Translation of the article
"**Übertragung prismatischer Korrektionen aus der Meßbrille in die Korrektionsbrille**",
which was published in Deutsche Optikerzeitung: DOZ 1992 No. 12, page 26-32.

Explanatory note: For the sake of convenience the German abbreviation dpt is used for dioptre instead of D.

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Transfer of prismatic corrections from the measuring frame into the spectacle frame*

1. Preface

In [1] important fundamentals of the prismatic effects of spectacle lenses had been explained. There it was illustrated that even when all until then available centration requirements are fulfilled the existing binocular-prismatic effect in the pair of visual points of the spectacle frame may differ more or less from the intended effect.
This incorrect binocular-prismatic effect could appear until now in particular with spectacles containing progressive-power lenses when a correct coordination between the centration of the trial lenses, the assumptions for calculating the correction lenses and the centration of the correction lenses did not exist.
Therefore in [1] proposals were submitted on how to possibly prevent these failures for the future. And the new "extended centre of rotation requirement" was established to that effect.
By way of discussions with different manufacturers of correction lenses in the past three years a system was developed with which the prismatic correction requirement can be fulfilled.
A measuring frame with for each side separately vertically adjustable trial lens supports is offered in the meantime [2].

Below several important concepts will be explained, the knowledge of which is necessary for the comprehension of the context. And it will be interpreted how in the new system the three segments on the way to prismatic spectacles will be performed in a correct manner, the three segments being centring of the trial lenses – calculation of the correction lenses – centring of the correction lenses.

* According to a lecture at WVAO-Congress 1992 in Cologne

2. Concepts

Starting point of any accurate refraction procedure, performed with a measuring frame, is the exact centration of the trial lens supports relative to the eyes of the test person. Basis for that is the straight ahead gaze direction of the single eye without trial lenses.

"Straight ahead gaze direction of the eye"
Direction of gaze horizontally straight ahead with unstrained posture of head and body at monocular vision.

The orientation of the geometric centre of the aperture of each side of the measuring frame to the centre of the eye in question is called pupil centre-centration.

"Pupil centre-centration" (abbreviated PCC)
The geometric centre of the aperture of each side of the measuring frame, respectively the reference point of each correction lens, is positioned in front of the pupil centre at straight ahead gaze direction of the eye.

The reference point is defined in a DIN standard of concepts, namely in [3, Lfd. Nr 6].

"Reference point"
Point on the object side area of a spectacle lens in which the required dioptric effect is to be reached.

The reference point has to be marked by the manufacturer of the correction lens. The prescribed spherical and when indicated also astigmatic power clearly emanates from the refraction procedure. The prescribed prismatic power has to be the power at the visual point of the trial lenses arranged in a row when looking upon the distant test chart, and that applies irrespective of the adjustment of the measuring frame.

The most important bundle of rays in vision is the one that images the object point which is looked at in the fovea centre, the so-called centrally imaging bundle. The most important ray in every bundle of rays is the chief ray. The chief ray of the centrally imaging bundle is called central chief ray [4].

"Central chief ray"
Chief ray of that particular bundle of rays which forms the image in the fovea centre.

When looking through any point of a spectacle lens, with the exception of looking through the optical centre, the central chief ray will be deviated from its original direction. When the visual point of a spectacle lens includes a prismatic power, than the direction of the central chief ray equals that of the visual axis only between the visual point and the eye, which is shown in figure 1.

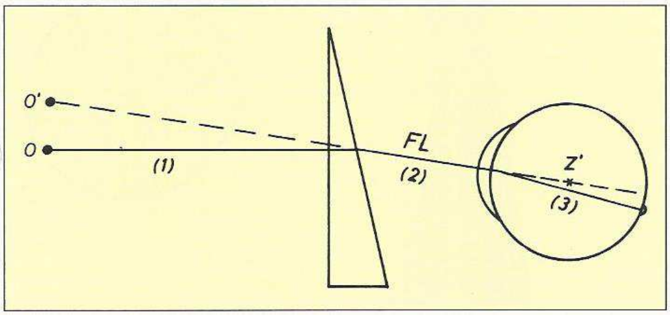

Fig. 1: Gaze through the reference point of a spectacle lens when there is a prismatic power, and when the extended centre of rotation requirement is achieved.
O: fixated object point; O': image point produced by the spectacle lens; FL: visual axis; Z': optical ocular centre of rotation; (1), (2), (3): path of the central chief ray.

