with near activities or with fatigue. Then, it becomes a constant deviation and this may be the starting point of developing amblyopia. Younger children may show increased eye rubbing while older ones may complain of asthenopia in the form of headaches or diplopia. Once suppression occurs, these complains disappear. The causative hyperopia of refractive esotropia is axial in nature and ranges from +1.5 Diopter (D) to 10 D or even more with average of +4.75 D. **(4)**

Accurate cycloplegic refraction is necessary for measuring hyperopia in young children. Cyclopentolate is the most common used eye drops to measure refractive error in children with atropine which has longer action and more potent cycloplegic effect specially in dark irides. The range of esotropia is usually between 15 and 45 prism diopters (PD) **(5).**

Treatment of refractive accommodative esotropia:

(1) Optical correction of the hyperopic error:

Several studies have shown increasing hyperopic error before appearance of esotropia. The full cycloplegic correction is the cornerstone of treatment. After prescribing the glasses, the hyperopia changes slowly in those children. It has been noticed that children become significantly less hyperopic after the age of 7 or 8 years **(6).**

The glasses should start as early as possible as delay in correcting hyperopia would result in loss of fusion ability, loss of stereopsis and development of amblyopia **(7).**

The glasses should be prescribed as continuous measure because intermittent use of glasses may cause insufficient relaxation of accommodation that causes blurring of vision. Also, after starting to use glasses, the angle of esotropia usually increases when the child takes off his glasses. This happens as the child gets used to exercising less accommodative effort **(8).**

The children are checked again after 1 to 2 months. Effective treatment involves adjusting their vision for both near and far distances within 8 to 10 prism diopters (PD), which is referred to as the monofixation range. When this is achieved, the patient is able to fuse images well and experiences a disappearance of symptoms related to eye strain.

If the distance esotropia remains high, another cycloplegic refraction should be conducted. If a significant deviation is still present at a distance, the patient may have a partially accommodative esotropia and surgery might be necessary. If the distance deviation is corrected but esotropia for near vision persists, the patient could have high accommodative convergence (AC:A) ratio esotropia **(9).**

We start to reduce numbers of diopters in glasses after the age of 9 or 10 years as the child can use fusional divergence to function without glasses. This is done by subtracting 0.5 or 0.75 D every 12 months.

Most ophthalmologists do not reduce the correction till the patient is old enough to prevent the occurrence of small angle esotropia which may affect fusion and cause amblyopia **(10).**

Reaching good binocular vision and stereoacuity relies on the age at which binocular disruption occurred, as well as the duration or intermittency of this disruption. Most children with refractive esotropia achieve good binocularity and stereoacuity but in most occasions it is not of high grades. Maturation of binocularity starts as early as 8-18 months and continues until 36 months of age. Although refractive esotropia presents later than this period, up to 75% of patients with refractive esotropia have subnormal binocularity **(11).**

Long-term alignment stability is associated with early optical and surgical correction of eye deviation and patients who lacked stereopsis also had a 17 times higher risk of requiring surgical correction of their esotropia **(12).**

In Ireland, **Mulvihill et al. (13)** studied refractive esotropia on 103 children over a 4.5 years follow-up period. At presentation, 61% were amblyopic in one eye, but at the end of the study this decreased to only 15% and 89% of children had stereopsis**.**

Fifty nine percent of children studied by **Berk et al. (14)** had amblyopia at presentation. After 5 years of follow up, 23% of them still had visual acuity of 6/12 or worse in the weaker eye. Although 73% of them achieved fusion ability, only 24% achieved higher grade stereoacuity ranging between 40 and 100 sec/arc. The likelihood of achieving better fusion ability was higher in children who developed esotropia at a later age (> 2 years)**.**

The possibility of weaning children off the spectacles is more uncertain, with variable results in different studies.

Lambert et al. (15) found that 60% of children who had fully accommodative esotropia and hyperopic errors of +1.50 to +5.00 D were weaned off spectacles starting at age of 8 years as a mean. Hyperopia of < 3D was associated with higher success rates**.**

According to **Mohney et al. (16)** the rate of glasses discontinuation in children with all types of accommodative esotropia after 5 years was 8%, after 10 years was 20%, and 37% after 20 years. It seemed that most children require glasses correction even after the second decade. Prematurity and greater hyperopic refractive errors are associated with lower likelihood of spectacle weaning off.

(2) Refractive surgery:

The first case who had photorefractive keratectomy (PRK) for accommodative esotropia was 19-year-old with refractive esotropia and was reported by Bilgihan in 1997 **(17).**

Since then, many studies have reported the effectiveness of refractive surgery as PRK and laser in situ keratomileusis (LASIK) for correction of hyperopia in refractive esotropia **(18).**

The role of refractive surgery is limited because refractive errors are generally not stable in this age group and the upper limits of these procedures to correct hyperopia are smaller than the high hyperopia associated with refractive esotropia.

