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Exploring Strabismus: From Classification to Contemporary Treatment Strategies

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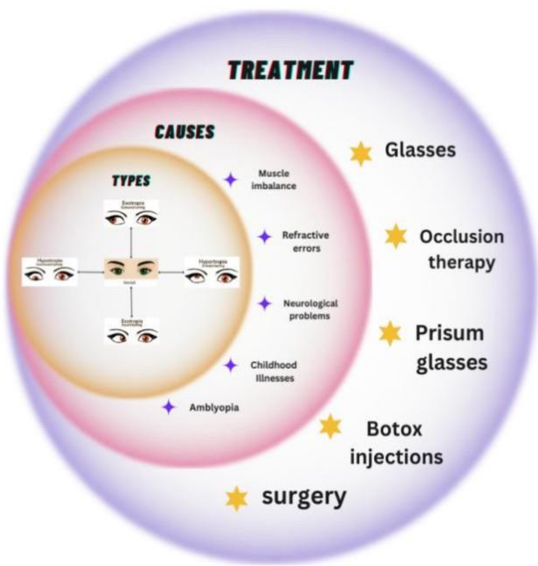
Schematic Abstract:



Abstract:

Eye misalignment resulting in each eye looking in a different direction is the hallmark of strabismus, often known as squinting. There are several ways that this disorder might present itself, depending on the direction of the eye deviation: esotropia, exotropia, hypertropia, and hypotropia. While it can occur later in life as a result of several conditions such amblyopia, neurological problems, childhood illnesses, and refractive defects, strabismus usually develops in childhood. It may cause double vision, poor depth perception, and incorrect head placement because it interferes with normal binocular vision. The Prism Cover Test (PCT), retinoscopy, visual acuity testing, and alignment evaluations such as the Hirschberg and Krimsky tests are some of the tests used to diagnose strabismus. Treatment options include prism glasses, occlusion treatment, corrective glasses, and in certain circumstances, injections of botulinum toxin or surgery, depending on the severity and underlying cause of the condition. Better visual results and the avoidance of further issues depend on early identification and treatment.

Key words: Squint, Eye alignment test, Prism glasses, Muscle imbalance, Botox injection.

INTRODUCTION:

Strabismus, sometimes known as a squint, is the misalignment of the eyes. [1] This is a condition causes the eyes to point in different directions because it interferes with their regular alignment. In certain instances, the misalignment may be continuous, whereas in others, it may only happen sometimes. The eye's deviation could be in any direction, including inward, either downward, upward, or outward. [2] Other names for it include strabismus, eye turns, crossed eyes, wall eyes, and drifting eyes, goggle eyes, deviating eyes, and swivel eyes. [2] This irregular alignment of the eyes may be continuous or sporadic, accompanied by abnormal motility of the eyes, double vision, blurry vision, or abnormal head positioning. In order to manage a squint and prevent more issues, early detection and treatment are typically advised, due to head positioning. Nevertheless, it's not always clear what causes a squint. [2] Some causes are presbyopia, myopia, hypermetropia, cataract, age-related macular Degeneration, trachoma, diabetic retinopathy, corneal opacities, glaucoma. [3] Typically, strabismus develops in childhood and can take numerous forms and intensities were either left untreated, treated ineffectively, or, in the case of initially successful treatment, the ocular misalignment returned 4,5. Both eyes point at the same point when vision is normal. The two visual images that we see are combined by the brain to create a single, three-dimensional (3-D) image. This is known as depth perception, and it allows us to determine an object's distance from us. The brain receives two distinct images when one of the eyes is misaligned. The brain adapts to disregard an image of the mismatched eye in a young child. Rather, it sees just the image as perceived by the better-seeing or straighter eye. The infant thereby loses their ability to perceive depth. [6] Let us assess the possible effects of faulty prenatal retinal waves, problems during postnatal visual experience, improper excitation/inhibition balance, and pathological asynchrony of brain activity on the alignment of the eyes in turn. [7]

SYMPTOMS OF STRABISMUS [8]:

Eyes that see at distinctive headings at the same time

Eyes that do not move together

Squinting or closing one eye in shinning daylight

Destitute fringe vision and Destitute profundity discernment

Causes:

There are various causes for the misalignment of the eyes:

- Muscle Imbalance: There are 6 types of muscles which are around each eye, the main responsibility of these muscles is controlling of the movement of eye. The eye can be moved to the right or left using separate muscles. The eye is moved up, down, and at an angle by the remaining four muscles. All six eye muscles have to work together when focusing on a single image. [6] This is a myogenic type of causes it may cause the incomitant type of squint by the incarceration of optical muscle fractures 4,6.
- Refractive errors: Refractive errors, especially anisometropia, which results in different pictures in both eyes, are the cause of squint. The most frequent cause is long-sightedness, which is corrected by the eyes through accommodation. Esotropia, also known as accommodative esotropia, is a persistent inward bend of the eye brought on by excessive accommodation. Children typically develop accommodating squints approximately the age of two. [9]
- Neurological problems**:** Several neurological disorders, including Down syndrome and cerebral palsy, can impair eye movement control and exacerbate strabismus. The term "neurological problems" refers to a broad category of illnesses that include developmental delays and issues like cerebral palsy, brain trauma, and premature birth. The probability of strabismus varies from case to case and might reach 50%. [10]

- Childhood Illnesses: Strabismus can result from some childhood illnesses that impair the nerves or muscles that control eye movement, such as meningitis or brain tumours 4,11.
- Amblyopia (Lazy Eye): Strabismus can occasionally lead to amblyopia, a condition in which one eye's vision is reduced because the brain fails to process the visual information from that eye. [12]
- OTHER CAUSES: These include psychological elements like rapid shock, familial influences, and circumstances that could impair resistance generally, like extreme exhaustion or overall illness, particularly if there is already a latent squint. While these causes should be addressed, the squint may not necessarily be affected in any way by their removal. Organic ocular diseases that cause vision loss in the squinting eye may give rise to secondary convergent squint. [13]

TYPES OF SQUINT 1,14:

Strabismus can be separated in terms of the course in which the eye turns. Here are the 4 diverse sorts of squints:

- Esotropia: inward turning.
- Exotropia: outward turning.
- Hypertropia: upward turning.
- Hypotropia: downward turning.

Esotropia:

The term "esotropia" refers to an eye misalignment when one eye veers towards the nose. Greek is the source of the term "esotropia," where "Eso" means "within" and "Tropia" means "a turn." It may be acquired or congenital, intermittent or continuous, and its patterns may gradually shift from intermittent to constant. Furthermore, depending on whether it is classified as contemporaneous or incomitant, the deviation may be constant or change in different gaze directions. Squinting may manifest in one or both eyes. [15]

Individuals who have esotropia are usually farsighted, which means they see objects farther away more clearly than objects closer to them. Esotropia can occasionally indicate the need for glasses to treat farsightedness. [16]

"Congenital esotropia" is another term for infantile esotropia. This is an esodeviation that manifests in the first six months of life and is frequently constant. Large angle deviations dissociated vertical deviations, overelevation in adduction, fusion maldevelopment nystagmus (latent nystagmus), a normal accommodative convergence to accommodation ratio, and age-appropriate refractive errors are associated with it. It's unclear what caused it. [17]

The most prevalent type of exotropia is intermittent exotropia. It might have an impact on 1% of people. [18] One to three percent of Americans suffer from a type of strabismus called esotropia, which is an eye misalignment. [16]

Exotropia:

Exotropia is the term for the outward displacement of the eyes from the nose. Exodeviations may develop over time or be inherited. These may occur concurrently or not. Concomitant deviation denotes that all gaze locations result in the same divergent deviation from the visual axis. The concept of incomitant deviation suggests that the visual axis' divergent deviation varies depending on the gaze. The restriction of extraocular motions resulting from paralysis or a restricted aetiology is frequently linked to these. [19] Consecutive exotropia is the term used to describe exotropia that develops in people who have previously experienced exotropia, either spontaneously or because of optical and surgical treatment. [20] Intermittent exotropia, also known as X(T), is a significant outward deviation of the eyes that periodically shifts to an outward turning of one eye. Closing or covering one eye interrupts fusion and result in the appearance of exotropia. [21] It Is present in 1% to 2% of children. [22]

Exotropia can be acquired or congenital (existing from birth). Intermittent exotropia, sensory exotropia, and consecutive exotropia—exotropia resulting from eye surgery to correct crossed eyes—are examples of acquired exotropia. [23]

Hypertropia:

One kind of strabismus, or improper eye alignment, is hypertropia. When a person is staring straight ahead, hypertropia specifically refers to a disorder where one of their eyes is higher over the other. This alignment error might happen diagonally, horizontally, or vertically. Congenital means that it may exist from birth 24,25. The least common type of strabismus is hypertropia. One child out of every 400 is thought to have hypertropia. Adults may also develop the condition, frequently because of an eye illness or injury 26,27.