When looking at a very distant object point the central chief rays of both eyes are practically parallel to each other in front of the spectacle lenses when there is a bicentral image formation, that is when the images are simultaneously located in the fovea centres of both eyes. When this object point is located horizontally straight ahead in front of the eyes, then it is the straight ahead gaze direction with spectacles.

"Straight ahead gaze direction with spectacles"
Direction of gaze straight ahead with parallel central object chief rays.

With a prismatic correction the visual axes of both eyes are no longer parallel to each other at straight ahead gaze direction with spectacles, which is shown in figure 2.

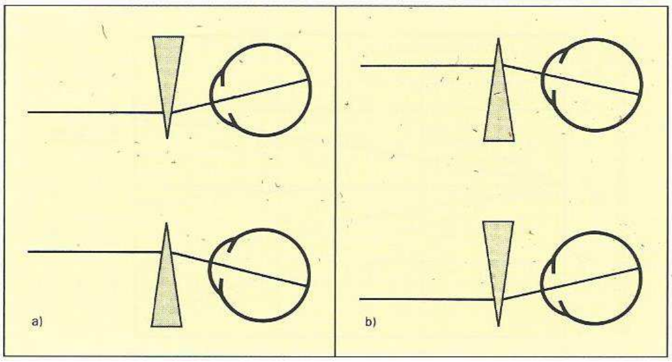

Fig. 2: Straight ahead gaze direction with spectacles containing prismatic fullcorrection for (a) Esophoria and (b) Exophoria.

This deviation from being parallel respectively from the straight ahead gaze direction of the eyes is in first approximation specified for each side by the rule for prism centring.

"Rule for prism centring"
Starting from the pupil centre-centration the aperture of each support of the measuring frame, respectively the reference point of each correction lens, has to be shifted by 0,25 mm per each prism dioptre against the base direction.

The binocular result from the refraction procedure will exactly be reproduced in the spectacles only when the prismatic correction requirement is achieved.

"Prismatic correction requirement"
At straight ahead gaze direction with spectacles the same binocular-prismatic power as in the pair of visual points of the measuring frame during refraction procedure has to exist in the visual points of the spectacles.

With conformance to the prismatic correction requirement the new extended centre of rotation requirement is of particular importance (see figure 1).

"Extended centre of rotation requirement"
A spectacle lens is centred correctly if the central object chief ray is perpendicular to the front surface of the lens when looking through the reference point.

Below the different approaches to comply with the prismatic correction requirement will be discussed.

3. Centration of Trial Lenses

The first step in the refraction procedure is to carry out the pupil centre-centration for each eye. If both eyes are in different height with unstrained posture of head and body it is compulsory to use a measuring frame with for each side separately vertically adjustable trial lens supports. For the subsequent measurement of associated heterophoria there are three different approaches to the adjustment of both sides of the measuring frame.

"PCC-Case"
The adjustment of the measuring frame according to the pupil centre-centration will remain unchanged during the complete refraction procedure.

In the PCC-Case the primary adjustment of the measuring frame, used in the first step for the monocular refraction procedure, will not be changed during the binocular eye examination. The disadvantage of this approach is that the prisms which are present in the measuring frame do not represent the true value of the associated heterophoria, this fact having already been illustrated in [1].

