# Clinical Importance of Accurate Refractor Vertex Distance Measurements Prior to Refractive Surgery

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## ABSTRACT

**PURPOSE: To determine directly measured vertex distances in a consecutive series of patients refracted at a refractor and to examine the clinical importance of such a measurements for improving refractive surgical results.**

**METHODS: Vertex distance measurements were obtained in 189 consecutive patients by using a new device capable of taking direct and accurate measurements behind a refractor. Eyelid thickness was measured with an industrial caliper in five patients.**

**RESULTS: The average true vertex distance was 20.4 mm with a range of 10 to 34 mm. Eyelid thickness was 3 mm in all five patients.**

**CONCLUSIONS: Precise measurement of true refractor vertex distance is important for accuracy of refractive surgical procedures. The practice of assuming an average vertex distance of 12 to 14 mm for all refractive patients underestimates the vertex distance in many patients refracted at the refractor, resulting in overcorrecting minus and undercorrecting plus refractions. [*J Refract Surg* 2002;18:444-448]**

Vertex distance, or the distance from the cornea to the spectacle trial lens, has been traditionally measured by the Distometer (Haag-Streit, Waldwick, NJ), a device designed to take vertex measurements over a range of 7 to 23 mm from behind a spectacle or trial lens. This device works well for most spectacle readings less than 23 mm, but because of its design and scissors-like action, cannot physically take any vertex measurements behind most refractors.

Solutions devised by refractor manufacturers involve estimation by direct sighting and through 90° mirrors located at the side of the refractor along with complicated correction factor tables. Although when used correctly, these methods can yield true vertex distance measurements, in clinical practice the headrest is correctly adjusted only infrequently, and correction factor tables are seldom used. When we tried the aforementioned methods according to the refractor manufacturer's instructions (even with separate hand-held corneal illumination from behind the refractor), we found them to be time-consuming and awkward—hampered by parallax errors, dim lighting, and poor visualization.

Many refractive surgeons assume an average vertex distance of 12 to 14 mm for all patients without measuring vertex distance. One published source of this commonly accepted convention is the Distometer operating instructions, which state that "clinical experience has established that the...spectacle lenses, when fitted properly, are placed on average 8 to 12 mm from the cornea" (Distometer: Instructions for Use. Distributed by Haag-Streit Service. Waldwick, New Jersey). Another source of this convention may be that when the forehead is adjusted so that, according to the Reichert Ultramatic RX Master Phoroptor instructions, the corneal apex is aligned with the zero sighting line, the vertex distance from the corneal apex to the posterior lens surface is designed to be 13.75 mm with this phoropter.

We introduce an alternative method of directly obtaining the vertex distance. We set out to conveniently and accurately measure the refractor vertex distance and found that it was almost always greater than commonly assumed. We examined the clinical implications of underestimating this distance for achieving predictable results in refractive procedures.

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*Dr. Weiss holds patent rights to device mentioned herein. The remaining authors have no proprietary interest in the materials mentioned herein.*

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## PATIENTS AND METHODS

One of the authors (RAW) has invented a new device (Fig 1), called the Weiss Vertexometer (OASIS Medical, Glendora, CA), to directly measure corneal vertex distance from behind the refractor or trial lens. Four investigators used this device to measure the refractor vertex distances for the right eye of 189 consecutive patients presenting for routine refraction. Two types of refractors were used, the Nidek TS 1200 (Nidek, Gamagori, Japan) and the Reichert Ultramatic RX Master Phoroptor (Reichert Ophthalmic Instruments, Buffalo, NY). Patients were placed behind the refractor and aligned in the usual manner, without making any changes in the refractor position (forehead bar) settings.

Patients were instructed to keep their foreheads pressed against the headrest, which remained untouched in a neutral position and unadjusted throughout the study, corresponding to the method of daily clinical use of this device in these offices. The vertex measurement was taken by having the patient close their eyes and carefully positioning the Vertexometer between the patient and the refractor (Figs 2, 3). One side of the Vertexometer tip was gently placed on the apex of the closed eyelid and a flexible measuring device was advanced from the opposite side of the tip to make light contact with the lens inside the refractor. The vertex distance was indicated on a scale at the base of the Vertexometer.

Measurements were taken directly against the posterior lens surface on the Reichert Ultramatic RX Master Phoroptor. The Nidek TRS 1200 refractor has a protective lens cover over the lens aperture, so direct measurements were taken from the back of the lens cover to the closed eyelid and corrected by adding the distance from the lens cover to the refractor lens system planes, as supplied by Nidek (4 mm).

