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A combination horizontal/vertical prism bar

A precisely calibrated tool for use in front of one eye

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Abstract The authors used an optical bench to investigate calibration and errors from improper positioning of prism bars manufactured by R.O. Gulden and Luneau. They urged Gulden to redesign its prism bars to be used back-to-back in front of one eye. The horizontal bar is held with its flat face posteriorly within a channel on the flat face of the vertical bar; the interface is positioned perpendicular to the direction of the fixation object, which demands that the horizontal prism bar be calibrated in the frontal plane position and the vertical bar in the Prentice position. Analysis of calibration demonstrated that Gulden's new combination horizontal/vertical prism bar can be used without significant error (within ± 0.5Δ of labelled values). Gulden's old vertical prism bar is also calibrated in the Prentice position. Luneau's horizontal and vertical prism bars are calibrated close to the frontal plane position (within ±1.0Δ and ±0.4Δ respectively). Improper positioning demonstrated an increasing error with larger prisms. Luneau's 25Δ segment measured 27.8Δ in the Prentice position, the 40Δ segment 67.5Δ. The 25Δ segment of Gulden's new and old vertical prism bars measured 23.25Δ in the frontal plane position. Gulden's vertical prism bars should always be held with the flat surface toward the examiner. Luneau's horizontal and vertical prism bars should be held one in front of each eye when used simultaneously; thus, neither eye is looking directly at the fixation object and defining primary and secondary deviations is not possible.

Key words Prism bar; prismatic deviation; strabismus; measurement; surgery

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The combination horizontal/vertical prism bar is manufactured by Gulden Ophthalmics, 225 Cadwalader Avenue, Elkins Park, PA 19117-2097. The Luneau prism bars are manufactured by Luneau Ophtalmologie, B.P. 252, 28005 Chartres Cedex, France. The authors have no proprietary or financial interest in these products or in the companies involved.

Introduction

Errors in measurement of an ocular deviation can occur if prisms are held in a position for which they are not calibrated,[1-3] and this fact may help explain variable results in strabismus surgery.

There are three commonly used positions of prisms, each with a different effect on the deviation measured (Fig. 1). The first is the *Prentice position*, where the line of sight bends only at one face of the prism and strikes the opposite face at right angles.[4] The second is the *minimum deviation position*,

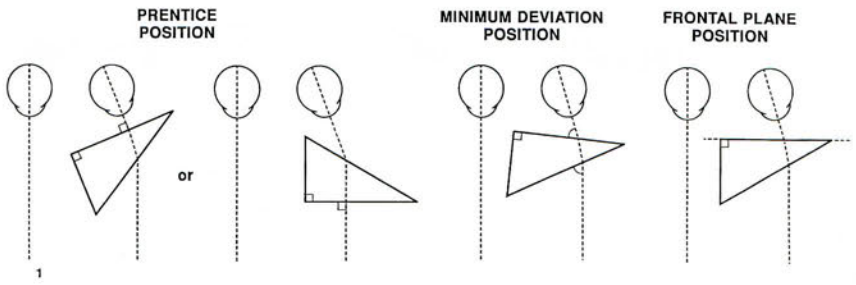

Fig. 1. In the *Prentice position* the light bends at one face of the prism only. At the opposite face the light ray is perpendicular to the surface of the prism. In the *minimum deviation position* light bends equally at the two faces of the prism. In any other position the angle of deviation is greater. In the *frontal plane position* the posterior face of the prism is held parallel to the frontal plane. Light bends slightly asymmetrically at the two faces of the prism.

where the line of sight bends symmetrically at the two faces of the prism and travels inside the prism perpendicular to the line bisecting the apex angle. The third is the *frontal plane position*, where the posterior face of the prism is held perpendicular to the line of sight anterior to the prism (perpendicular to the direction of the fixation object); this position has been advocated by Thompson and Guyton because the posterior face of the prism can be positioned conveniently in the frontal plane for distance measurements in primary position;[1] for measurements at near and for measurements in the diagnostic positions of gaze, however, the prism should be rotated away from the frontal plane of the patient's head so that the posterior face of the prism remains perpendicular to the direction of the fixation object.[5,6]

