Theme section

Prisms in Ophthalmology

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Abstract *With their numerous diagnostic and therapeutic applications, prisms are an indispensable part of ophthalmology. Prisms have been used as reflectors in various ophthalmic instruments, while their other properties have made them an essential tool in the diagnosis and management of strabismus. Hence, an in-depth knowledge of their correct use is crucial for all ophthalmologists. This article aims to summarise the various types of prisms, their optics, and their applications in ophthalmology.*

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A prism is a portion of a refracting medium bordered by two plane surfaces inclined at a finite angle. Prisms have been used in ophthalmology for many years for diagnostic and therapeutic purposes, as well as a part of many ophthalmic instruments, and hence form an indispensable part of ophthalmology.

Parts of a Prism

Prism, a transparent solid triangular refracting medium, has two parts – an apex and a base. The finite angle at which the two surfaces of the prism are inclined is known as its refracting angle (α) or apical angle. A line bisecting this angle is the axis of the prism and the opposite surface is called its base (Figure 1). Orientation of prism is indicated by the position of its base e.g. base-in, base-out, base-up, base-down.

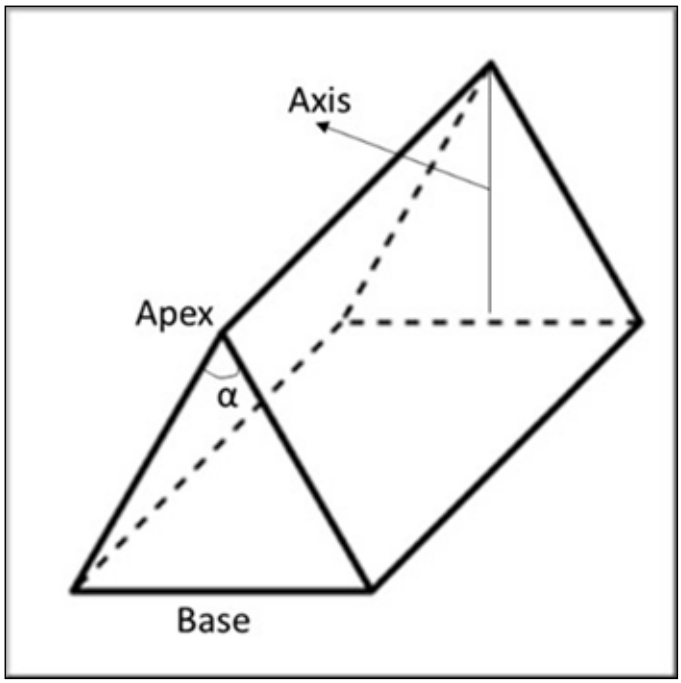

Figure 1: *Parts of a Prism*

Optics of Prism

Light passing through a prism is deviated as per Snell's law, such that a ray of light deviates towards the prism's base (Figure 2). Hence, the image formed by a prism is virtual, erect and displaced towards its apex (Figure 3). The net change in the direction of the light ray is called the angle of deviation which depends on:

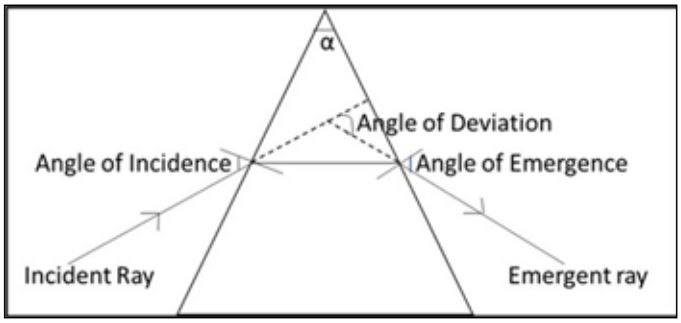

Figure 2: *Optics of a prism*

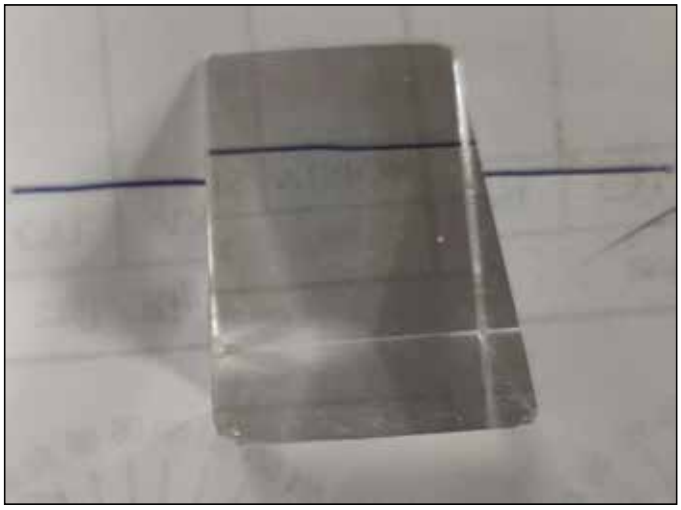

Figure 3: *A straight line drawn on a paper appears displaced towards the apex of the prism*

1. Refractive index of the material used to make the prism
2. Refracting angle (α) of the prism
3. Angle of incidence of the light ray

This angle of deviation is least when the angle of incidence equals the angle of emergence, and is known as angle of minimum deviation, while it is greatest when the ray strikes one face of the prism at normal incidence. Thus, the power of a prism can be specified in two positions: the position of minimum deviation and the Prentice position. In the Prentice position the surface of prism is at 90 degrees to the ray of light such that all deviation takes place at the other surface. Since the angle of deviation in this position is more than the angle of minimum deviation, the power of any prism in the Prentice position is greater than its power in position of minimum deviation.[1]

Power of a prism is often donated in prism diopters, wherein one prism dioptre (PD) is defined as the prism power which produces an apparent linear displacement of 1cm of an object situated 1m from the prism.

Types Of Ophthalmic Prisms

Ophthalmic prisms can be made up of either glass or plastic. Glass prisms have a higher refractive index and therefore deflect light more than plastic prisms. The Prentice position power in which prisms are held with their back perpendicular to the line of sight is normally specified for glass prisms while power in the position of minimum deviation is used for plastic prisms (Figure 4). In practice, plastic prisms are usually held in the frontal plane position with their back surface parallel to the face as this is near enough to the position of minimum deviation.

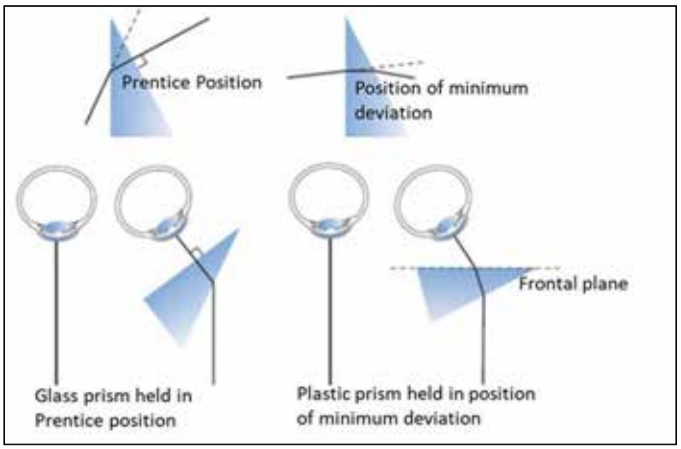

Figure 4: *Positioning of prisms*

Fresnel prism consists of a plastic sheet of parallel tiny prisms of identical refracting angles (Figure 5). It is based on the principle, that the power of an optical system is unaffected by changes in the thickness of the system elements or their separation. Thus, the overall prismatic effect is same as that of a single large prism with the added advantage of the lighter weight of these sheets which can be easily stuck on patient's glasses. Moreover, these Fresnel prisms are more acceptable cosmetically as they are affixed to the concave surface of the spectacle lens, and they allow much larger prismatic corrections (up to 40 PD).[2] However, these are not without problems, some of which are - decreased visual acuity, especially towards the base which may induce an abnormal head posture, decrease in contrast sensitivity and chromatic aberrations.[3] Majority of these problems can be mitigated by closely matching the refractive index of the spectacle lens material and the prism.