The eye alternates between looking straight ahead and slanting upward in hypertropia. This occurs when the eyes do not focus on a single object as a team. Double vision results from the brain receiving two distinct images. [27]

Hypotropia:

One eye that strays lower than the other when focused on an item is known as hypotropia. This particular form of eye misalignment is known as strabismus. While the other eye remains in its normal position, the affected eye points downward when hypotropia occurs. [28] Dissociated vertical deviation (DVD) can rarely present as unilateral or bilateral hypotropia, although it usually invariably exhibits hypertropia of the afflicted eye. This uncommon form of DVD, known as "dissociated hypotropia," affects two patients, both of whom had successful surgical procedures. [18] A misaligned eye is a common feature of a set of diseases known as strabismus, which includes hypotropia. It is estimated that 5% to 2% of people have hypertropia strabismus. [29]

Diagnosis:

Prism cover test (PCT):

Eye care experts utilise the Prism Cover Test (PCT) as a diagnostic tool to determine the degree and direction of eye misalignment in patients with strabismus, or squint. Quantifying the deviation of one eye when it is covered can assist reveal any latent or obvious squint. Using of backpropagation learning, the StrabNet expert system employs a variety of multi-layer perceptron's. There are three neural networks in the array. [30]

i. Network 1: divides PCT data into squints that are either hypotropia (downward) or hypertropia (upward);
ii. Network 2: assigns StrabNet Classes 1–4 to Hypertropia PCT data (Table 1)
iii. Network 3: assigns StrabNet Classes 5 through 8 to hypotropia PCT data (Table 1)

Ten PCT prism values (6 in the 6-position subset) in a range of -40 to +40 degrees of deviation are the inputs for each net, which is made up of three layers with five log-sigmoid nodes in the hidden layer. [31]

TABLE 1: Classification of strabismus that is vertical 30,31:

HYPERTROPIC (upward deviation)		**HYPOTROPIC (downward deviation)**	
StrabNet class	**CLASS**	**StrabNet class**	**CLASS**
1	Superior oblique palsy on one side accompanied by inferior oblique overaction	**5**	syndrome of the superior oblique tendon sheath
2	Superior oblique palsy on both sides	**6**	Sheath syndrome of the superior oblique tendon plus
3	Superior oblique palsy on one side accompanied by a lax superior oblique tendon	**7**	Thyroid eye disease with a less involvement of the rectus
4	Prolonged upper oblique palsy	**8**	Fracture from orbital floor blow-out

Visual Acuity Testing:
This involves checking the sharpness of vision in each eye individually using an ‘‘Snellen Charts’’**.** A family of ten non-serif letters (DEFHNPRUVZ) is used in visual acuity charts. These letters are created on a framework that measures five units high by four units wide, with limb widths of one unit. It had been demonstrated that these letters were similarly readable. The 1968 BSI letters have a more organic or familiar appearance than the five letters most frequently used in "Snellen Charts. They resemble the letters in Arial bold or Helvetica bold typefaces. Firstly, choose the optotypes, and then choose the logarithmic size progression. There are two major logarithmic progressions in that the first method is proposed by Green, a logarithmic progression with a ratio of (2^1/3 = 1.2599), and the second is proposed by Solan, whose ratio is (10^0.1 = 1.2589). Then make the chart read by a patient. In order to improve visual acuity, viewing distances closer to 20/200 (6/60) were recommended. We looked for a more straightforward and straightforward way to quantify angular size because Snellen fractions using various numerators for various distances appeared cumbersome. Then finally record the visual acuity scores as log MAR. [32]

Refractive Test (Retinoscope):
"Refraction" refers to the evaluation of the eye's refractive state. Subjective and objective refraction is the classification given to it. In order to find the best-corrected visual acuity with relaxed accommodation, subjective refraction is the evaluation of refractive status using a combination of spherical and cylindrical lenses. Jackson's cross-cylinder and duo-chrome test, Snellen's visual acuity chart, pinhole, occlude, trial lenses, trail frame, manual refraction unit, and Snellen's phoropter are among the devices required for subjective refraction. This test determines if there is any refractive error (such as near sightedness, farsightedness, or astigmatism) present in each eye. [33] A fundamental characteristic of light, refractivity explains how the path taken by light rays alters when they are transmitted or propagated through various substances or optical media. In the human eye, the primary tissues

responsible for refractive error are the layer of cornea and crystalline lens. A field of physics known as geometrical optics is intimately related to vision and examines the variations in light ray paths that are detected when they are refracted by different materials. [34]

A retinoscope is a light source from the outside that is used in retinoscopy examinations. It projects light rays via a transparent ocular medium and records the reflections of those light rays off the retina. Even though automated optical instruments have significantly improved due to ongoing innovations, retinoscopy is still a valuable clinical method. It falls into one of two basic categories: dynamic or static. The patient must be in a relaxed, accommodating state for the purpose of static retinoscopy; this state can be produced naturally or with medication. A dynamic retinoscopy needs to be accommodated actively. In static retinoscopy, the person being evaluated looks for reflex neutralisation when the patient consistently fixes their gaze on an immobile target, optotype, or visual stimulus at optical infinity, which is six metres or twenty feet away. Regular noncycloplegic or cycloplegic objective refraction evaluations might make use of static retinoscopy. In order to ascertain the intrinsic accommodative response to presented stimuli at specific distances, dynamic retinoscopy necessitates fixation at a close object at a distance less than optical infinity. [34]