Hutchinson et al. studied this type of treatment and in most cases, the desired correction was within 0.5 D of cycloplegic hyperopic error of refraction. Most cases achieved good alignment within 10 PD of orthophoria with only the refractive surgery. However, like all corneal refractive surgeries, there is always a risk of complications, including corneal haze in PRK, and corneal striae, diminution of vision, and diffuse lamellar keratitis for LASIK cases **(19).**

II. Non-Refractive Accommodative Esotropia

In this type of esotropia, the angle of squint is larger in near than in distance because of the abnormal high accommodative convergence (AC:A) ratio. The angle at near is larger as accommodation occurs at near distance. So, the accommodative effort results in abnormal high convergence at near and this is known as abnormal high AC:A ratio. **(20)**

Clinical picture:

The age of onset of high AC:A ratio esotropia is between the age of 2 and 3 years. A normal AC:A ratio is from 3 to 5 PD: 1 D. The refractive error in these cases may be hyperopia or myopia and sometimes it occurs in emmetropic patients. We should measure the angle for near with accommodative fixation targets to elicit the full angle of esotropia. We can measure AC:A ratio with several methods as Heterophoria and gradient methods beside measuring the near and distant deviation. **(20)**

Gradient Method at 33 cm:

Conduct prism cover test (PCT) at near, with the patient wearing the necessary refractive correction.

Perform PCT at near with the patient wearing the necessary refractive correction, and with an additional +3.00 DS convex lens.

$$\text{Calculate AC: A Ratio} = \frac{(\mathbf{A}-\mathbf{B})}{\mathbf{3}}$$

Heterophoria Method:

$$\text{AC: A Ratio} = \text{Interpupillary Distance (cm)} + \frac{(\text{Near PCT PD} - \text{Distance PCT PD})}{3}$$

(20, 21).

Treatment of non-refractive accommodative esotropia:

There is no agreement on the best treatment modality for high AC:A ratio esotropia, but some of the options available:

(1) Observation:

As children with excessive esotropia when focusing on nearby objects tend to show improvement as they grow older, numerous eye specialists opt to monitor the condition without taking any immediate action. Nevertheless, existing research has not proven the sustained advantages of monitoring as opposed to undergoing surgery or using bifocals. Studies indicate that utilizing bifocals can enhance the ease of combining images from both eyes for close-up vision, yet they do not guarantee flawless fusion and depth perception. **(22)**

(2) Bifocal glasses:

The most common treatment option for non-refractive accommodative esotropia is bifocal glasses. Bifocals are used to relax accommodation at near and enhance near fusion, thus correcting the near esotropia **(23).**

It is common practice to give the smallest hyperopic bifocal correction to the patients to achieve alignment at near. Reducing the amount of near add to make esophoria of about 4 to 6 prism diopters enhances fusional divergence, but also is efficient in providing binocular fusion. The most common type of bifocals prescribed are the “executive-type” flat-top style bisecting the pupil in primary position. First, we prescribe the distance refractive correction then we give +2.50 D to +3.00 D add or the initial bifocal power may be estimated according

to the near esodeviation. Bifocals are prescribed on full-time basis. The child is seen after 1 month, and the esotropia at near improves on bifocal prescription in most cases. Gradually, the power of bifocals can be reduced to increase the amplitude of divergence. **(24)**

(3) Miotic agents:

The use of miotics is an old way of treatment that is rarely used nowadays. Miotic agents like ecothiopate iodide 0.125% are used in children less than 1 year old, as they may be non-compliant with glasses due to their poor cooperation, their flat nasal bridge, and the difficult spectacle fitting. Ophthalmologists generally prefer to prescribe bifocals to give miotics as miotic agents have several side effects although miotics are equal in effectiveness to optical correction with bifocals. Miotics affects the ciliary muscle by its parasympathomimetic action, thus decreasing the effort of accommodation required to achieve a clear retinal image. Consequently, the convergence reflex also reduces. (**25)**

According to **Park et al. (8)** using miotics puts the AC:A ratio into normal, but with discontinuation the AC:A ratio increases. They have many side effects including pupil margin cysts. In older patients, drawbacks may include brow ache and spasm of pupil sphincter. At these doses in children, no cases of angle-closure glaucoma or retinal detachment have been discovered. Sometimes, significant systemic side effects give rise to gastrointestinal disturbance, nausea, and headaches. Besides, echothiophate eliminates pseudocholinesterase from the blood, rendering the patient prone to depolarizing muscle relaxants such as succinylcholine, which would aggravate respiratory paralysis during reversal of anesthesia. In those patients, using non-depolarizing muscle relaxants is advised during general anaesthesia.

(4) Surgery of non-refractive accommodative esotropia:

There is controversy about the surgical option in treatment of non-refractive esotropia. The main aim of surgery is to correct esotropia and normalize the high AC:A ratio beside cessation of using bifocals **(26).**

There are two main types of operations commonly done in high AC:A ratio form of accommodative esotropia. O'Hara and Calhoun operated for the full esotropia angle at near. Although some children had small esodeviation at distance and developed exotropia, most of patients had good alignment at near **(22).**

Another technique entails making Faden or a posterior fixation procedure, in the treatment of non-refractive esotropia **(27)**

The amount of medial rectus recession depends on the angle of esotropia at distance instead of the angle at near, but the Faden procedure further corrects the abnormal higher esodeviation at near. This augmented surgical technique, targeting the angle at near, was more successful in terms of esotropia reduction and discontinuation of using bifocals **(28).**

Sometimes, a posterior pulley fixation is used instead of Faden suture as it does not require making scleral sutures and so, it has a lower risk of scleral perforation **(29).**

III. Partially Refractive Accommodative Esotropia (PRAET)

Partially accommodative esotropia is an acquired strabismus characterized by high hyperopia, a normal AC/A ratio, and a deviation that responds only partially to spectacle correction. Surgery is done for the non-accommodative portion of the deviation. Partially accommodative esotropia may also refer to an esotropia that was initially fully accommodative, but subsequently decompensated over time **(16).**

Treatment of partially refractive accommodative esotropia:

The initial treatment of partially accommodative esotropia is correction of the full hyperopic error.