For diagnostic purposes, loose prisms (Figure 6), prism bars (Figure 7), trial set prisms (Figure 8), or Fresnel prisms can be used. Prisms in the trial set range from ½ PD to 12 PD, loose prisms range from 5 PD to 60 PD while prism bars range from 1 PD to 40 PD. Fresnel prisms range from 1 PD to 40 PD.

When deviation exceeds the largest amount of prism available, stacking of prisms over one another is not recommended because light entering the second and subsequent prisms is not at the correct incident angle, thus the

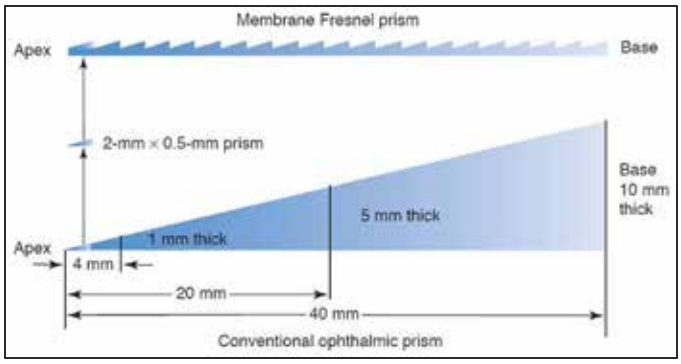

Figure 5: *Fresnel Prism*
(Image source: *Redrawn from Duane TD, ed. Clinical Ophthalmology. Hagerstown, MD: Harper & Row; 1976: vol 1, chap 52, fig 52-2)*