Eye Alignment Test:

The corneal light reflex's location within the pupil is used by the Hirschberg test to measure eye alignment, and the Krimsky test additionally uses a prism. [35]

The Hirschberg and Krimsky tests are used to manually identify strabismus; however, even in the hands of highly skilled Strabismologists, the results are examiner dependent and significantly less accurate. [35]

The Hirschberg test has been carried out in which a medical professional compares the locations of the corneal images of a light to determine the strabismic angle. varying degrees since its debut a century ago. The test was initially explained in terms of the landmarks that the corneal limbus and pupillary margin provided. [36]

The test apparatus is made up of a moving fixation target to cause esotropia, a fixed position fixation target to produce Purkinje images, and a video system to capture a full-face image. [37]

To diagnose strabismus in a patient, the Hirschberg test requires that the fixating eye's first Purkinje's image be positioned in relation to its optical centre, and as a result, the yaw needs to be noticed in the other eye, the non-fixating eye. By comparing the light reflection on the anterior surface of the cornea with its optical centre and determining whether there is an alignment error, the yaw is deduced. The yaw will be assessed in relation to the anatomic centre of the eye, or, to put it another way, in relation to the pupil's centre, since it is challenging to pinpoint the exact location of a non-fixating eye. This explanation makes clear that there is an additional variable—the Kappa angle—that tampers with the yaw observation. When assessing the reflex, this angle needs to be measured specifically for that eye.

Nevertheless, other variables affect how the luminous reflection on the non-fixating eye is positioned in relation to the position the reflex takes in the obsessive gaze. These include refraction, corneal curvature, and the size of the cornea and eye. The evaluation may be disturbed if the data from the two eyes are too different from one another. For this reason, all these factors must be considered when using the Hirschberg method to analyse or quantify the yaw. [37]

Krimsky Test & Alternate prism cover test (APCT):

The most popular technique for determining the angle of deviation in strabismus patients is the alternate prism cover test (APCT), but it can only be applied when both eyes have adequate vision for fixation. [38]

We placed a prism over the dominant eye of each patient and gave them instructions to focus on a target six meters away. The light source was placed in the centre of the prism, 33 centimetres away of the two eyebrows. We calculated the angle of deviation after locating the corneal light reflections in each cornea's centre.

We computed the extent of concordance by comparing the deviation angles obtained from the APCT and the distance Krimsky test to assess the accuracy of the latter. These outcomes were contrasted with the degree of agreement between the traditional Krimsky both the APCT and the test.

Before measuring the horizontal strabismic angle in the event of an accompanying vertical strabismic angle, the vertical deviance detected by the APCT at a distance was corrected using prism in the Krimsky distance test. [38]

Treatment:

The severity of the condition, the patient's age, and the underlying reason all affect how strabismus, is treated. The following list of typical therapies:

Glasses:

Glasses can typically correct the squint if hypermetropia, or long-sightedness, is the cause 39,40.

Prescription glasses are the primary line of treatment for youngsters with squint eyes. Having glasses on all the time helps stop lazy eyes from forming. Many times, a child's squint lessens or even goes away when they wear glasses. We refer to this situation as Accommodative Squint. Once the glass is taken off, the squint will resurface. Several kids can get rid of their squint simply by donning glasses. [41]

Occlusion therapy using an eye patch:

Here, a customised patch covers the better-seeing eye for a few hours each day. The lens on one side could be covered for person who use glasses. To make the weaker eye work harder is the goal of this treatment. The Latin term "to shut or close" is where the word "occlusion" originates.

One eye is typically more nearsighted or farsighted than the other in children who have lazy eyes, or they may have astigmatism. Then, glasses are used to first correct that other eyesight issue. That may be sufficient to treat sluggish eyes in some kids. To effectively treat lazy eye, however, many youngsters also require the use of an eye patch or eye drops.