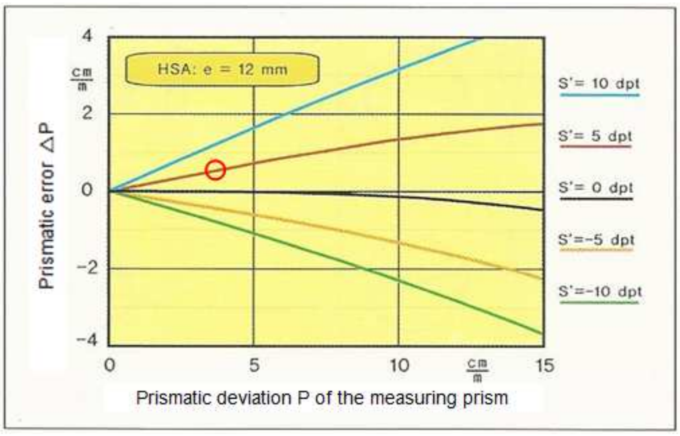

Fig. 3: Prismatic error △P as a function of the prismatic deviation P of the measuring prism and of the vertex power S' of the lens correcting the refractive error in the PCC-Case of the measuring frame calculated for a vertex distance (HSA) of 12 mm.

In figure 3, being valid for the single eye, the prismatic deviation P of the measuring prism is drawn to scale on the x-coordinate and the prismatic error $\triangle P$ on the y-coordinate, where $\triangle P$ is the difference between the angle W and the prismatic deviation P of the measuring prism, the angle W representing the deviation of the visual axis from the original straight ahead gaze direction of the eye without prism.

$$\boxed{\triangle P = W - P}$$

The vertex power S' of the trial lens with spherical vertex power, correcting the refractive error, serves as parameter in the diagram. As the prismatic error is also dependent on the distance between the centre of rotation and the lens vertex, this diagram is valid only for the vertex distance (HSA) specified above. With equal distribution of the prisms to both sides the prismatic error from figure 3 represents half of the difference between the sum of the present prismatic trial lenses and the real magnitude of the associated heterophoria. It can be gathered from the diagram that the magnitude of the associated heterophoria is larger than the sum of the present prismatic trial lenses with hyperopia, in contrast to myopia where it is smaller.

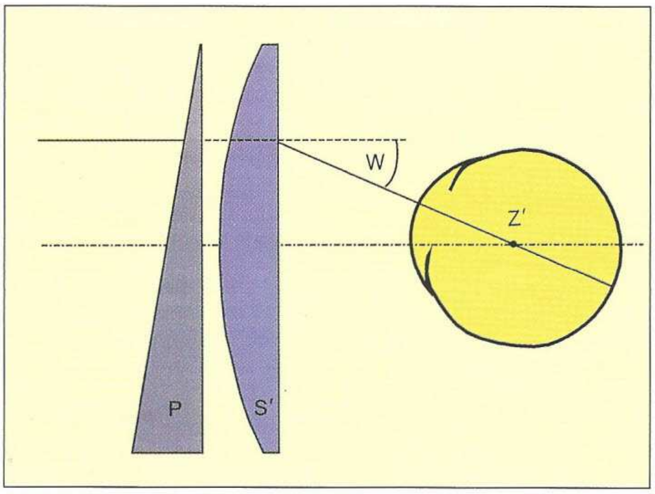

Fig. 4; "PCC-case" with hyperopia.
P: measuring prism; S': lens correcting the refractive error; W: angle between the visual axis of the eye and the optical axis of the lens S'.

In any case the prismatic error does not depend upon the direction of the associated heterophoria. The prismatic error only depends on the prismatic power at the visual point of the lens correcting the refractive error. With hyperopia the prismatic error is positive as the base position of the prismatic power in the visual point of the lens correcting the refractive error equals that of the measuring prism, which is illustrated in figure 4.
With myopia the prismatic error is negative because the base position of the prismatic power in the visual point of the lens correcting the refractive error is contrary to that of the measuring prism, which is illustrated in figure 5.

For example with both-sided hyperopia of 5 dpt and with a measuring prism of 3,5 cm/m on both sides the prismatic error already amounts to approximately 0,5 cm/mm for each side (see the red circle in figure 3). Thus the associated heterophoria amounts to 8 cm/m in this example, although there are just prisms of 7 cm/m in the measuring frame.

