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Subject: Measurement of Add Power on Progressives and Other Multifocals

BACKGROUND HISTORY

When I started work at AO in the mid 1940s, Trial Frames and Trial Lenses were still in common use for doing refractions. AO's 'Phoroptor' and B&L’s ‘Green’s Refractor’ were rapidly gaining acceptance. When using a trial frame, the recommended procedure was to set up the distance correction in the posterior cells, and then determine the amount of additional plus power needed for reading by inserting an additional lens into the outermost cell. It is easy to see where the term ‘addition’ or ‘add’ came from.

When AO’s Phoroptor was designed, a set of ‘Presbyoptic Spheres’ was designed to go with the instrument. These lenses were intended to be used in the same way the ‘additional’ lenses were used with a trial frame; they were to be placed in front of the Phoroptor after the distance correction had been set up. These lenses would represent the ‘add’.

As nearly as I can make out, these lenses, though they were designed and specification drawings issued, were never actually made. Instead, a near refraction was accomplished by turning the wheels, and noting the amount of additional plus required for the patient to see at near. The optics of these two situations are similar, but not identical.

Going back to the days when separate ‘additional’ lenses were used to determine the near correction, it was apparent that any procedure for measuring the bifocal addition should be aimed at determining the power of the ‘add’, taken by itself. It could be demonstrated that a good approximation to this condition was achieved by placing the *segment* side of a bifocal lens against the focimeter nose and taking two sets of readings, one through the segment center and the other at a point in the distance portion equidistant from the optical center; these readings were then differenced to obtain the add power.

CURRENT PRACTICE

Today, the generally accepted method for measuring the add power of conventional multifocals is to place the *convex* (segment) surface against the focimeter nose, taking two readings as described above and differencing them. Because lateral chromatic aberration may significantly blur the tangential focus, making an accurate reading of the horizontal line difficult, it is often suggested that only the vertical (or most nearly vertical) line be used in determining add power. Let’s examine the reasoning behind why a multifocal lens is reversed (convex side against the focimeter nose) for measuring add power, whereas the concave side is positioned against the focimeter nose for making distance measurements.

The optical principle of a focimeter involves a telescope which is fixed-focused at infinity. Thus, the target is seen clearly only when parallel light is entering the objective lens of the focimeter telescope. When a lens is positioned with its concave surface against the focimeter nose, its front surface is toward the telescope. This means that parallel light exists between the lens under test and the telescope in order for the focimeter target to appear in focus. In the case of a lens to be used for distance viewing, this is just what is wanted to duplicate the condition the wearer will encounter. Rays of light entering a spectacle lens from a distant object are parallel.

Turning our attention now to measuring a bifocal addition, if we were to again position the lens with the concave side against the focimeter nose, parallel light would exist between front surface (at the reading portion) and the telescope. But, for measuring a near vision situation, the light rays should not be parallel, but should be diverging from the near object.

WHY ADDS ARE READ WITH THE LENS REVERSED

To see how this situation is approximated by reversing the lens relative to the focimeter nose, it is perhaps easiest to think of a bifocal lens having a plano distance portion, and to visualize the add as a little lens positioned just in front of the distance lens. With the add placed against the focimeter nose, parallel light is now between the rear surface of the lens and the focimeter telescope. This is exactly the situation we want, since no distance correction is needed. Parallel light also exists between the little 'additional' lens and the front surface of the distance lens. A vergence, equal to the reciprocal of the add power, must then exist on the front side of the little 'additional' lens. This technique, then, enables us to obtain a measurement of the power of the 'additional' lens, taken by itself.

It is apparent that the situation is unchanged if the 'additional' lens is placed directly on the front surface of the distance lens, or if that 'additional' lens is bonded and becomes a part of that front surface. When the distance portion is not plano, the situation becomes less clear, in that there is parallel light emerging from the concave side of the distance portion, a situation which is not representative of what happens when the lens is worn. However, by making two readings with the lens reversed on the focimeter nose, one through the reading and the other through the distance portion, and differencing the two, the effect of the distance portion is subtracted out.