Some are concerned that because the healthy eye isn't being utilised as much while receiving treatment, covering it could weaken it. However, studies conducted in this field have not confirmed that. [40]

Prisum glasses:

Ocular misalignment is one of the problems that can be corrected using prism glasses, which are lenses that deflect light. Prisms are used in ophthalmology to treat and assess eye misalignment as well as to create misalignment in order to enable certain testing. Measurement of the misalignment is a prerequisite for treatment. Prisms can be held in front of either of the eyes to achieve this alignment. [42]

To quantify the squint; In order to deflect or refract light rays flowing through them, ophthalmic prisms are composed of two nonparallel refracting surfaces that connect at the apex. The light rays always bend towards the base of the prism, which is located opposite the apex. In contrast to degrees, prism diopters, a measurement of an ocular prism's power, are frequently used to express prisbismic variations. When a light beam travelling through an ophthalmic prism (made of glass or plastic) is measured one metre (100 cm) distance from the prism, its power, expressed in prism diopters (Δ), is equal to the deviation, expressed in centimetres (cm). Be aware that 15Δ should not be referred to as 15 "diopters." While it is possible to stumble across 15 "prisms" on occasion, the correct term to use is 15 prism diopters Prism diopters of deviation and degrees of deviation are not linearly connected, but rather trigonometrically (degrees = tan-1(Δ/100) ×180/π). Each degree is roughly equal to 2Δ for angles lower than 45° (or 100Δ). However, the assumption of 2Δ per degree for angles bigger than 45° (or 100Δ) is no longer accurate; as one approaches 90°, the number of prism diopters per degree increases to infinity {figure 1}.

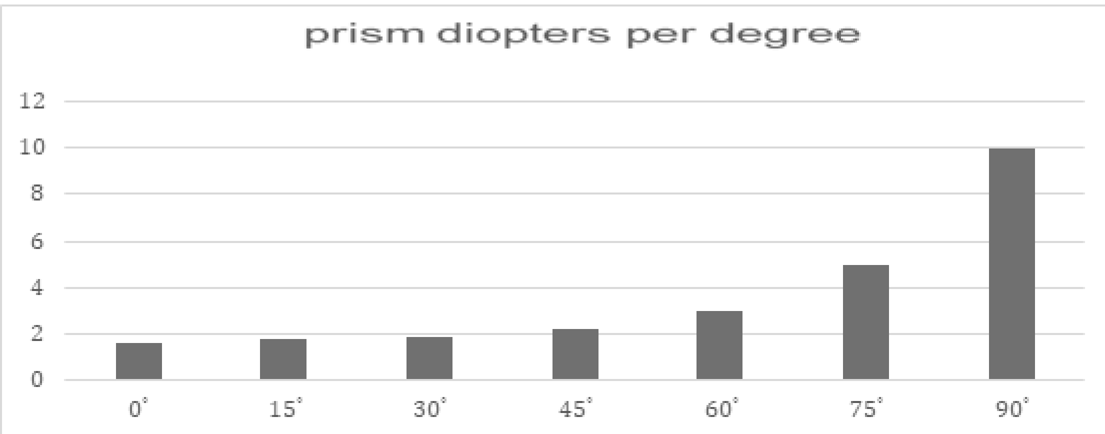


Figure 1: Relationship between prism diopters and degrees. For angles smaller than 45° (or 100^{Δ}), the number of prism diopters per degree is about 2. For angles larger than 45° (or 100^{Δ}), this approximation becomes invalid, and as one approaches 90°, the number of prism diopters per degree goes up to infinity

A prism's ability to produce or measure strabismic deviation is dependent upon its orientation. [43]

Botulinum toxin (Botox) injections:

The medication known as botulinum toxin, or Botox, is derived from a toxin that the bacteria Clostridium botulinum produces. This toxin, when consumed insufficient quantities, can result in botulism, a nerve-damaging disease. [44] It has been reported to be effective in treating a variety of conditions, including exposure keratitis, strabismus, nystagmus, facial muscle spasms, and corneal ulcerations. [45] Botulinum toxin has several therapeutic applications for treating strabismus, including helping patients with decompensating deviations or recovering sixth nerve palsy regain their fusion, aligning the cosmetic form of strabismus, supporting surgical overcorrections and under corrections, and helping patients with acquired nystagmus improve their visual acuity by reducing oscillopsia (the perception of moving images) 45,46.

An alternate method that has gained traction in the treatment of adult strabismus patients is the injection of botulinum toxin into the extraocular muscles. There has been less research on its use in kids. Due to the requirement for anaesthesia and difficulties from the toxin leaking into the levator palpebral superioris muscle (the muscle responsible for elevating the eyelid), which causes a droopy top lid known as ptosis, it is thought to be challenging to employ in children. [45]

The Low dose of botulinum toxin A (BTXA) was injected on the lateral or medical rectus muscle. Regardless of its magnitude, the ocular deviation was reduced by an average of 60%. [47]

The way that Botulinum Toxin type A operates is by immobilising the extraocular muscle that is causing the eye to misalign. During the early phase of paralysis, strabismus will be overcorrected when the paralysed muscle is overpowered by the normally functioning antagonist (also known as "the effect"). The antagonist will contract and the paralysed muscle will extend as a result of this overcorrection. The lengths of the paralysed muscle and its antagonist will alter over this period, as will the length-tension curves inside these muscles. Sarcomere density has changed, according to histology. Some of these modifications will last after the effects of BT-A wear off, resulting in a net adjustment to the eyes' alignment (referred to as "the after-effect"). While the eye is different, the following modifications are probably going to happen:

1. The LMR will extend and get strained;
2. The LMR's length-tension curve will alter;
3. Additionally, the LLR's length-tension curve will alter;
4. The LLR will get shorter.
5. Both of these muscles' sarcomere densities will gradually alter.