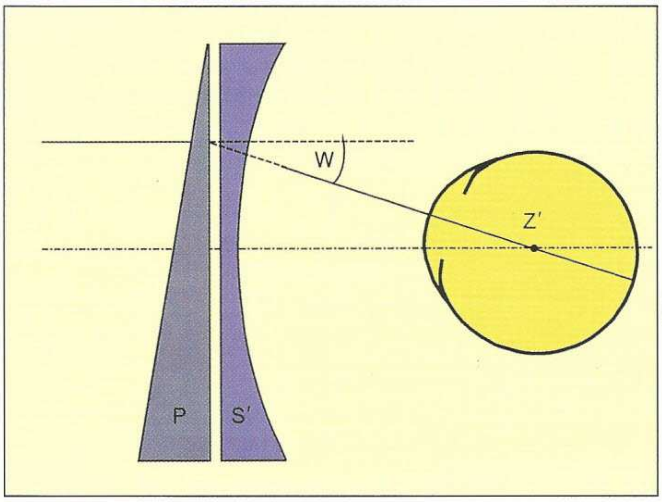

Fig. 5: "PCC-case" with myopia.
P: measuring prism; S': lens correcting the refractive error; W: angle between the visual axis of the eye and the optical axis of the lens S'.

"Formula-Case"
When inserting prisms in the measuring frame a deviation from the primary pupil centre-centration will be carried out according to the rule for prism centering, that is a displacement of 0,25 mm for each prism dioptre against the base direction.

In the Formula-Case of the measuring frame the primary pupil centre-centration will not be maintained during the binocular eye examination. In its place, when inserting measuring prisms, the centration will be changed for each side separately according to the rule for prism centring. When prisms with vertical base setting have to be used a measuring frame with for each side separately vertically adjustable trial lens supports is compulsory (figure 6).

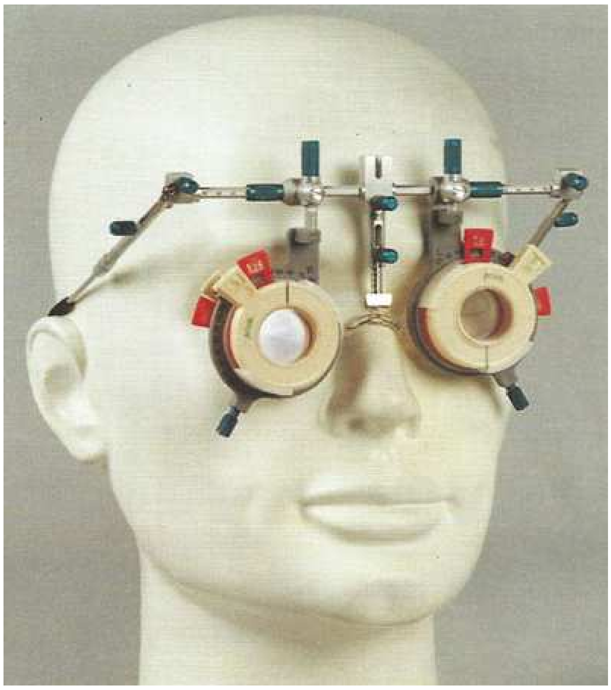

Fig. 6: Measuring frame with inserted vertical prisms when the trial lens supports of both sides are adjusted to different heights.

This approach makes sure that in good approximation each eye will gaze through the centre of the aperture of the measuring frame and thereby through the optical centre of the lenses, which correct the refractive error, so that these lenses do not cause an additional prismatic deviation of the central chief ray. Then all the prismatic deviation in the visual point is only due to the measuring prism.

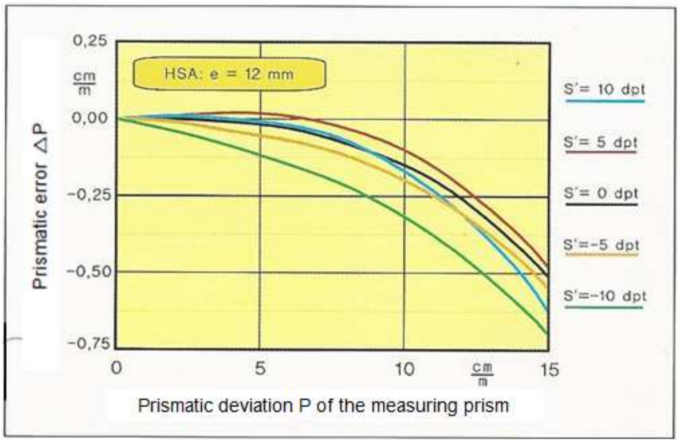

Fig. 7: Prismatic error △P as a function of the prismatic deviation P of the measuring prism and of the vertex power S' of the lens correcting the refractive error in the "Formula-Case" of the measuring frame calculated for a vertex distance (HSA) of 12 mm.