Because the center of the reading portion is nearly always located several millimeters away from the center of the distance portion, measurements taken through the reading portion are made at a point on the lens which often has significant prism. Also, and equally important, the lens is now angled in a fashion which bears no relation to the way that lens will be positioned when worn. For these two reasons, the recommended procedure for measuring multifocals involves taking the measurement through the distance portion at a point equidistant from the distance optical center to that point used while measuring the reading portion. For conventional bifocals (without prescribed prism) this amounts to taking the distance measurement at a point having the same amount of prism as was the case when the reading portion measurement was taken. By following this procedure, errors due to prism and obliquity are also subtracted out when the two readings are differenced.

INACCURACIES INVOLVED

There are, of course, both inconsistencies and approximations involved with the use of the above procedure. For one thing, we encounter a conflict when we compare a reading correction made up in bifocal form with the same one provided as a single vision reading prescription. Nobody advocates measuring a single vision reading prescription with the lens reversed on the focimeter. Parallel light on the concave side of a single vision reading Rx would be correct only for the patient who requires no distance correction. There aren't two readings to be differenced, so any errors could not be subtracted out.

The fact is that the reading power through a bifocal is not the same as the reading power through a single vision reading lens. Fortunately, the differences are small for the average prescription, but they become significant enough to reckon with for high powered corrections. As recently as the late 1970s, AO published a chart for use with cataract prescriptions which enabled the practitioner to determine the needed adjustments in power then switching from a bifocal to a single vision reading Rx, or vice versa. Such charts had been available from AO for decades.

The errors just referred to are close relatives to the differences encountered between refracting procedures referred to earlier in this memo. Again, they become significant only for the higher powered corrections.

Other discrepancies arise when it is remembered that most patients employ some accommodation when viewing a near object through a reading correction, whether a multifocal or a single vision reading Rx. Still others occur when there is prescribed prism; of course, such prism introduces errors into the distance correction as well as the reading. It's fair to say that we never really know the effective Rx (distance or reading) when large amounts of prescribed prism are present.

FURTHER COMPLICATING FACTORS

Nevertheless, measurement of add power cannot be ignored completely. However, it must be recognized that there is probably no absolutely correct method. An already messy situation has become more complicated in recent times with the advent of rotationally symmetric aspheric surfaces (e.g., Aspheric Cataract Progressive Multifocal lenses), and prismatic thinning.

The introduction of automatic or semiautomatic lens measuring equipment may have made lens measurement easier, and perhaps more reproducible, but it hasn't really resolved the issue of how to correctly measure a multifocal add. The Humphrey Lens Analyzer is perhaps the most common such instrument in current use, and it is probably one of the best. It is my understanding that it utilizes an average of the two meridional readings in both the distance and reading portions, which are then differenced to determine the add power. There is cause to wonder how such an instrument deals with a 'fuzzy' tangential image, and how it copes with curves whose radii are changing significantly over its aperture. Also, the system will not detect astigmatism in the reading portion. These issues aside, the same questions remain as to what combination of measurements result in the best approximation to true add power.

Many standards, and the proposed ISO Standard is an example, involved making a determination of add power on semi-finished blanks. For any transmission method to yield reliable results, the second surface must be of optical quality as regards uniformity of curvature – just being adequately cleared is not enough. True, a sandwich technique employing an index-matching fluid and a mating glass cover plate can be used to cancel out second side aberrations, but such an approach is messy and time-consuming at best.