After a period of 4 to 6 weeks during which the full hyperopic error is corrected, surgical intervention is recommended if the remaining esotropia exceeds 10 prism diopters (PD) for both near and far vision. There are differing opinions among surgeons regarding the threshold for surgical correction. Some surgeons opt for surgery to correct any angle below 10 PD, as this promotes the development of monofixation syndrome, leading to improved functional outcomes through peripheral fusion. Monofixation syndrome is believed to enhance motor fusional vergence, thereby maintaining proper alignment over a longer period. However, other ophthalmologists argue that surgery should only be considered for the non-accommodative component if it causes noticeable cosmetic concerns, as these patients may not derive additional benefits from peripheral fusion. Parents should be informed that surgical correction does not entirely replace the need for wearing glasses. However, it does facilitate fusion when glasses are worn. **(16)**.

Prism adaptation:

There is a method that prescribes base-out prisms for residual esotropia after full correction of the hyperopic error. After two weeks, the patient is examined again and if the deviation has increased, a larger prism is given. This process continues at 1- to 2-weekly intervals until the angle of deviation has been stable. The surgery then is done on the full "prism-adapted" angle. This method was studied in large multicenter research (The Prism Adaptation trial) and showed that standard surgery resulted in a success rate of 75% compared to 85% with the prism-adapted angle method. The disadvantage of this method is being more costly and requiring much more time **(30).**

Surgical treatment of partially refractive accommodative esotropia:

Many surgical approaches were described for treating patients with partially accommodative esotropia which includes:

- Unilateral Medial Rectus (MR) muscle recession
- Bilateral symmetric MR muscles recessions
- Bilateral Scleral Posterior Fixation Sutures, sometimes with MR Recession
- Bilateral Pulley Fixation Sutures with MR Recession
- Bilateral Symmetric Slanted Recession of the MR Muscles
- Bilateral Combined Resection and Recession of the MR Muscle (**31).**
- Bilateral symmetric MR muscle fenestration

The determination of the surgical approach used in patients with partially accommodative esotropia relies on the residual angle observed after full hyperopic correction, specifically for distance vision. In cases where the near deviation exceeds the distance deviation, particularly in situations with a high AC:A ratio, the near angle of deviation is considered. However, this particular technique has a relatively high rate of under-correction, approximately 25%.

Chun et al. (32) in their study on patients with partially accommodative esotropia, employed a different approach. They used a target angle based on the average between the near angle with optical correction and the near angle without optical correction. When comparing the augmented surgical technique to the standard surgery, they found that 93% and 74% of patients, respectively, achieved successful reduction to less than 10 PD. Patients

with a high AC:A ratio at the beginning of the study had a higher likelihood of being overcorrected for distance, resulting in intermittent distance exotropia. However, their alignment for near vision was maintained. This was because the correction depended solely on the angle for near vision.

In cases involving a high AC:A ratio, a modification of the procedure is implemented. This modification utilizes the average between the near deviation without optical correction (i.e., the largest deviation) and the distance deviation without optical correction (i.e., the smallest deviation). This approach enables a smaller angle of correction compared to what would have been achieved with the augmented surgical formula. **(33)**

Medial rectus muscle weakening Techniques

Standard recession technique:

The classic technique for recession of the rectus muscle is the same for all four rectus muscles. The rectus muscles may be accessed using either a limbal or a forniceal approach. Each surgeon chooses the surgical approach depending mainly on his preference. Recurrent cases operations and surgeries on patients with a thin or friable conjunctiva are often operated through a limbus incision, as this approach requires minimal stretching of the conjunctiva and reducing the risk of tearing of the conjunctiva, a drawback which may make the closure of the conjunctiva more challenging **(34).**

The medial rectus muscle, on contrast to the other recti, does not attach directly to any of the oblique muscles. If the medial rectus muscle is lost during surgery, it is more difficult to regain. So, much dissection of the intermuscular septum and rectus muscle capsule is not encouraged. In addition to be unnecessary, it may alter the muscle pulleys and make the risk of iatrogenic muscle trauma during surgery more possible **(35).**

After isolation of the rectus muscle on a muscle hook, a suture is put in the muscle fibers near its attachment to the sclera. This suture should not generally be put nearer than 1 mm from the muscle's attachment to the sclera. A single double-armed suture made from polyglactin is used. A suture pass is commenced at the midpoint of the muscle and put at half thickness through the muscle fibers. This is called the transverse pass. The needle is manipulated to exit at the rectus muscle border. The needle is then passed in the other direction starting in the midpoint of the muscle and that the transverse pass crosses the entire width of the muscle posterior to its attachment site. The small space between the sclera and the suture makes a negligible effect of resection after surgery. **(36)**