Figure 7 is constructed analogous to figure 3 and shows, taking account of the difference in the scale for the y-coordinate, that with refractive errors up to S' = ± 10 dpt the prismatic error △P remains smaller than ± 0,125 cm/m with measuring prisms up to 5 cm/m. Thereby for an associated heterophoria up to about 10 cm/m the prismatic error is insignificant when the Formula-Case is applied. In the earlier mentioned example of both-sided hyperopia of 5 dpt and with a measuring prism of 3,5 cm/m on both sides the prismatic error is practically nil when the Formula-Case is used; so that in this case the associated heterophoria actually amounts to 7 cm/m.

In the so-called "Special-Case" the adjustment of both sides of the measuring frame may be arbitrarily operated.

"Special-Case"
The adjustment of the measuring frame may be carried out according to any arbitrary requirement.

This approach considers the fact that there are a few pair of eyes which are so problematical to test binocularly that even with the best available measuring frame the Formula-Case cannot be carried out. If for instance a very large esophoria exists and in addition to a relatively small interpupillary distance there is a broad nose as well, than the necessary adjustment of each support of the measuring frame, containing base out prisms, in the direction of the nose according to the Formula-Case is no longer possible.

When the "Special-Case" is applied it is necessary to provide the lens manufacturer with as many data as possible, using a special order form for corrective lenses, so that the prismatic correction requirement can be fulfilled accurately.

4. Calculation of Correction Lenses

In order to calculate a correction lens every manufacturer has to make certain assumptions. What kind of assumptions had been used until now to calculate correction lenses with a prismatic power in the reference point had been pointed out in [1]. But regrettably it turned out that in some cases the binocular-prismatic power in the pair of visual points of the spectacles did not equal the intended power, and that was true even in spite of a conscientiously performed binocular refraction procedure.

When for instance the PCC-Case of the measuring frame was used in the refraction procedure and the lens manufacturer had calculated the correction lenses according to the PCC-Case, but the correction lenses in the spectacles were centred according to the rule for prism centering, then a wrong binocular-prismatic power in the pair of visual points of the finished spectacles was the result, particularly with progressive-power lenses. The error which thus is the consequence for each side corresponds to the prismatic error △P illustrated in figure 3 for prisms equally distributed to each side.

The prismatic correction requirement was only met when the correction lenses in the spectacles were centred in the very same manner as the trial lenses in the measuring frame. A peculiarity yielded for instance for prismatic progressive-power lenses when these were centred in the spectacles according to the rule for prism centring to fulfill the field of vision requirement. Then the intended binocular-prismatic power in the pair of visual points of the spectacles would have only been achieved when the measuring frame had been used according to the Formula-Case, because manufacturers used to calculate the lenses in accordance with the PCC-Case and up to now marked that point as reference point which corresponded to the centre of the measuring frame aperture.

For an accurate calculation of correction lenses with a prismatic power the lens manufacturer has to know first of all which case was used during the binocular refraction procedure, that is PCC-Case or Formula-Case, and secondly how the correction lenses shall be centred in the spectacles. In [1] it was suggested to take the Formula-Case, used with the measuring frame and with the final spectacles, as standard case for the calculation of prismatic power lenses. As the values for the vertex distance also take part in the lens calculation, it is necessary that the lens manufacturer will give the information about these values, for instance 12 mm for the measuring frame and 15 mm for the spectacles.

However, to enable the lens manufacturer to calculate the best possible prismatic power lens he will need additional information. The calculation will be the more accurate the more information the optometrist who performed the refraction procedure and later on will fabricate the spectacles provides for the manufacturer. Therefore the last two pages of this article provide a recommended order form for prismatic power lenses when the "Special-Case" had been applied. This order form consists of three chapters.