SURFACE CURVE MEASUREMENT

Most multifocals in common use today are of onepiece construction. In light of all the difficulties mentioned above, and some I have probably forgotten, it's hard to escape the conclusion that the most reliable method for determining add powers on onepiece multifocals is to measure the curve at the center of the addition, and subtract from it the measured curve value at the center of the distance portion. The curve values must, of course, be stated in terms of the index of the lens material in question. One problem with this method is the lack of commercially available instrumentation for making such measurements. The Reflection Lensometers, designed and built at AO, are the best instruments I am aware of for this purpose. Other methods, which are less convenient and probably less accurate, are the Optical Sphereometer, Interference Techniques involving calibrated test-plates, and Mechanical Gauges.

A method has been suggested for determining the front curves by calculation, given a known second side curve and a focimeter measurement of the front or back vertex power at a given point. Such a method would seem to suffer from most of the problems associated with transmission measurements described above.

THE COMMONLY ACCEPTED METHOD

The generally recognized method for measuring non-aspheric multifocals, a version of which has been incorporated into ANSI Z-80.1, has been described earlier in this memo. The lens is first positioned with the convex surface against the focimeter nose, at the point which represents the center of the reading portion. Power measurements are then made, noting the amount and direction of any prism. It is sometimes suggested that only the vertical, or most nearly vertical, line be read; preferably, two readings are taken representing the two principle meridians. The lens is then repositioned, again with the convex side against the focimeter nose, at a point in the distance portion which is as far above the distance Major Reference Point (MRP) as the measurement through the reading portion was below the distance MRP. If there is no prescribed prism, prism thinning, or random unwanted prism, the amount of prism at this point should be the same (but of opposite direction) as was noted at the point where the reading portion measurements were made (in practice, this point of equal prism is often used to locate the place at which to take the distance portion readings). A new set of power measurements are now taken, and these are subtracted, meridian by meridian, from the measurements previously made through the reading portion. The difference yields the power of the add.

The problems with using this method for semi-finished blanks are obvious, and have already been described. The validity of using this method with aspheric lenses is not so obvious; in fact, the method is really not appropriate for use with Progressive multifocals, because there is no appropriate place to take the distance portion readings. Even when we forget about prescribed prism or prism thinning, the ‘equidistant point’ will not have prism equal to that which was encountered while making the reading portion measurements. Stated differently, the rear curve of the lens will be angled differently with respect to the focimeter when making the distance portion readings than it was when making the reading portion measurements (remember, neither angle bears any relationship to the angles which will be encountered when the lens is worn). Since the prism and angling are not the same, differencing the readings taken in the distance and near portions will not cancel out errors, as happens when the method is used with regular, non-aspheric, multifocals.

A DIFFERENT APPROACH

There is another approach which might be worthy of consideration – one which would be valid for all finished multifocals. Unfortunately, it is not without its problems. This method would require the lens be positioned with the concave side against the focimeter nose, held in such a way that it may be pivoted about an assumed center-of-rotation. The distance portion reading would be taken through the distance MRP with the back surface flush against the focimeter nose. The lens would then be pivoted about the assumed center-of-rotation until the center of the reading portion is in the line of measurement. Up to this point, the method is essentially the ‘Eurom’ proposal. However, before making a reading, a supplementary lens would be introduced in front of the telescope to provide the required vergence, dependant on the power of the add being measured (alternatively, the telescope could be equipped with a calibrated focusing capability). Now, the measurements are made through the reading portion. If the lens is error-free, the readings should be the same as those taken through the center of the distance portion. If such a system were employed, consideration might be given to reducing the focimeter aperture to something more nearly representative of the average pupil diameter, as projected to the concave surface of the lens.

Difficulties with such a system are apparent. No such instruments are currently available and, while modification of a standard focimeter can be envisioned, modifications to automated instruments (such as the Humphrey Lens Analyzer) might present major problems. More fundamental is that the method requires knowledge of a center-of-rotation distance, which would probably have to be considered a variable, depending on the design parameters of the specific lens being measured. Finally, such measurements yield a result which includes the usual off-axis errors; thus, more than just the add power is being measured. The approach might be a valuable development tool, however, for if properly set up, it should give a good indication of what the patient actually sees.