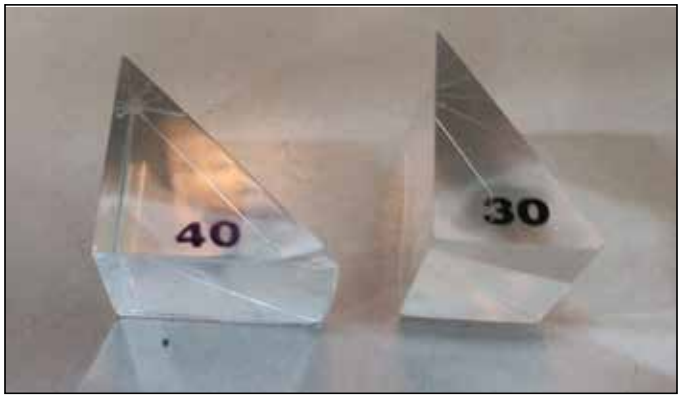

Figure 6: *Loose prisms*

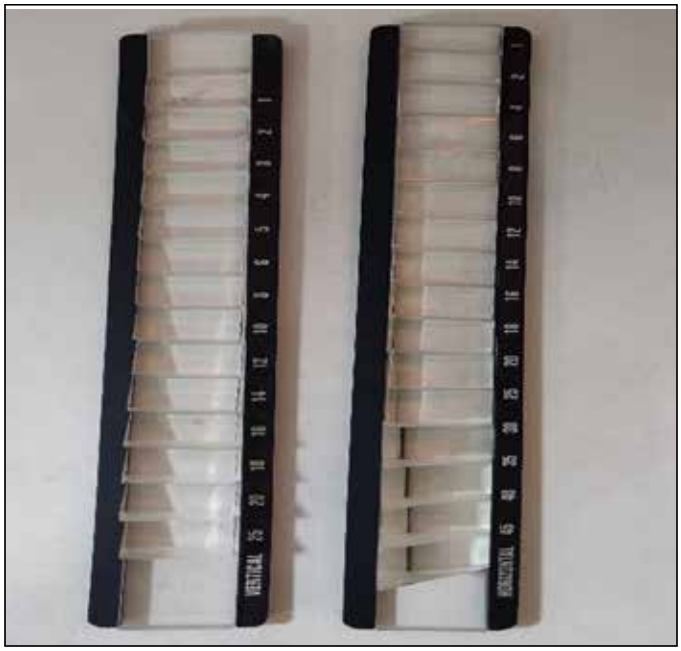

Figure 7: *Prism bars with vertical and horizontal prisms*

effective power of such a stack will be significantly different from the sum of powers of individual prisms. In such cases, prisms can be split between the two eyes (Figure 9) but even then, measurement is slightly different from the sum of the powers of the two prisms. (Table 1) gives the combined effect of different pairs of prisms held in front of the two eyes.[4] On the other hand, a vertical and a horizontal prism can be stacked in front of each other as their planes of refraction

Figure 8: *Prisms in trial set*

Figure 9: *Splitting of prism between two eyes when deviation exceeds the largest amount of prism available*

are perpendicular and therefore independent of one another.

For therapeutic purposes, prisms can either be worn temporarily in the form of clip-on spectacle prism for trial wear or they can be worn permanently by incorporation of prism into patient's spectacles by either grounding them into a spectacle lens or decentring the spherical lenses already present. The prismatic effect of spherical lenses is given by the Prentice rule which states that the prismatic power of a lens at any point on its surface is equal to the distance from its optical centre in centimetres times the power of the lens in diopters.

Clinical Applications Of Prisms

Prisms in ophthalmic instruments

Prisms are commonly used in ophthalmic instruments as reflectors of light. The common instruments in which prisms are used are as follows:

- Synaptophore
- Direct ophthalmoscope
- Indirect ophthalmoscope
- Operating microscope
- Slit lamp microscope
- Goldmann applanation tonometer
- Stereoscopes
- Pachymeter
- Keratometer
- Haidinger brushes
- Exophthalmometer
- Pupillometer

Prisms in Strabismus

Another important application of prisms is in the field of strabismus. Various tests have been described for the diagnosis and measurement of squint to aid in correct surgical planning. Some of the tests have been discussed here briefly.

1) Prism Alternate Cover test

The prism alternate cover test is the gold standard to measure the angle of deviation on near or distance fixation and in any gaze position. Prisms of increasing strength are placed in front of one eye with the apex pointed in the direction of deviation (that is base-in prism for exotropia, base-out prism for esotropia, base-up prism for hypotropia and base-down prism for hypertropia). The alternate cover test is performed continuously as stronger prisms are introduced, the amplitude of refixation movement should gradually decrease as the strength of prism approaches the extent of deviation (Figure 10). The end point is reached when no movement is seen. The strength of the prism at this position gives the angle of deviation.

2) Krimsky Test

In this test prism is placed in front of the deviating eye (with its apex towards the deviation) to correct the deviation of the corneal light reflex. The strabismus measurement is equal to the amount of prism necessary to centre the corneal light reflex on the pupil of the deviating eye.

3) Modified Krimsky Test

This test is similar to Krimsky test, with the only difference that here the prism is placed in front of the fixating eye to centre the corneal light reflex on the pupil of the deviating eye. The advantage of this technique is better visualisation of the light reflex in the deviating eye as it is not covered by the prism.

Table 1: Deviation in prism diopters for the addition of two prisms (glass or plastic) with one prism held in front of each eye.