In the first chapter A of the order form details concerning power and arrangement of the trial lenses have to be provided. In the tables the values sph (spherical power), cyl (cylindrical power), A (cylinder axis), pr (prism power), B (prism base setting) and f / b (orientation of the prism bevel) have to be recorded for every single trial lens. In the adjacent draft to the right of each table six mounts for trial lenses are assumed, two behind the plane of the frame and four in front. This draft only serves for the correct correlation of the values in the table to the position of each trial lens in the row. For prismatic trial lenses the orientation of the prism bevel is important as well, and therefore it is necessary to state whether it is forward-facing as in figure 4 and figure 5 or backward-facing as in figure 1, and the applied direction has to be marked in the table as f or b. This is important as the opposite orientation of the bevel causes a significant difference for the path of rays and therefore for the calculation. Finally the corneal vertex distance (HSA) of the trial lens being nearest to the eye is important and should be supplied.

In the second chapter B of the order form details concerning the adjustment of the measuring frame have to be given. The necessary information have to be read off the scales of the measuring frame. These are in number 1 the data for the adjustment of the trial lenses at pupil centre-centration before prisms have been inserted, and in number 2 the data for the final centration present after the whole examination procedure had been finished. The centration distance for each side horizontal right (R) and left (L) is read off the scale in the usual way, but for vertical right (R) and left (L) up or down, which is relative to the zero point (centre point) of the vertical scale, the reading is only possible when a measuring frame with for each side separately vertically adjustable trial lens supports is available (see figure 6).

Important for the calculation of prismatic power lenses is the difference between the adjustments written down in number 1 and number 2 in connection with the trial lenses present in the measuring frame. As solely the difference between both adjustments is included in the calculation, the position of the zero point for both the horizontal and the vertical scale does not matter. The zero point for the horizontal direction lies customarily in the middle of the upper rim of the measuring frame.

An accurate calculation of lenses also requires that further geometrical details about the situation during the refraction procedure must be known. Therefore two more requirements have to be fulfilled to guarantee standard and reproducible circumstances. Firstly the horizontal orientation of the upper rim of the measuring frame has to be horizontally orientated with unstrained posture of head and body of the test person and secondly the pantoscopic tilt of the measuring frame has to be arranged in a way that the visual axis of the eyes will be perpendicular to the plane of the measuring frame when looking upon the distant test chart using the pupil centre-centration.

In the third chapter C of the order form details for the intended spectacle frame have to be provided. Apart from the pantoscopic tilt, the corneal lens plane distance with measuring film and the frame dimensions the position of the facet of the lens is of specific importance. For the calculation of lenses it is generally assumed that the extended centre of rotation requirement is fulfilled in the spectacles. But if anatomical reasons make it necessary to differ from that requirement it has to be indicated how the optometrist intends to orientate the bevel of the prismatic power lens, either backward-facing or forward-facing.

As the coordinates of the centration point [5, Lfd. Nr 13] relate to the boxed lens system [6], a deviation from the horizontal orientation of the spectacles has to be accounted for, if this is required from anatomic reason. In such a case modifications of the cylinder axis and of the prism base setting are essential. Therefore the deviation from the horizontal direction has to be stated in the order form. The easiest way to solve this problem is to work with a modern centring technology (for instance Video-Infral).

5. Centration of correction lenses

It was suggested in [1] to carry out the calculation of lenses for all types of lenses in such a way that all prismatic power lenses have to be centred with their marked reference point according to the rule for prism centring, irrespective of the PCC-Case or the Formula-Case having been used with the measuring frame. In this way the centration of correction lenses would not need different rules for different types of lenses anymore, but the centration according to the rule for prism centring would be valid for every type of prismatic power lens, that is also for single-vision lenses.

Of course it would be the own decision of every manufacturer of lenses whether the PCC-Case or the Formula-Case will be the lens calculation standard case which is specific for his firm. But the respective other case should be offered to the optometrist who orders the lenses as possible option.