After making of the transverse suture pass, locking suture passes are performed at the muscle borders near the scleral attachment. These locking suture passes should involve at least 1 mm of muscle fibers to make a secure muscle-suture union. The sutures should not be passed through the anterior ciliary arteries, as this may cause inadvertent bleeding. It is often advised to pass the sutures around these arteries to ligate them and avoid bleeding when the muscle is later cut from the sclera. We should take care to pass the needle directly through the bulk of the muscle. After passing the suture full thickness through the muscle, a locking bite is created by passing the needle holder through the suture loop. It is advisable to pull on the suture rather than the needle to avoid causing damage to the needle. **(35).**

The muscle sutures are put between two fingers. If the surgeon holds the muscle hook in his hand and is able to grasp the sutures with his fingers independently of the hook, he will create more space between the muscle insertion and the sutures, making detachment of the muscle easier and reducing the risk of damaging the muscle sutures.

Locking forceps are put on the periphery of the muscle insertion stump after the muscle has been cut from the sclera. A caliper is used to measure the distance of the desired entrance site for the next needle pass where the new attachment site of the muscle will be placed starting either from limbus or the original attachment site of the muscle. **(37)**

The relationship between the muscle attachment site and the limbus has been found to be different in children before the full development of the anterior segment. It was found that posterior migration of the muscle tendon from the site of the limbus with growth of the anterior segment of the eye makes the rectus muscle insertions to reach their adult site approximately between the age of 1- 2 years **(38).**

A caliper is used to make a scleral mark by indentation at the new site of muscle insertion. This method displaces fluid from the sclera and make the visualization of the underlying choroid easier, resulting in a blue spot on the sclera. The surgeon should take care not to make a firm pressure with the caliper. The scleral mark for both needle passes can be made simultaneously. However, the second mark sometimes becomes very faint by the time the surgeon is about to pass the second suture. It is also possible that the tips of the caliper soaked in ink from a sterile gentian violet skin-marking pen to make a persistent mark on the sclera. The sutures are then put into the sclera at the desired marked sites. The needle pass should be a minimum of 2 mm in length and 200 μm. in depth in the sclera. Longer scleral bites are sometimes encouraged by many surgeons, but the 2 mm long needle passes are enough to make a secure attachment of the muscle to the sclera. The two scleral passes are performed to make what is called "crossed swords" to allow the sutures to be near to each other without the second needle pass destroying the first passed suture. **(37)**

To avoid cheese wiring of the sclera, the sutures are preferably pulled in their direction of pass through the sclera. The muscle becomes attached in its new insertion site by maintaining traction in the anterior direction and the sutures are then tied and cut after making a knot. If the needle passes are too near to each other, the central part of the muscle may sag back. To overcome this, the needle is passed back through the central part of the muscle and posterior to the previous sutures, before cutting the muscle sutures. The sutures are then tied to exert traction on the muscle up to its desired insertion site. **(39)**

Figure (1): Hooking of the rectus muscle **(39)**

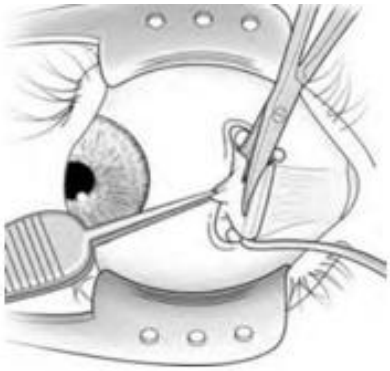

Figure (2): Removal of the surrounding connective tissue **(39)**

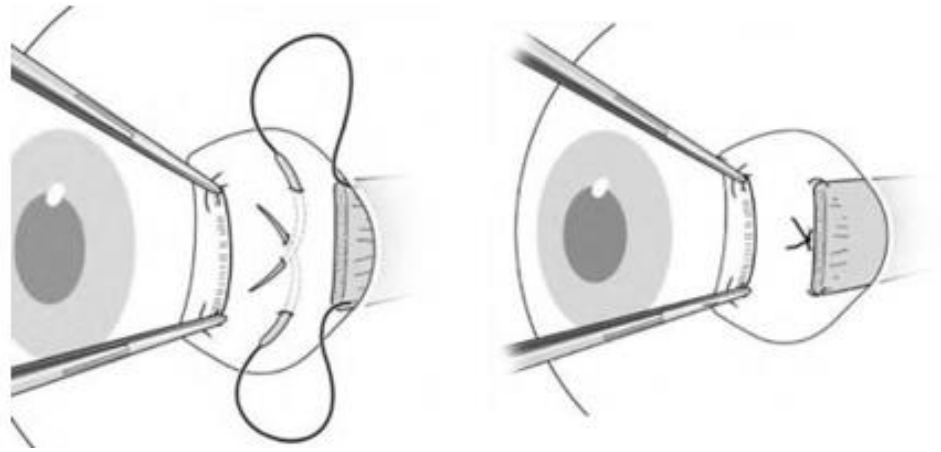

Figure (3): Making a knot to secure the muscle into sclera **(39)**

Hang-Back recession technique:

The results of the standard surgical techniques of the recti muscles are improved by inventing the concept of the adjustable sutures and was first described by Jampolsky in 1970s **(40).**

Using of adjustable sutures resulted in the appearance of hang-back or suspension recession surgical techniques. First, Repka and Guyton used adjustable sutures in correction of strabismus without post-operative modifications. This technique became known as a hang-back recession. The procedure introduced by Guyton and Repka was different from the previous standard "loop" recessions **(41).**

Gobin used two separate sutures that were out at both sides of the muscle and the needles were apart from each others. Because of this separation of the sutures, the measurement of the amount of recession became more challenging. Hang-back and hemi hang-back surgical techniques can be performed by experienced and the less experienced surgeons. Any rectus muscle can be recessed via hang-back technique and this can be done through either limbal or forniceal approach. The procedure has many advantages. The technique is performed at the original attachment site (hang-back) or more forward than a standard recession (hemi hang-back). As a result, the muscle is adequately exposed even if a large amount of recession is desired. So, the surgeon can work independently and not require a skilled assistant in large amounts of recessions. **(42)**

An important advantage of the excellent exposure and the more anterior site of the surgical field is the lower risk of scleral perforations by needles because of the less tendency for deep needle passes. Even if a scleral perforation happens with this technique, it is less likely to damage the retina as the needle passes at the insertion, except in the case of superior rectus muscle which is located more anterior to the ora serrata.

Many surgeons are interested in using hang-back sutures. The frequency of undercorrections in the hang-back technique would be larger than the frequency in the standard recession method as in hang-back technique there is possibility of anterior migration of the rectus muscle before the muscle has reattached firmly to its new insertion site **(43).**

Besides, surgeons who use adjustable sutures do not raise this concern, even though the muscle is not secured directly to the sclera during adjustable sutures technique**.** The muscle is dissected and disinserted as in the standard recession and toothed locking forceps are put on the edges of the original attachment site. The sutures are passed through the original attachment site in a shape of crossed swords. **(44)**

The needles emerge just anterior to the original insertion and close to each other by passing at an angle. If the exits of the needles are too far from each other, it is possible to have inaccurate measurements of the muscle recession. We can add 0.5 mm to make the measurements more accurate to compensate for the problem resulting from the wide separation of the needle exits**. (37)**

Advancement of the sutures are made anteriorly through the sclera till the muscle firmly rests against the original insertion site. Undercorrection would result if the muscle migrated anteriorly after performing hang-back sutures especially in large amounts of recession. To compensate for this, many surgeons use the hemi hang-back recession technique for performing recessions more than 8 mm. In this technique, the needles are passed through the sclera more or less half the distance between the desired recession site and original insertion position. **(45)**

It is necessary to have the needle exits close to each other as in the hang-back technique in a crosswords fashion. The muscle is then dragged up to center and the rest of the surgical technique is similar to the conventional hang-back technique. Both, the conventional recession technique and the hang-back recession technique, use absorbable sutures to reattach the rectus muscle to the sclera after being disinserted from the globe. From this point, they have some of the complications in common that may happen due to pass of the needle through sclera. Inadvertent deep scleral pass of the needle may result in scleral perforation. In most cases, the perforation results in a chorioretinal scar, however in some cases can produce vitreous hemorrhage, retinal detachment or even endophthalmitis. Suture granuloma can develop few weeks after surgery. The granuloma presents at the suture site as a hyperemic localized and elevated mass that often respond to steroids. Slippage of the muscle occurs when

the sutures hold only the superficial muscular fibrous capsule instead of securing the bulk of the muscle. Post-operatively, the muscle bulk retracts within the muscle capsule, resulting in variable degrees of loss of the function of the slipped muscle. **(39)**

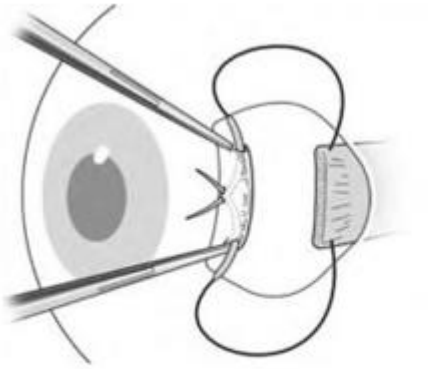

Figure (4): Passing the sutures through sclera at the site of insertion. **(39)**

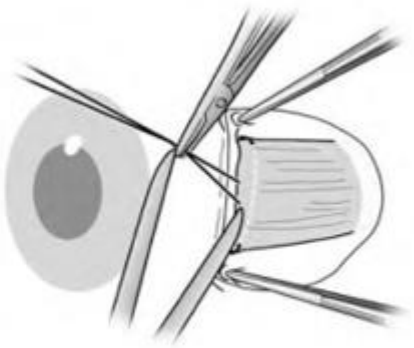

Figure (5): Making a slipped knot **(39)**

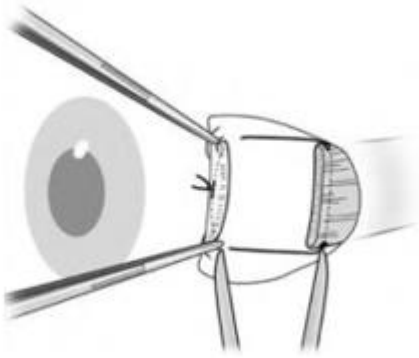

Figure (6): Securing the knot after recessing the muscle back at the desired distance. **(39)**