Single plastic prisms are calibrated in the minimum deviation position[7] but are most practically held in the frontal plane position.[1] Glass prisms are calibrated in the Prentice position. The calibration of prism bars is not well standardized, and they are often held in positions that are convenient rather than necessarily accurate. If only one prism bar is used to measure either a horizontal or a vertical deviation, the bar is usually held in the frontal plane position. But, if horizontal and vertical prism bars are used in front of the same eye, the prism bars are most conveniently held back-to-back. The rear prism bar, being reversed from the usual position, will give an erroneous measurement.

In this study we determined the calibration and correct position of various prism bars manufactured by two companies, R.O. Gulden and Luneau. We also measured the errors arising from improper positioning of the various prism bars, and we urged Gulden to design a new combination horizontal/vertical prism bar with the appropriate calibration for use in front of one eye.

Materials and methods The new combination horizontal/vertical prism bar is held with the horizontal prism bar anteriorly and the vertical prism bar toward the patient. The horizontal prism bar slides vertically within a channel created by rails along the flat surface of the vertical prism bar (Fig. 2). The flat surfaces of both prism bars are thus held perpendicular to the direction of the fixation object, which demands that the horizontal prism bar be calibrated precisely in the frontal plane position, and the vertical prism bar in the Prentice position.

We used an optical bench to investigate calibration of various prism bars and errors arising from improper positioning (Fig. 3). The various prism bars were placed at the designated angular position exactly 1m from a horizontal centimeter scale, and the deviation of a 1.0 mW HeNe laser beam induced by each prism was read directly from the centimeter scale.

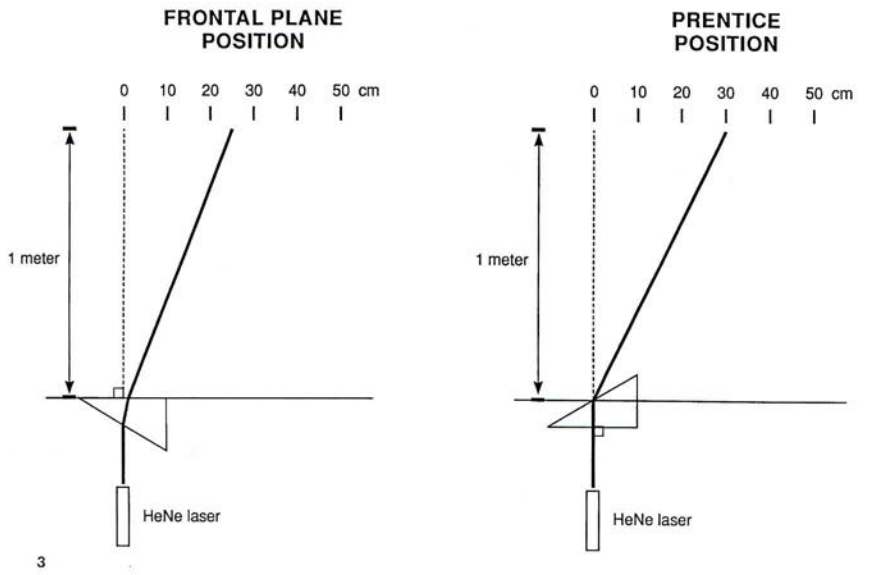

Fig. 2. Gulden's new combination horizontal/vertical prism bar: the horizontal bar is held with its flat face posteriorly within a channel on the flat face of the vertical bar. The interface is positioned perpendicular to the direction of the fixation target.

Fig. 3. Optical bench arrangement to investigate calibration of various prism bars.