The "Special-Case" is meant for optometrists who make a point of getting the nowadays highest possible precision for the binocular-prismatic power in the pair of visual points of the spectacles. In this case the lens manufacturer will specify how the position of the reference point of each lens has to differ from the pupil centre-centration which was applied with a measuring film, that is without prism. The centration data for the reference point of each lens, provided by the lens manufacturer for that purpose, are to be understood relative to the coordinates of the PCC-point, which is the straight ahead visual point in the measuring film and are accordingly to be considered for the determination of the coordinates for the centration point.

The conventionally stated optical centre distance has no value any more in these cases. With the new concept it is a matter of centration requirements for the single eye. With that the old source of error would be eliminated as well, where the middle of the spectacle frame is situated in the face respectively on the nose not exactly as the middle of the measuring frame was during the eye examination.

Finally it shall be pointed out that the presented considerations are exclusively meant for prismatic power lenses which serve to correct associated heterophoria. But if on the other hand for lenses without prismatic power in the reference point the boxed centre distance of the chosen spectacle frame is that much larger than the person’s interpupillary distance that the uncut diameter of the type of lens in question is insufficient for a correct centration, then the lens manufacturer must explicitly be informed about the necessary predecentration [3, Lfd. Nr 39] of the optical centre towards the nose. In such a case it would be wrong to order so-called decentration prisms as it is not a question of prismatic power lenses but of predecentrated lenses without prismatic power. These are mounted in the frame in such a way that each eye will look through the optical centre of the merely monocular correcting lens when looking into the distance.

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Order form for prismatic correction lenses – Part 1

A. Details relating to the power and to the arrangement of the trial lenses

1. Power and arrangement of the trial lenses:

The orientation of the prism bevel has to be indicated in the table as either **f** (forward-facing) or **b** (backward-facing).

R	sph	cyl	A	pr	B	f / b
1						
2						
3						
4						
5						
6						

Right Eye

------------- trial lens 1
------------- trial lens 2
========== measuring frame
------------- trial lens 3
------------- trial lens 4
------------- trial lens 5
------------- trial lens 6

L	sph	cyl	A	pr	B	f / b
1						
2						
3						
4						
5						
6						

Left Eye

------------- trial lens 1
------------- trial lens 2
========== measuring frame
------------- trial lens 3
------------- trial lens 4
------------- trial lens 5
------------- trial lens 6

2. Corneal vertex distance (HSA) of the trial lens being nearest to the eye:

R ________ mm L ________ mm

Order form for prismatic correction lenses – Part 2

B. Details relating to the adjustment of the measuring frame

Precondition: Horizontal orientation of the upper rim of the measuring frame when the test person adopts an unstrained posture of head and body and gazes vertically through the plane of the measuring frame.

1. Pupil centre-centration (Adjustment during the determination of the refractive error of each eye):

Centration distance: horizontal R ________ mm
L ________ mm

vertical R ________ mm up ☐ down ☐
L ________ mm up ☐ down ☐

2. Final centration (Existing adjustment after the determination of associated heterophoria):

Centration distance: horizontal R ________ mm
L ________ mm

vertical R ________ mm up ☐ down ☐
L ________ mm up ☐ down ☐

C. Details for the intended spectacle frame

1. Pantoscopic frame tilt
(Tilt of the bottom rim of the measuring frame towards the cheeks with unstrained posture of head and body):

Angle between the vertical and the plane of the measuring frame: ________ degrees

2. Corneal lens plane distance with measuring film (Gaze perpendicular to the plane of the spectacle frame):

R ________ mm L ________ mm

3. Frame dimensions:

Horizontal lens size: ________ mm bridge width: ________ mm
Vertical lens size: ________ mm

4. Orientation of the prism bevel at grinding-in:

According to the extended centre of rotation requirement the object side of the lens has to be placed front parallel, that is the prism bevel is to face backward. If from anatomical reason it must be differed from that requirement the orientation of the prism bevel has to be indicated.

Percentage of the bevel facing forward: ⅓ ☐ ½ ☐ ⅔ ☐

5. Orientation of the upper rim of the spectacle frame:

If from anatomical reason it must be differed from the horizontal orientation of the upper rim of the spectacle frame the actual orientation has to be indicated.

The difference between the orientation of the upper rim of the spectacle frame and the horizontal amounts to:

________ degrees, with the right side of the frame pointing up ☐ down ☐