Tenotomies of the rectus muscles:

Conventional strabismus surgery, such as rectus muscle recession and hang-back recession, is performed to correct moderate to large-angle deviation, more than 10 PD. There is risk of overcorrection in patients with angles less than 10 PD. Tenotomy of the rectus muscle was first done as early as the late 1800s. Route cut the tendon without dissecting it from its surroundings and the nearer to its insertion, the smaller the angle of deviation being corrected **(46).**

To avoid overcorrection, the tenotomy technique was modified leaving the middle of the tendon intact (partial lateral tenotomy), but this has been abandoned until Scott developed graded rectus muscle tenotomy in 2006 **(47).**

In this technique, subconjunctival injection of local anaesthesia is done and the conjunctiva is incised to expose the muscle tendon. Starting at one pole of the tendon, about half the tendon was removed, leaving the other one attached to sclera. So, the cut tendon slanted back at an angle of 45°. To correct 4 PD of deviation, Scott did tenotomy of about 60% of the tendon, or removed about 6 mm of tendon.

The slanted tenotomy technique moves the insertion, thus changes the vector of muscle force by moving the muscle insertion. Thus, inducing incomitance. Scott noted that if tenotomy is done in the upper part of medial rectus and another one is done in the lower part of the contralateral medial rectus, there will be some vertical deviation. If the upper poles of both medial rectus muscles were removed, an A pattern would develop or a V

pattern would be reduced by moving the insertions downwards **(48).**

Another technique is the mini-tenotomy which is performed on the central tendon. The central tenotomy maintains the original rectus muscle insertion by keeping the tendon poles intact. So, it avoids the induced incomitance of the slanted tenotomy technique. It can correct vertical deviation of angles up to 6 PD and horizontal deviation up to 16 PD **(49).**

If we recess the rectus muscle more than the recommended figures in the standard surgical tables, this will limit the action and affect its function in the direction of its movement causing a higher risk of overcorrections. To augment the weakening effect of recession, a central tenectomy of the recessed rectus muscles can be done limiting ductions and it is very effective especially in patients with esotropia. This is called combined resection-recession single muscle surgery which results in much less incomitance as long with minimal effect on primary gaze **(50).**

Fenestration of the rectus muscles:

Recently, extra ocular muscle fenestration has been reported as a new surgical technique for weakening of the extraocular muscles without using sutures or botulinum toxin. The fenestration technique reduces the muscle force by removing a block of the muscle close to its insertion which is done in between 2 peripheral muscle strips. It is a promising simple technique that might avoid the complications of using sutures such as foreign body reactions and granuloma formation. **(51)**

After sterilization and draping of the eyes, an eye speculum is inserted. The muscle is exposed and hooked through either a fornix-based or limbal-based incision. Careful dissection is carried out to delineate the muscle edge, under which another muscle hook is then passed. The 2 hooks are used to stretch the muscle fibers in between. A small Stevens' tenotomy hook is then used to create 2 peripheral muscle strips about 1.5 mm each. The peripheral muscle strips can be isolated with 5/0 silk sutures to separate them from the central part of the muscle, or just pulled away from the central part of the muscle using 2 small hooks. The length of the created peripheral strips determines the amount of muscle weakening. The length should be approximately 1 mm more than the standard amount of conventional recession. The planned site of excision is marked either by pen marker or diathermy burn. The 2 muscle strips are then separated on each side by 2 small hooks or by pulling on the 5/0 silk sutures, and the muscle belly in between is excised using Wescott scissors, leaving a bare sclera. The conjunctival incision is then repositioned and closed. **(51)**

Recession is the standard technique for weakening of extraocular muscles. Despite being the most common surgical procedure, complications related to suturing and muscle disinsertion may occur. In addition, disinsertion of rectus muscles interrupts the vascular supply of the anterior segment of the eye and might carry the risk of anterior segment ischemia if several muscles are disinserted. A number of muscle weakening techniques have been described as an alternative to standard recession. The principle of muscle fenestration differs from these weakening procedures in that it reduces the muscle force by removing a block of muscle belly close to its insertion, thus reducing the number of contracting fibers, leaving the peripheral muscle poles intact, rather than just making cuts across the muscle. The length of the block removed can be graded to achieve the weakening effect needed. In addition to being simple, keeping the muscle in its place reduces the incidence of accidental transposition of muscle during recession, which might induce vertical deviation or result in new strabismus patterns. The connections between the muscle and check ligaments remain intact, and this avoids postoperative widening of palpebral fissure. **(51).**

References:

1. Boyd K., Alba-Campomanes A.G. and Turbert D. (2024): Strabismus in Children. American Academy of Ophthalmology. Available at: https://www.aao.org/eye-health/diseases/strabismus-in-children
2. Rutstein R.P. (2008): Update on accommodative esotropia. Optometry; 79(8):422-31.