Results Table 1 shows the measurements of the old and redesigned prism bars manufactured by Gulden and of the horizontal and vertical prism bars manufactured by Luneau. From the deviations measured at the designated angular positions, one can determine the position of the prism bar intended by the manufacturer and the deviations produced by positioning the prism bars incorrectly. Measurements of the combination horizontal/vertical prism bar designed by Gulden and of the horizontal and vertical prism bars designed by Luneau are plotted in the graphs of Figs. 4 and 5. One can easily recognize the intended position of calibration of the various prism bars by the plot that is closer to the line designating the intended deviation by the manufacturer. A given prism segment in the Prentice position produces a larger deviation than in the frontal plane position and the difference of prismatic deviation produced at the two angular positions increases progressively for larger prisms. It is readily apparent that significant errors result from incorrect positioning only for values of 20Δ or higher.

One can see that the old horizontal prism bar manufactured by Gulden is calibrated in the minimum deviation position, because when held in the frontal plane position larger prisms produce slightly larger deviations than their labelled values; the maximum is reached with the 40Δ segment which produces a 41.8Δ deviation (Table 1). Following our suggestion, Gulden redesigned its horizontal prism bar to be calibrated precisely in the frontal plane position (measured deviations were within ±0.45Δ of labelled values), and the redesigned vertical prism bar is calibrated in the Prentice position (within ±0.5Δ). Gulden's old vertical prism bar has also always been calibrated in the Prentice position (a surprise to the Company). When both Gulden's old and new vertical prism bars are held by mistake in the frontal plane position, the 25Δ segment produces only 23.25Δ of deviation; in the Prentice position the 25Δ segment produces 25.4Δ or 25.5Δ of deviation.

The horizontal and vertical prism bars manufactured by Luneau, as we have determined, are calibrated close to the frontal plane position (within ±1.0Δ and ±0.4Δ respectively), and when held in the Prentice position, the 25Δ segment produces 27.75Δ or 27.8Δ of deviation and the 40Δ horizontal segment produces 67.5Δ of deviation.

TABLE 1. Measured deviations in prism diopters in the frontal plane and Prentice positions, versus the labelled values, for various prism bars.

Prism bars	*Labelled values*	*Measured deviations*					
		In frontal plane position			*In Prentice position*		
		Gulden new	*Gulden old*	*Luneau*	*Gulden new*	*Gulden old*	*Luneau*
	(PD)	*(PD)*	*(PD)*	*(PD)*	*(PD)*	*(PD)*	*(PD)*
h	1	1.15	0.85	1.0	1.1	0.8	0.8
o	2	2.25	1.9	2.0	2.2	1.9	1.9
r	4	4.1	4.05	3.9	4.0	4.0	3.8
i	6	5.9	6.0	5.9	5.9	5.9	5.8
z	8	7.9	7.9	7.9	8.0	7.85	7.8
o	10	9.9	10.0	9.9	10.1	10.1	9.9
n	12	12.1	12.0	11.9	12.3	12.2	12.1
t	14	14.1	14.0	13.95	14.5	14.45	14.2
a	16	16.3	16.15	15.8	17.0	16.9	16.4
l	18	18.4	18.25	17.8	18.4	19.2	18.6
	20	19.9	20.45	19.7	21.5	21.8	20.9
	25	25.0	25.5	24.7	28.4	28.75	27.75
	30	30.45	30.6	29.25	38.0	36.8	35.2
	35	35.3	36.6	34.1	48.5	50.2	45.6
	40	40.1	41.8	39.0	67.0	69.25	67.5
v	1	1.1	1.0	1.0	1.3	1.0	1.0
e	2	2.15	2.0	2.0	2.25	2.0	2.0
r	3	3.3	3.0	3.0	3.4	3.0	3.0
t	4	4.2	4.0	3.9	4.25	4.0	4.0
i	5	5.05	5.0	4.9	5.1	5.0	5.0
c	6	6.1	6.1	5.9	6.2	6.0	6.0
a	8	8.15	8.1	7.9	8.1	8.15	8.0
l	10	10.3	10.0	9.9	10.35	10.0	10.1
	12	12.2	11.9	11.9	12.35	12.2	12.35
	14	13.9	13.9	13.9	14.3	14.25	14.45
	16	15.8	15.7	15.6	16.25	16.1	16.5
	18	17.5	17.4	17.7	18.25	18.35	19.0
	20	19.3	19.2	19.8	20.55	20.3	21.4
	25	23.25	23.25	24.6	25.4	25.5	27.8