A good motor fusion range, also known as the "capture range," will have a higher effect on the misalignment than what the mechanical after-effect effects may have indicated. [47]

Surgical techniques used for weakening the muscles:
Internal rectus tenotomy has been largely disregarded and is extremely uncertain. Protocols have been described as putting the insertion further back in order to weaken the internal rectus. The principle of suturing the muscle to the is the same for all of them. roughly four or five millimetres behind the initial insertion in the sclera. When executed correctly, Jamieson’s recession is a very good operation that produces positive outcomes. [48]

An ophthalmologist with a specialty in paediatric ophthalmology or strabismus typically performs strabismus surgery. even though performing such procedures is a part of the general training required for all ophthalmologists. [49]

After strabismus surgery, anterior segment ischemia (ASI) is an uncommon but potentially dangerous side effect.[50]

Dellen are described as well-defined, shallow excavations at the corneal margin. They usually have a diameter of 1.5 to 2 mm and appear when the cornea dehydrates and evaporates locally. The disruption of the tear film and subsequent localized evaporation cause the corneal stromal lamellae to become more compact. All patients undergoing surgery for strabismus experience mild chemosis, though it can occasionally become more noticeable. It is rare to observe severe chemosis after routine strabismus surgery, but hydraulic dissection has the potential to damage the suspensory attachments to the conjunctival fornix. After strabismus surgery, endophthalmitis is so uncommon that it is frequently misdiagnosed at first. After strabismus surgery, endophthalmitis typically has a poor visual outcome and a delayed diagnosis may contribute to this in part. Therefore, it is still crucial for surgeons to be aware of risk factors, clinical presentation, and treatment. [51]

Recurrent or residual strabismus is a common issue that is discovered following strabismus surgery. [51]

Conclusion:
To properly manage its different manifestations, strabismus is a complicated and diverse disorder that need thorough examination and customised treatment options. In especially for youngsters, early diagnosis is crucial to reducing the long-term effects on visual development. Healthcare professionals can apply focused therapies that correct the physical misalignment and the resulting visual impairments by comprehending the underlying reasons

and using the proper diagnostic instruments. More sophisticated treatments, including as the use of prism glasses and botulinum toxin injections, are available for more severe or chronic instances, even if glasses and occlusion therapy are still the first line of treatment for many individuals. To get the best results for people with strabismus, a multidisciplinary strategy combining medical, visual, and occasionally surgical treatments is required.

Reference:

1. Helveston EM. Understanding, detecting, and managing strabismus. Community Eye Health [Internet]. 2010 Mar 1;23(72):12–4. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2873668/

2. Alnuman R, Alhablani F, Alruwaili E, Alruwaili G, Alruwaili R, Alruwail R, et al. Prevalence of squint in primary school children and its associated sociodemographic factors in Sakaka City, Aljouf Region, Saudi Arabia. International Journal of Medicine in Developing Countries. 2021;1085–91.

3. World Health Organization. World report on vision [Internet]. www.who.int. 2019. Available from: https://www.who.int/publications/i/item/9789241516570

4. Kanukollu VM, Sood G. Strabismus [Internet]. PubMed. Treasure Island (FL): StatPearls Publishing; 2021. Available from: https://www.ncbi.nlm.nih.gov/books/NBK560782/

5. Beauchamp, MD GR, Black, MD BC. The management of strabismus in adults—I. clinical characteristics and treatment. Journal of American Association for Pediatric Ophthalmology and Strabismus [Internet]. 2003 Aug 1 [cited 2021 Apr 29];7(4):233–40. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1091853103001125 /

6. Puente, Jr., MD MA. What Is Strabismus? [Internet]. American Academy of Ophthalmology. 2014. Available from: https://www.aao.org/eye-health/diseases/what-is-strabismus

7. Bui Quoc E, Milleret C. Origins of strabismus and loss of binocular vision. Frontiers in Integrative Neuroscience [Internet]. 2014 Sep 25;8. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4174748/

8. Dr Vikram Jain. Squint Eye | Causes and Corrections | Prasad Netralaya [Internet]. Prasad Netralaya. 2020 [cited 2024 Aug 25]. Available from: https://prasadnetralaya.com/squint-eye/

9. Al-Tamimi E, Shakeel A, Yassin S, Ali S, Khan U. A clinic-based study of refractive errors, strabismus, and amblyopia in pediatric age-group. Journal of Family and Community Medicine [Internet]. 2015;22(3):158. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4558737/

