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Measurement Errors Induced by Inaccurate Positioning of Ophthalmic Prisms and a Simple Way to Minimize Them

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Abstract: *Purpose:* Ophthalmic prisms are routinely used to measure ocular deviation. However, large measurement errors could be induced when a prism is not accurately positioned at its calibration position. We report a simple way to minimize the errors. *Methods:* We measured powers of prisms and plastic prisms at their calibration position and at angles the prism was rotated away from the calibration position. Glass prisms that have power of 20, 25, 30, 40, 50, and 60 prism diopters (PD) and plastic prisms that has power of 20, 25, 30, 35, 40, 45, 50 PD were used. To minimize the errors, we developed a pair of prism frame so that the prism can always be positioned accurately. *Results:* We have demonstrated large errors induced by rotating glass prisms and plastic prism away from their calibration position. Larger errors were recorded with glass prisms than with plastic prisms. The measurement errors are significant even with a small angle rotation for a large power glass prism. For instance, a 10-degrees rotation of a 50PD glass prism produces an error of 30PD. However, measurements errors were minimized when the prism frame was used. *Conclusion:* It suggests that the glass ophthalmic prism should be abandoned and the use of ophthalmic prisms in strabismus measurement should be standardized with assistance of the prism frame.

Keywords: Ophthalmic Prisms, Strabismus, Ocular Deviation

1. Introduction

Ophthalmic prisms are routinely used to measure ocular deviations and to determine the amount of correction in strabismus surgeries. Inaccurate measurement of ocular deviation could lead to over-correction or under-correction of strabismus. However, measurement deviation errors can be induced when a prism is not held at a calibrated position. This problem was pointed out long time ago and all authors focused on theoretical calculation [1-3]. Authors in a recent review paper summarized the issues related to this problem [4]. However, there has been no efficient solution to the problem.

Glass prisms are calibrated in the Prentice position where their posterior surface is perpendicular to the line of sight of the deviated eye. Plastic prisms are calibrated in the minimum deviation position where symmetric prismatic deviation occurs at each of the two faces. Frontal plane position is the position where the posterior face of the prism is perpendicular to the direction of the fixation target along the line of sight. Actually, the two kinds of prisms are commonly held to let their posterior face parallel to the frontal plane in the clinical practice because of its convenience. This position is not a Prentice position for glass prisms because the line of sight of a deviated eye is not perpendicular to the posterior surface of the glass prisms. Thus, when a glass prism is held in the frontal plane position, large measurement errors can be induced. Not only may these errors lead to under-correction or over-correction in strabismus surgery, but also the measurement errors cause confusion in international communication when different prisms are used in different countries.

Because different calibration positions are required for the plastic and glass prisms, the sizes of the deviations measured by two kinds of prisms are systematically different when they are both held in the frontal plane position. The surgical dosages determined by measurement of plastic prisms can be misleading to an ophthalmologist who usually use glass prisms.

In some countries, glass prisms are still widely used. It takes many years for younger ophthalmologists to adapt the systematic difference by errors and trials.

In addition to the above systematic errors, inaccurate positioning of prisms causes randomized errors. The randomized errors may cause unexpected results in strabismus surgery. Thus, it is important to position the prisms accurately. However, it is difficult to eliminate the errors because prisms are usually held with a hand.

To minimize the errors, we have developed a pair of prism frame that allows prisms to be precisely positioned and steadily held. In this paper, we will demonstrate the optical measurement errors and introduce the prism frame. This work has been reported at an annual meeting of American Association for Pediatric Ophthalmology and Strabismus [5].

2. Materials and Methods

2.1. Measurement of the Prisms Power

We used following prism calibration settings to perform optical measurements for glass prisms and plastic prisms. See Figure 1. In these settings, one centimeter deflection of the laser beam is one prism diopter (PD) when a prism is placed at its calibration position. In Figure 1A, a glass prism is positioned at Prentice position. It is necessary to point out that the glass prism is not at the Prentice position when it is held like this in the frontal plane position because the measured eye is deviated and the posterior surface is not perpendicular to the line of sight of the deviating eye. In Figure 1B, a plastic prism is set at minimum deviation position. In Figure 1C, a plastic prism is positioned at the frontal plane position. In fact, the measured eye is always deviated to the side of sharp angle of the prism in this situation, so the prisms are always at the minimum deviation positions. See details in the Figure 1.