Discussion The amount of ocular deviation neutralized by an ophthalmic prism depends on how the prism is held with respect to the patient's line of sight.[1-3]

Prism bars are routinely held in various positions. When only one prism bar is used, it is most conveniently held in the 'frontal plane' position, that is with the posterior face perpendicular to the direction of the fixation object. But when the horizontal and the vertical prism bars are used simultaneously, they are usually held back-to-back in front of one eye. The light ray from the fixation object enters the front prism bar appropriately but enters the rear prism bar effectively at right angles, that is, in the Prentice position.

Gulden's new combination horizontal/vertical prism bar can be used in front of one eye without any significant error, with the interface held perpendicular to the fixation object (Table 1, Fig. 2). The horizontal prism bar is calibrated precisely in the frontal plane position (within ±0.45Δ); its flat face

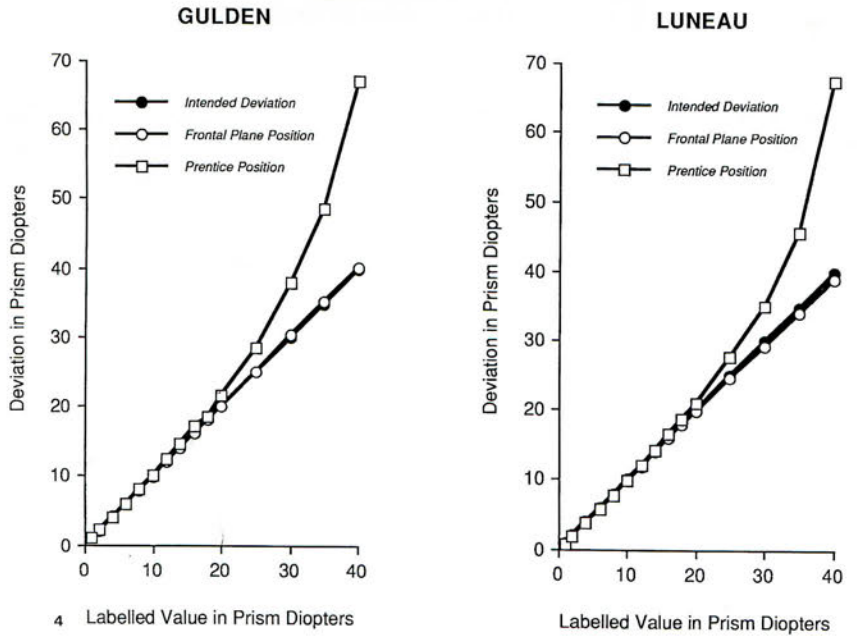

Fig. 4. Measured deviation in prism diopters in the frontal plane and Prentice positions, versus the intended deviations, for Gulden's redesigned horizontal prism bar (left) and Luneau's horizontal prism bar (right).