10. Beauchamp, M.D. GR. What Causes Strabismus? [Internet]. www.pediatricophthalmologypa.com. Available from: https://www.pediatricophthalmologypa.com/causes-strabismus/#:~:text=Neurological%20problems%20encompass%20a%20diverse

11. Isa L, Ngelis E. The New Eng land Jour nal of Medicine B RAIN T UMORS. Medical Progress [Internet]. 2001;114(2). Available from: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=49a567f6b33dd690f1e01aaec5a73b759483a938

12. Information NC for B, Pike USNL of M 8600 R, MD B, Usa 20894. Lazy eye (amblyopia) in children: What are the treatment options for lazy eye (amblyopia)? [Internet]. www.ncbi.nlm.nih.gov. Institute for Quality and Efficiency in Health Care (IQWiG); 2020. Available from: https://www.ncbi.nlm.nih.gov/books/NBK279463/

13. Lyle TK. Treatment of Squint in Children. BMJ [Internet]. 1951 Jun 2 [cited 2024 Aug 25];1(4717):1253–6. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2069125/?page=1

14. American Optometric Association. Strabismus (crossed eyes) [Internet]. www.aoa.org. Available from: https://www.aoa.org/healthy-eyes/eye-and-vision-conditions/strabismus?sso=y

15. Kaur K, Gurnani B. Esotropia [Internet]. PubMed. Treasure Island (FL): StatPearls Publishing; 2022. Available from: https://www.ncbi.nlm.nih.gov/books/NBK578207/

16. Esotropia: Types, Causes & Treatment [Internet]. Cleveland Clinic. Available from: https://my.clevelandclinic.org/health/diseases/23145-esotropia

17. Triantafilou D. Esotropia - EyeWiki [Internet]. eyewiki.aao.org. 2024. Available from: https://eyewiki.aao.org/Esotropia

18. Kraft SP, Long Q. Dissociated Hypotropia: Clinical Features and Surgical Management of Two Cases. Vol. 10. Journal of American Association for Pediatric Ophthalmology and Strabismus; 2006.

19. Kaur K, Gurnani B. Exotropia [Internet]. PubMed. Treasure Island (FL): StatPearls Publishing; 2022. Available from: https://www.ncbi.nlm.nih.gov/books/NBK578185/

20. yurdakul sefi. Analysis of Risk Factors for Consecutive Exotropia and Review of the Literature. Journal of Pediatric Ophthalmology and Strabismus. American optometric associations; 2013.

21. Wright K, Ning Y, Springerlink (Online Service. Color Atlas of Strabismus Surgery: Strategies and Techniques. New York, Ny: Springer New York; 2015.

22. Mohney BG, Huffaker RK. Common forms of childhood exotropia. Ophthalmology. 2003 Nov;110(11):2093–6.

23. Exotropia - American Association for Pediatric Ophthalmology and Strabismus [Internet]. aapos.org. Available from: https://aapos.org/glossary/exotropia

24. Tamhankar MA, Kim JH, Ying G-S, Volpe NJ. Adult hypertropia: a guide to diagnostic evaluation based on review of 300 patients. Eye [Internet]. 2011 Jan 1 [cited 2021 Sep 21];25(1):91–6. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3144639/

25. Health S. Hypertropia – Causes, Symptoms, Risk factors and more [Internet]. Star Health. 2022 [cited 2024 Aug 25]. Available from: https://www.starhealth.in/blog/hypertropia

26. Christiano D. What Is Hypertropia? [Internet]. Healthline. Healthline Media; 2017. Available from: https://www.healthline.com/health/eye-health/hypertropia

27. Kelley S. What Is Hypertropia? [Internet]. All About Vision. 2021. Available from: https://www.allaboutvision.com/conditions/strabismus/hypertropia/

28. Sawers N, Jewsbury H, Ali N. Diagnosis and management of childhood squints: investigation and examination with reference to red flags and referral letters. The British Journal of General Practice [Internet]. 2017 Jan 1 [cited 2020 Sep 12];67(654):42–3. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5198597/

29. Yetman D, Duncan, MD KE. Hypotropia: Everything You Need to Know [Internet]. Healthline. 2023 [cited 2024 Jun 9]. Available from: https://www.healthline.com/health/hypotropia#causes

30. Fisher AC, Lake SP, Cunningham IP, Arvind Chandna. Web-StrabNet: A Web-Based Expert System for the Differential Diagnosis of Vertical Strabismus (Squint). Computational and mathematical methods in medicine. 2010 Jan 1;11(1):89–97.