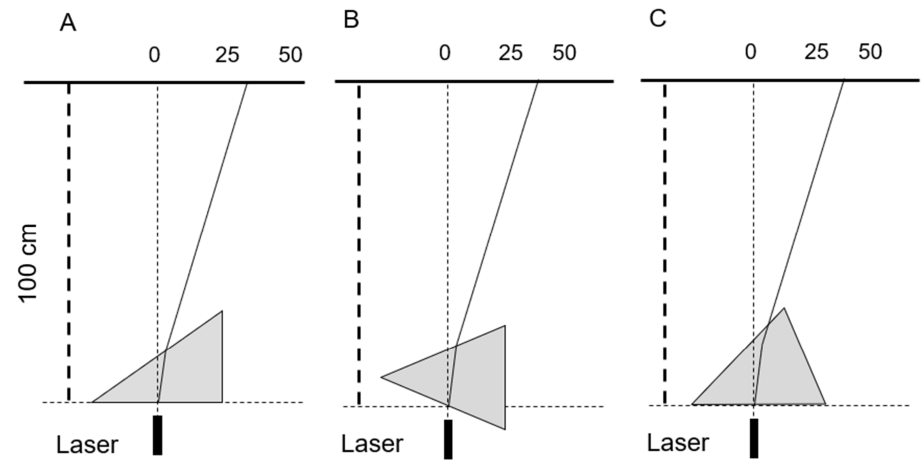

Figure 1. *Settings for prism measurement. A laser pointer was positioned 1 meter away from a screen that has marks in centimeters and prisms were placed next to the laser pointer. The glass prism is positioned at Prentice position (A) and a plastic prism at minimum deviation position (B). In clinical practice, the two kinds of prisms are positioned at the frontal plane position (C). The power of a prism can be read directly from the screen.*

By clockwise and anti-clockwise rotating a glass prism from Prentice position, or clockwise and anti-clockwise rotating a plastic prism from the minimum deviation position, the powers of glass and plastic prisms were recorded. A step of a prism rotation is 10 degrees. The measured powers of the prisms were shown in Table 1 and table 2 in the next section.

2.2. The Prism Frame

The prism frame consists of a pair of spectacle frame, a metal bar, and two magnetic discs mounted on the bar. A small piece of metal is glued to the bottom of a prism. The frame allows a prism to be precisely positioned at different angles as needed. The prism can be horizontally rotated so that deviation at any secondary eye position can be measured, and the bar can also be rotated so that tropia can be measured at up gaze and down gaze. (see Figure 2). In combination of bar and prism rotations, any tertiary position can also be reached.

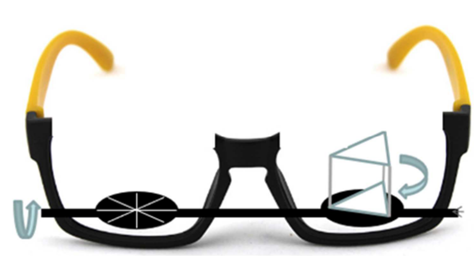

Figure 2. *A diagram of the prism frame. A metal coronal bar is mounted on a pair of glass frame and magnetic discs are fixed to the bar. A small piece of metal is glued to the bottom of a prism so that the prisms can be firmly held. The curved arrows indicate the horizontal rotations of the prism and vertical rotation around the coronal bar.*

3. Results

The power of glass prisms increased and decreased significantly when the glass prisms were rotated away from

Prentice position to each side. The power of the plastic prisms moderately increased or decreased when they were rotated away from the frontal plane position. The measured data are listed in table 1 for glass prism and in table 2 for plastic prisms.

Table 1. *Measured prism power at varied rotations of glass prisms.*

Degrees of Prism Rotations/°	Powers of Prisms/PD					
	20	25	30	40	50	60
30	20	24	25	32	36	38
20	19	22.5	26	32	36	38
10	19	22.5	25	33	40	43
0	20	25	30	40	50	60
-10	24	29	37	60	80	90
-20	28	34	55	80		

In the table 1 and table 2, the first column is the degrees of prism rotations. The first row contains powers of prisms used for the measurement, and all others are measured values in prism diopters. For example, a 50 PD glass prism has a measured power of 80PD when it is anti-clockwise rotated by 10 degrees, see details in table 1. That means the error is 30 PD. However, the same amount of rotation of a plastic prism will show a power of 57 PD (table 2). The error is only 7 PD.

Table 2. *Measured prism power at varied rotations of plastic prisms.*

Degrees of Prism Rotations/°	Powers of Prisms/PD						
	20	25	30	35	40	45	50
30	23	31	42	45	51	55	60
20	21	27	36	40	46	49	53
10	20	25	31.5	36	41	45	50
0	20	25	30	35	40	45	50
-10	21	25	30	35	42	47	57
-20	25	27.5	31.5	40	47	58	80

To better demonstrate the effects of the prism rotations, we also presented the data in Figure 3. As it is shown in Figure 3A, a prism of 60 PD can produce a power of 90 PD if it is rotated away from Prentice position by 10 degrees. That means the errors are 30 prism diopters.