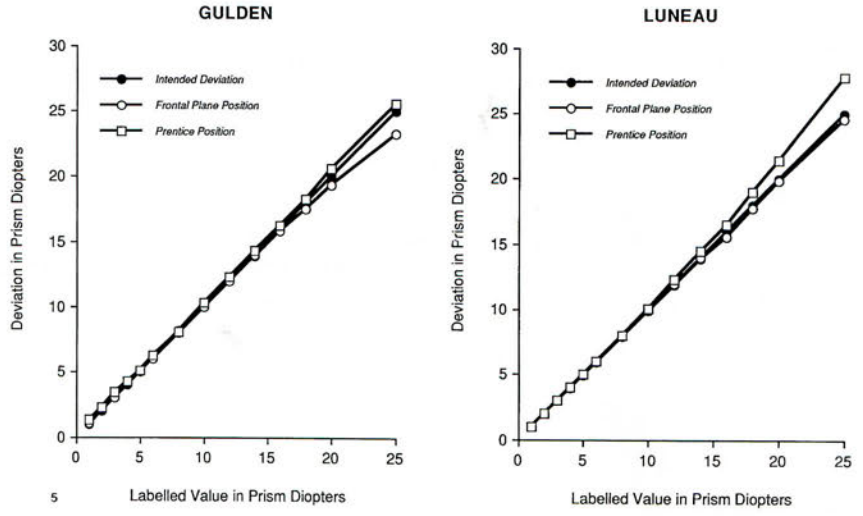

Fig. 5. Measured deviation in prism diopters in the frontal plane and Prentice positions, versus the intended deviations, for Gulden's redesigned vertical prism bar (left) and Luneau's vertical prism bar (right).

is held posteriorly within a channel on the flat surface of the vertical bar. This design ensures that the horizontal prism bar is not held with its flat face anteriorly, in which case large deviations would be grossly underestimated (a 67Δ ocular deviation would measure 40Δ). Gulden's new vertical prism bar is calibrated precisely in the Prentice position (within ±0.5Δ), and whether used in the combination or by itself, it should be held with the flat face anteriorly, toward the examiner.

As we discovered, Gulden's old vertical prism bar is also calibrated in the Prentice position. The old horizontal prism bar was determined to be calibrated in the minimum deviation position because when used in the frontal plane position prismatic deviation measured slightly more than the labelled values, at maximum 1.8 prism diopters more for the 40Δ segment (Table 1).

Luneau's horizontal and vertical prism bars, as we determined, are each calibrated close to the frontal plane position (within ±1.0Δ and 0.4Δ respec-

tively), and they should be held one in front of each eye when used simultaneously. As a consequence, however, neither eye is looking directly at the fixation object, and strictly defining primary and secondary deviations is not possible. If held back to back, with the vertical bar behind the horizontal bar, large vertical deviations will be slightly underestimated (a 27.8Δ ocular deviation will measure 25Δ), and if held back to back with the horizontal behind the vertical bar, large horizontal deviations will be grossly underestimated (a 67.5Δ deviation will measure 40Δ).

One might argue never to use prism bars at all, because they require different calibrations for the front and rear bars when used simultaneously and therefore have the risk of being interchanged and used in an incorrect angular position. But using horizontal and vertical prisms in front of one eye is a prerequisite for defining primary and secondary deviations when evaluating incomitant strabismus[8] and holding prism bars back to back together facilitates proper positioning of the prism segments during prism and cover testing. Only one plane, the interface between the prism bars, has to be positioned perpendicular to the direction of the fixation object, whereas with single plastic prisms the posterior face of each prism must be positioned correctly with respect to the patient's line of sight.

Errors from improper positioning occur when a prism bar calibrated in the frontal plane position is used in the Prentice position and *vice versa.* In the Prentice position a given prism produces a larger deviation than in the frontal plane position. The difference in prismatic deviation between these two angular positions becomes significant for prism values 20Δ or higher. For example incorrect positioning of the 25Δ segments results in an error from −1.75Δ to +3.75Δ (Table 1). This error in measurement of an ocular misalignment can lead to 1mm more or less rectus muscle surgery based on quantitative surgical guidelines.[9] Grading rectus muscle procedures based on millimeters of surgery per degree, or per prism diopter, of ocular deviation has improved accuracy and reproducibility of strabismus surgery.[9] Understanding the proper positioning of prisms and prism bars in measuring strabismic deviations may further improve surgical results.

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