31. A. Jampolsky, A simplified approach to strabismus diagnosis, in symposium on strabismus, in Transactions of the New Orleans Academy of Ophthalmology, H.M. Burian, et al., eds., Mosby, St Louis, MO, 1971, pp. 34 – 912

32. Bailey IL, Lovie-Kitchin JE. Visual acuity testing. From the laboratory to the clinic. Vision Research. 2013 Sep; 90:2–9.

33. Kaur K, Gurnani B. Subjective Refraction Techniques [Internet]. PubMed. Treasure Island (FL): StatPearls Publishing; 2022. Available from: https://www.ncbi.nlm.nih.gov/books/NBK580482/

34. Enaholo ES, Musa MJ, Zeppieri M. Objective Refraction Technique: Retinoscopy [Internet]. PubMed. Treasure Island (FL): StatPearls Publishing; 2024. Available from: https://pubmed.ncbi.nlm.nih.gov/37983333/

35. Potdar RM, Mishra A, Yadav S. Real Time Squint Eye Detection. International Journal of Engineering and Advanced Technology. 2011 Jan 1;1(2249 – 8958).

36. Miller JM, Mellinger M, J Greivenkemp, Simons K. Videographic Hirschberg measurement of simulated strabismic deviations. PubMed. 1993 Oct 1;34(11):3220–9.

37. Sousa D, Ana Maria Silva, Anselmo, Juarez J. Computational methodology for automatic detection of strabismus in digital images through Hirschberg test. T SciVerse ScienceDirect. 2012 Jan 1;42(1):135–46.

38. Kampanartsanyakorn S. The Outcomes of Horizontal Strabismus Surgery and Influencing Factors of the Surgical Success. Journal of the Medical Association of Thailand = Chotmaihet Thangphaet. 2005 Dec 1;88.

39. Felman A, Corte R. Squint, or strabismus: Causes and treatment [Internet]. www.medicalnewstoday.com. 2017 [cited 2024 Aug 2]. Available from: https://www.medicalnewstoday.com/articles/220429#:~:text=Prompt%20treatment%20reduces%20the%20risk

40. Information NC for B, Pike USNL of M 8600 R, MD B, USA 20894. Lazy eye (amblyopia) in children: What are the treatment options for lazy eye (amblyopia)? [Internet]. www.ncbi.nlm.nih.gov. Institute for Quality and Efficiency in Health Care (IQWiG); 2020. Available from: https://www.ncbi.nlm.nih.gov/books/NBK279463/

41. Foundation TE. https://www.theeyefoundation.com/eye/squinted-eyes-have-normal-vision [Internet]. www.theeyefoundation.com. [cited 2024 Aug 2]. Available from: https://www.theeyefoundation.com/eye/squinted-eyes-have-normal-vision

42. Cossack M, Salini B. Prism Glasses [Internet]. PubMed. Treasure Island (FL): StatPearls Publishing; 2024 [cited 2024 Aug 2]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK541122/#:~:text=In%20ophthalmology%2C%20prisms%20are%20used

43. Irsch K. Optical issues in measuring strabismus. Middle East African Journal of Ophthalmology. 2015;22(3):265.

44. Satriyasa BK. Botulinum toxin (Botox) A for reducing the appearance of facial wrinkles: a literature review of clinical use and pharmacological aspect. Clinical, Cosmetic and Investigational Dermatology [Internet]. 2019 Apr;Volume 12(12):223–8. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6489637/

45. Rowe FJ, Noonan CP. Botulinum toxin for the treatment of strabismus. The Cochrane Database of Systematic Reviews [Internet]. 2017 Mar 2 [cited 2020 May 4];2017(3). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6464099/

46. Escuder AG, Hunter DG. The Role of Botulinum Toxin in the Treatment of Strabismus. Seminars in Ophthalmology. 2019 May 19;34(4):198–204.

47. Elston JS, Lee JP, Powell CM, Hogg C, Clark P. Treatment of strabismus in adults with botulinum toxin A. The British Journal of Ophthalmology [Internet]. 1985 Oct 1 [cited 2022 Oct 26];69(10):718–24. Available from: https://pubmed.ncbi.nlm.nih.gov/4052354/

48. Modi NC, Jones DH. strabismus: Background and Surgical Techniques. 2008 Dec;18(1467-1026).

49. Rosenbaum AL, Alvina Pauline Santiago. Clinical strabismus management: principles and surgical techniques. Philadelphia: Saunders; 1999.

50. Olitsky S, Coats D. Complications of strabismus surgery. Middle East African Journal of Ophthalmology [Internet]. 2015;22(3):271. Available from: https://dx.doi.org/10.4103%2F0974-9233.159692

51. Kowal L, Wong E, Yahalom C. Botulinum Toxin in the treatment of strabismus. A review of its use and effects. Disability and Rehabilitation. 2007 Jan;29(23):1823–31.