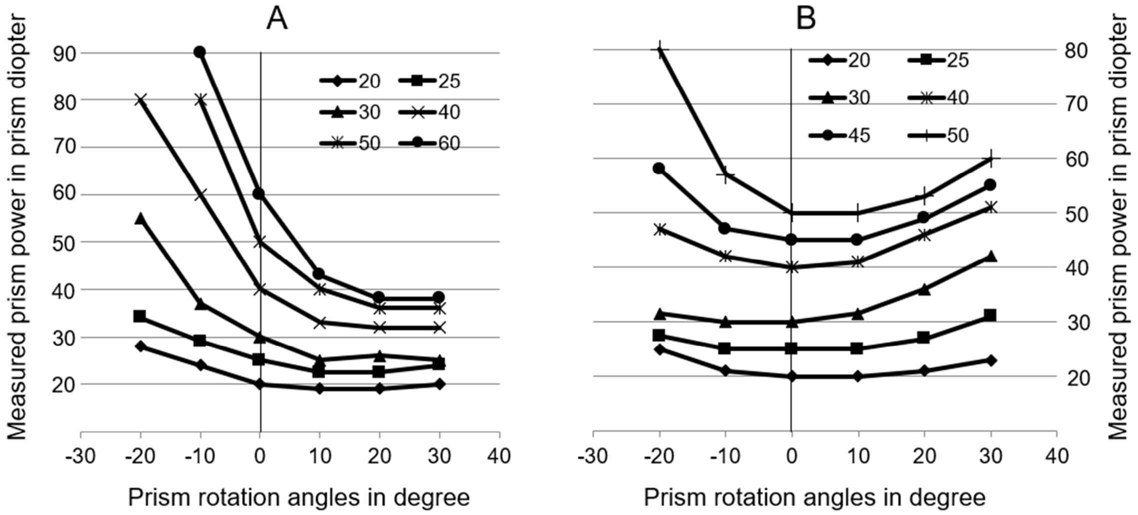

Figure 3. *Measured power of prisms at different angles of prism rotations. Power of large glass prisms significantly increased or decreased when the prism rotated a small angle away from the initial position (A). Power of plastic prisms also changed when the prism rotated, but with a mild degree (B).*

Similar, but smaller changes were obtained with plastic prisms. See Figure 3B for the plastic prisms.

It is also clearly shown that the measured powers are accurate as long as the prisms are accurately positioned, meaning errors are minimized. This can be seen in the two tables and Figures. For example, the 60 PD prism has a power of 60 PD if it is not rotated away from the 0-degree position (calibrated position).

4. Discussion

The measurement errors in the use of optical prisms were pointed out [1-4, 6-9]. However, there is no solution to this issue, and attention has not been paid to the issue since the glass prims are still widely used in some countries. This is an important issue because the strabismus surgery plan is dependent on the measurement [10]. It is important to accurately position the prisms to avoid under-correction or over-correction of a deviation as pointed by von Noorden and Campos in their book chapter [6]. We have demonstrated that large measurement errors are produced when a large glass prism is anti-clockwise rotated by a small angle.

Clinically, the prisms are always held in the frontal plane position. with a glass prism, this position is not a Prentice position because the measured eye is deviating or the line of sight of the deviating eye is not perpendicular to the posterior surface of the glass prisms. Thus, when a glass prism is held in the frontal plane position, large measurement errors is induced. The problem is that these errors can not be avoid because clinically it is impossible to hold a glass prism at its calibrated position where the line of sight of the deviating eye is not perpendicular to the posterior surface of the glass prisms. To do that, the size of the deviation need to be known before the measurement takes place. The way that one can use glass prism is to learn by errors and trials and to adjust the dosage in performing large numbers of surgeries. Thus, we think the glass prisms have their fatal weakness in the clinical use.

Not only does the errors lead to under-correction or over-correction of strabismus, but also the errors cause confusion in international communication when ophthalmologists in different country use different prisms. In contrast, the measurement errors are much smaller in plastic prisms. Thus, we suggest that the glass prisms should not be used anymore due to the large errors they can produce.

In fact, it is difficult to accurately position a prism when a prism is held with an unsteady hand. There is no good solution in the literatures. To minimize the errors, we built a pair of prism frame. With the support of the prism frame, the measured prism power is equal to the labeled prism power as the prism can be accurately positioned. The results can be seen in the two tables and Figures. For example, the 60 PD prism has a power of 60 PD when it is not rotated away from the 0-degree position.

This means that accurate measurement can be achieved as long as the prism is in a correct position. The prism frame allows precise prism positioning so that the measurement errors can be minimized.

5. Conclusion

We have demonstrated systematic and randomized measurement errors induced by inaccurate positioning of the prisms, especially with the glass prisms. Thus, we suggest that the glass prisms should be abandoned. To minimize the measurement errors, we built a pair of prism frame. The measurement results show that the frame works well in holding prisms in an accurate position.

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Biography

Dongsheng Yang, Corresponding Author is an ophthalmologist at Shandong Liangkang Eye Hospital. He received his MS degrees in ophthalmology in 1992, and his PhD in vision science from Chinese Academy of Sciences in 1997. He did postdoctoral research at NEI of NIH. He worked as an assistant and associate professor at the University of Pittsburgh and Northeast Ohio Medical University. He published about 40 journal papers. His research interests include binocular vision and eye movement disorders.