3. Weakley D.R., Birch E. and Kip K. (2001): The role of anisometropia in the development of accommodative esotropia. J aapos; 5(3):153-7.
4. Uretmen O., Pamukcu K., Kose S. and Egrilmez S. (2003): Oculometric features of hyperopia in children with accommodative refractive esotropia. Acta Ophthalmol Scand; 81(3):260-3.
5. Sani R.Y., Hassan S., Habib S.G., et al. (2016): Cycloplegic effect of atropine compared with cyclopentolate-tropicamide combination in children with hypermetropia. Niger Med J.; 57(3): 173–177.
6. Rubin S.E. (2006): Bringing the management of accommodative esotropia into sharp focus. Am J Ophthalmol; 141(5):914-5.
7. Fawcett S., Leffler J. and Birch E.E. (2000): Factors influencing stereoacuity in accommodative esotropia. J aapos; 4(1):15-20.
8. Park K.A., Kim S.A. and Oh S.Y. (2010): Long-term changes in refractive error in patients with accommodative esotropia. Ophthalmology; 117: 2196-2207.
9. MacEwen C.J., Lymburn E.G and Ho W.O. (2008): Is the maximum hypermetropic correction necessary in children with fully accommodative esotropia? Br J Ophthalmol; 92(10):1329-32.
10. Li C.H., Chen P.L., Chen J.T. and Fu J.J. (2009): Different corrections of hypermetropic errors in the successful treatment of hypermetropic amblyopia in children 3 to 7 years of age. Am J Ophthalmol; 147(2):357-63.
11. Fawcett S.L., Wang Y.Z. and Birch E.E. (2005): The critical period for susceptibility of human stereopsis. Invest Ophthalmol Vis Sci; 46(2):521-5.
12. Birch E.E., Stager D.R., Berry P. and Leffler J. (2004): Stereopsis and long-term stability of alignment in esotropia. J aapos; 8(2):146-50.
13. Mulvihill A., MacCann A., Flitcroft I. and O'Keefe M. (2000): Outcome in refractive accommodative esotropia. Br J Ophthalmol; 84(7):746-9.
14. Berk A.T., Kocak N. and Ellidokuz H. (2004): Treatment outcomes in refractive accommodative esotropia. J aapos; 8(4):384-8.
15. Lambert S.R., Lynn M., Sramek J. and Hutcheson K.A. (2003): Clinical features predictive of successfully weaning from spectacles those children with accommodative esotropia. J aapos; 7(1):7-13.
16. Mohney B.G., Lilley C.C., Green-Simms A.E, et al. (2011): The Long-term Follow-up of Accommodative Esotropia in a Population-Based Cohort of Children. Ophthalmology; 118(3): 581–585. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3223483/
17. Bilgihan K., Akata F., Or M. and Hasanreisoglu B. (1997): Photorefractive keratectomy in refractive accommodative esotropia. Eye (Lond); 11 (Pt 3):409-10.
18. Magli A., Forte R., Gallo F. and Carelli R. (2014): Refractive surgery for accommodative esotropia: 5-year follow-up. J Refract Surg; 30(2):116-20.
19. Hutchinson A.K. (2012): Refractive surgery for accommodative esotropia: past, present, and future. Eur J Ophthalmol; 22(6):871-7.
20. Ansons A. and Davis H. (2001): Ocular Deviation. In: Ansons A., Davis H. (eds). Diagnosis and Management of Ocular Motility Disorders. 3rd ed. Oxford: Blackwell Science; 92-4.
21. Rowe F.J. (2012): Orthoptic Investigative Procedures. In: Rowe F.J. (ed). Clinical Orthoptics. 3rd ed. Chichester, West Sussex: Wiley-Blackwell; 71-2.
22. Olitsky S.E., Chan E.W., and Farzavandi S., (2016): Strabismus: Accommodative Esotropia. American Academy of Ophthalmology. https://www.aao.org/education/disease-review/strabismus-accommodative-esotropia.
23. Kim W.K., Kang S.W., Rhiu S., et al. (2012): The Analysis of AC/A Ratio in Nonrefractive Accommodative Esotropia Treated with Bifocal Glasses. Korean J Ophthalmol.; 26(1): 39–44. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3268167/
24. Whitman MC, MacNeill K, Hunter DG. (2016): Bifocals Fail to Improve Stereopsis Outcomes in High AC/A Accommodative Esotropia. Ophthalmology. 2016 Apr;123(4):690-6. doi: 10.1016/j.ophtha.2015.12.025. Epub 2016 Feb 4. PMID: 26854034; PMCID: PMC4808433.
25. Bahl R.S (2021): Accommodative Esotropia Treatment & Management. Medscape. Available at: https://emedicine.medscape.com/article/1199512-treatment?&icd=login_success_email_match_fpf