Left eye prism (labeled value in prism diopters)	Right eye prism (labeled value in prism diopters)											
	10	12	14	16	18	20	25	30	35	40	45	50
10	20	22	24	26	29	31	36	41	47	52	58	63
12	22	24	26	29	31	33	38	44	49	55	60	66
14	24	26	29	31	33	35	40	46	52	57	63	69
16	26	29	31	33	35	37	43	48	54	60	66	72
18	29	31	33	35	37	39	45	51	57	63	69	75
20	31	33	35	37	39	42	47	53	59	65	71	78
25	36	38	40	43	45	47	53	59	66	72	79	86
30	41	44	46	48	51	53	59	66	73	80	87	94
35	47	49	52	54	57	59	66	73	80	87	95	103
40	52	55	57	60	63	65	72	80	87	95	104	113
45	58	60	63	66	69	71	79	87	95	104	113	123
50	63	66	69	72	75	78	86	94	103	113	123	133

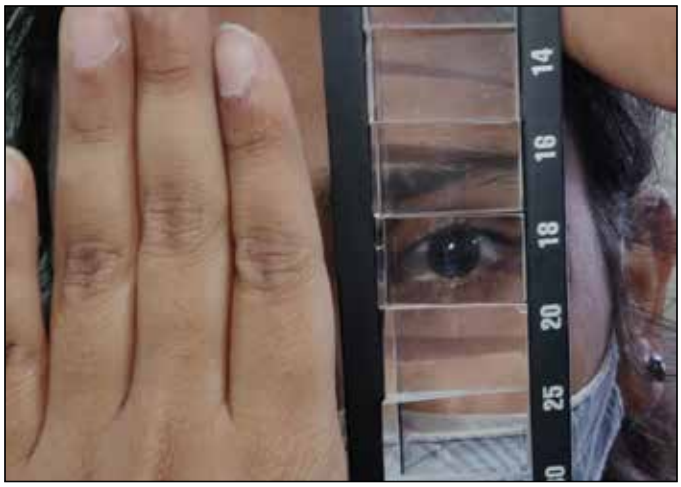

Figure 10: *Prism alternate cover test*

4) 4 Prism-Diopter Base-Out Test

This test is used to distinguish normal bifoveal fixation from foveal suppression/central suppression scotoma in microtropia. Herein, a 4 PD base-out prism (as microtropia is commonly esotropic) is placed in front of one eye which results in the deviation of image away from the fovea temporally. In case of normal bifoveal fixation a corrective movement is noted in both eyes in the direction of the prism apex followed by an opposite fusional re-fixation movement by the fellow eye not under prism.

In the presence of microtropia, 4 PD base-out prism is placed in front of the eye with suspected central suppression scotoma. As the image is moved temporally it falls within the central suppression scotoma and hence, no movement is observed in either eye. The prism is then moved to the other eye which adducts to maintain fixation and as per Hering's law, movement is also observed in the eye with central suppression scotoma, but no fusional refixation movement is observed in this eye as now the second image falls within the central suppression scotoma. (Figure 11)

5) Simultaneous Prism Cover Test

A prism of approximate power (as estimated by Hirschberg test) is placed in front of the deviating eye while an occluder is simultaneously placed over the fixing eye. The power of prism is increased till there is no refixation movement observed behind the prism.[5]

6) Prism Adaptation Test

Introduced by Jampolsky, this test is performed preoperatively in acquired esotropia as well as intermittent exotropia to determine the maximum angle of strabismus and fusional potential. Herein, a prism is introduced in front of the deviating eye (with apex towards the deviation) so as to first correct the deviation. The prisms maybe required to be used for longer periods varying from few hours to days. While some patients show no further movement others might eat-up the prism with re-establishment of the deviation. In such cases the prism power is increased till the deviation is stable and the amount of surgery is augmented in accordance with the amount of increased prism adapted angle.[6,7]