26. Vivian A.J., Lyons C. J. and Burke J. (2002): Controversy in the management of convergence excess esotropia. Br J Ophthalmol.; 86(8): 923–929. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1771224/
27. Kim M.J., Na K.H, and Kim S.H. (2019): Faden operation in consecutive esotropia. Eye (Lond).; 33(9): 1504–1508. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7002427/
28. Huang L.J., Wu Y.Y., and Li N.D. (2022): Y-splitting medial rectus muscle and recession in treatment for convergence excess esotropia. Int J Ophthalmol.; 15(4): 661–665. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8995735/
29. Wabulembo G. and Demer J.L. (2012): Long-term outcome of medial rectus recession and pulley posterior fixation in esotropia with high AC/A ratio. Strabismus; 20(3):115-20.
30. Choe H.R., Yang H.K., and Hwang J.M. (2019): Long-term outcomes of prismatic correction in partially accommodative esotropia. PLoS One.; 14(12): e0225654. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0225654
31. Akar S. (2013): Surgical treatment for partially accommodative esotropia. EMJ Ophth; 1(2):27-33.
32. Chun B.Y., Kwon S.J., Chae S.H., et al. (2007): Reduction of Deviation Angle During Occlusion Therapy: In Partially Accommodative Esotropia with Moderate Amblyopia. Korean J Ophthalmol.; 21(3): 159–162. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2629679/
33. Reynolds M.M., Diehl N.N., and Mohney B.G. (2021): Outcomes in Accommodative Esotropia with a High AC/A Ratio. Eur J Ophthalmol. 31(6): 3342–3348. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10153757/
34. Mojon D.S. (2007): Comparison of a new, minimally invasive strabismus surgery technique with the usual limbal approach for rectus muscle recession and plication. Br J Ophthalmol. 2007 Jan;91(1):76-82. doi: 10.1136/bjo.2006.105353. PMID: 17179123; PMCID: PMC1857554.
35. Clark R.A. and Demer J.L. (2006): Magnetic resonance imaging of the effects of horizontal rectus extraocular muscle surgery on pulley and globe positions and stability. Invest Ophthalmol Vis Sci; 47(1):188-94.
36. Holmes J.M., Hatt S.R., and Leske D.A. (2010): Lateral rectus posterior fixation suture. J AAPOS. 14(2): 132–136. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2918234/
37. Helveston M.E. (2017): Surgical Management of Strabismus. 5th ed. American academy of ophthalmology. Pediatric ophthalmology education center. https://www.aao.org/education/disease-review/surgical-management-of-strabismus
38. El-Fayoumi D., Bahgat N., Khafagy M. et al. (2020): Horizontal Extraocular Muscle Insertion Site in Relation to Axial Length Using Swept-Source Anterior Segment OCT. Clin Ophthalmol.; 14: 3583–3589. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7605956/
39. Coats D.K and Olitsky S.E. (2007): Recession of the rectus muscles and other weakening procedures; in: Strabismus surgery and its complications. New York: Springer; 2007. p. 93-95.
40. Jampolsky A. (1979): Current techniques of adjustable strabismus surgery. Am J Ophthalmol; 88(3 Pt 1):406-18. https://pubmed.ncbi.nlm.nih.gov/384803/
41. Nihalani B.R. and Hunter D.G. (2011): Adjustable suture strabismus surgery. Eye (Lond); 25(10): 1262–1276. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3194320/
42. Breckenridge A.L., Dickman D.M., Nelson L.B., et al. (2003): Long-term results of hang-back medial rectus recession. J Pediatr Ophthalmol Strabismus; 40(2):81-4.
43. Rodrigues A.C., Nelson L.B. (2005): Long-term results of hemihang-back lateral rectus recession. J Pediatr Ophthalmol Strabismus; 42(5):296-9.
44. Hassan S., Haridas A., and Sundaram V. (2018): Adjustable versus non-adjustable sutures for strabismus. Cochrane Database Syst Rev.; 2018(3): CD004240. https://pubmed.ncbi.nlm.nih.gov/29527670/
45. Agrawal S., Singh V., Yadav A., et al. (2017): Modified adjustable suture hang-back recession: Description of technique and comparison with conventional adjustable hang-back recession. Indian J Ophthalmol.; 65(11): 1183–1186. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5700590/
46. von Noorden G. (2012): Strabismology from its beginnings to the middle of the 19th century. In: von Noorden G (ed). The History of Strabismology. Oostende, Belgium: J.P. Wayenborgh; 2012. 41-6.
47. Scott A.B. (2006): Graded rectus muscle tenotomy. Arch Chil Oftal; 63(2):127-8.

48. Van der Meulen-Schot H.M., van der Meulen S.B., and Simonsz H.J. (2008): Caudal or cranial partial tenotomy of the horizontal rectus muscles in A and V pattern strabismus. Br J Ophthalmol; 92(2):245-51.
49. Wright K.W. (2009): Mini-tenotomy procedure to correct diplopia associated with small- angle strabismus. Trans Am Ophthalmol Soc; 107:97-102.
50. Ameri A., Akbari M.R., Jaafari A.R.K., et al. (2014): Combining rectus muscle recessions with a central tenectomy to treat large-angle horizontal strabismus. J aapos; 18(6):534-8.
51. Rageh MA, Awadein A, and Arfeen SA. (2020): Extraocular muscle fenestration: a novel weakening procedure. Can J Ophthalmol. 2020 Oct;55(5):455-457. doi: 10.1016/j.jcjo.2020.05.018. Epub 2020 Aug 26. PMID: 32860744.