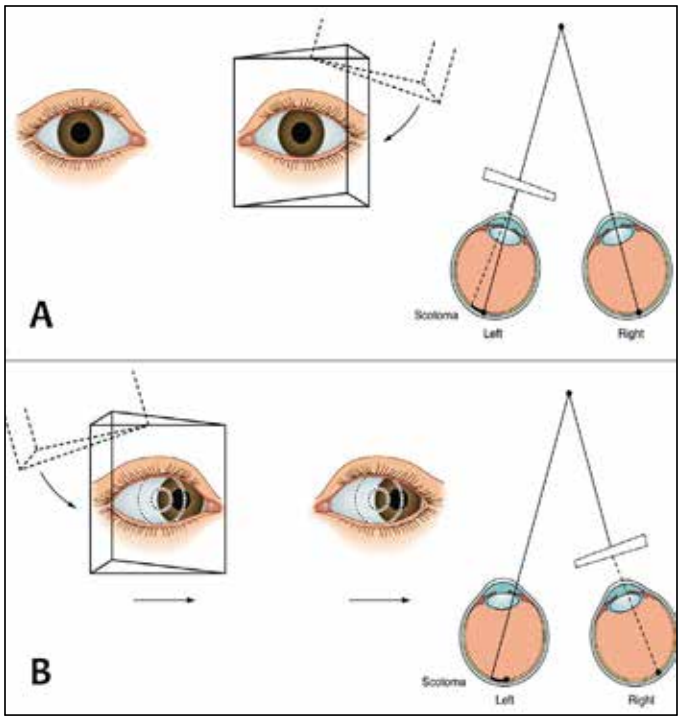

Figure 11: *4 PD base-out test in left microtropia with central suppression scotoma.* ***(A)*** *No movement of either eye* ***(B)*** *Both eyes move to the left but there is absence of re-fixation. (Image source: Bowling, B. (2015). Kanski's clinical ophthalmology (8th ed.). W B Saunders, chapter 18, fig. 18.27.)*

Apart from these diagnostic uses, prisms are also used in the treatment of many conditions as discussed below.

7) Prisms To Relieve Diplopia

Prisms are used to relieve diplopia and increase the field of binocular single vision in patients with incomitant strabismus like acquired third, fourth or sixth cranial nerve palsies as well as in acute acquired comitant esotropia, decompensated heterophoria and convergence insufficiency. These prisms also stimulate the unaffected antagonistic muscle in paralytic strabismus, thereby preventing its secondary contracture.[8]

8) Orthoptic Exercises

Orthoptic exercises have been an established part of therapy for heterophoria, intermittent strabismus, convergence insufficiency and accommodative problems for many years. Adverse prisms, that is, prisms with their base towards direction of deviation are prescribed for giving exercise to weak muscles.[9]

9) Prisms In Treatment Of Phorias And Tropias

Prisms are more commonly used for the treatment of heterophorias than tropias. They can be used both for esophoria as well as exophoria with their apex pointing towards direction of deviation. An accurate cycloplegic refraction followed by prescription of appropriate glasses should be done first and then the minimum power of prism that eliminates symptoms should be prescribed.

10) Prisms For Abnormal Head Posture

Patients with nystagmus often adopt an anomalous head posture to place their eyes in null position. Prisms which place eyes in such position can be prescribed to these

patients to abolish anomalous head posture. A trial of prisms can be given before surgery or in cases where surgery is contraindicated.

Patients with head or neck positioning problems, such as patients with severe ankylosing spondylitis, may also benefit from prisms. In patients with an orthopedic chin-down posture, for example, bilateral equal-power, base-up yoked prisms can allow for improvement in straight-ahead vision and thereby facilitate mobility.

Prisms As Low Vision Aids

Prisms can be tried in patients with hemianopia or tubular vision due to advanced glaucoma or retinitis pigmentosa. Prisms are used to reorient the visual field such that images from the area of visual field defect are brought to areas where vision is intact. Prisms have also been used for redirection of incoming images towards the preferred retinal loci (PRLs) for restitution of potential visual acuity (PVA) in low vision cases with age-related macular degeneration.[10]

Prisms In Patients with Hemispatial Neglect

Recent studies have shown that yoked prisms which move both visual fields to the opposite side improve function in patients with hemispatial neglect. The mechanism for this improvement is believed to be that, in order to compensate for the shifted binocular visual field, the patient must remap his or her sensorimotor coordinates, and this has been shown to improve function on the neglected side.[11]

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