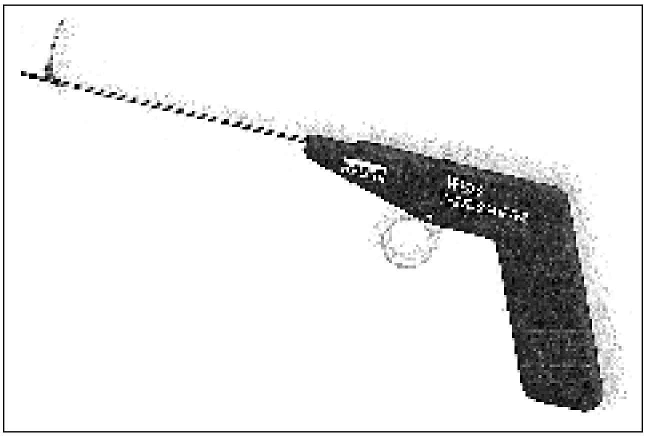

**Figure 1.** Weiss Vertexometer, with a tip that can directly measure vertex distance to the lens system within the refractor tube.

Eyelid thickness was measured in five randomly selected eyelid surgical patients. The eyelid was everted and the central thickness was determined with an industrial micrometer after the conjunctiva was anesthetized with a topical anesthetic.

## RESULTS

The average measured distance from the refractive lens plane to the closed eyelid was 17.4 mm. Eyelid thickness in all five patients was 3.0 mm. Thus, the average true vertex distance in this series

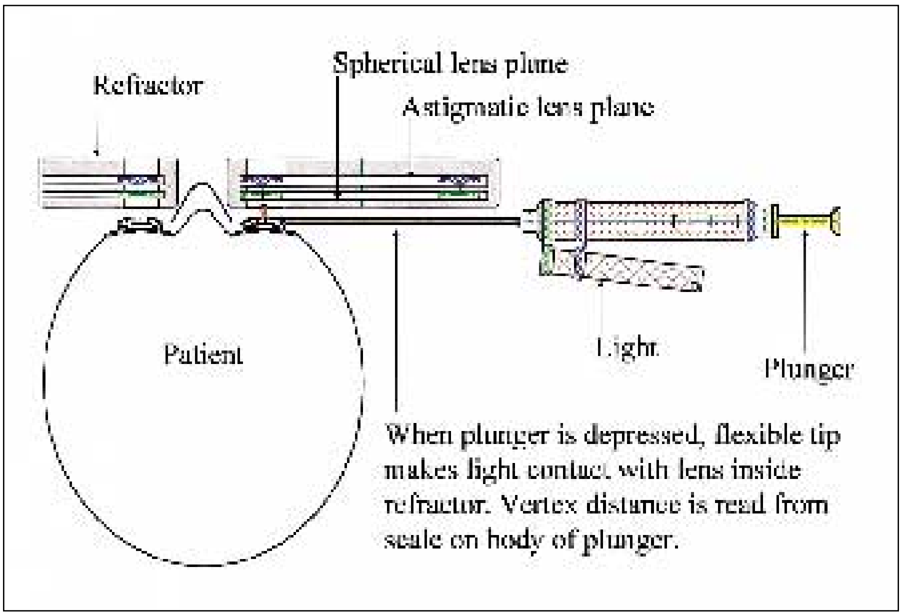

**Figure 2.** Diagram of Weiss Vertexometer (prototype) in place between patient and refractor.

**Figure 3.** Weiss Vertexometer in place between patient and refractor.

was 20.4 mm. The true vertex range (eyelid thickness included) was 10 to 34 mm.

## DISCUSSION

Almost all refractive surgical methods alter the refractive power of the cornea at the plane of the corneal apex (the only exception to this being refractive intraocular lenses). Spectacle trial lenses and refractors each measure the correcting refractive power of a lens in a plane other than the cornea. Therefore, the measured power at the corrective lens plane must be converted to the corrective power that is needed at the plane of the corneal apex, where the actual corneal power change takes place.

Vertex distance is defined as the distance between the back surface of the refractive lens and the corneal apex.[1] This measurement is critical because it is an important variable in the equation that converts dioptric power at the refractive lens plane to dioptric power at the corneal apex, or the corneal vertex diopter power ($D_{cv}$).

That equation is $D_{cv} = D_{vp}/(1-d*D_{vp})$, where $D_{cv}$ is the dioptric power at the corneal plane, $D_{vp}$ is the power at the posterior lens plane, and d is the vertex distance in meters.[2] Using this equation, we can examine the effect of vertex distance (within the range of our measured true vertex distances) on the corneal vertex dioptric power with increasing phoropter lens powers (Table).

A lens power of -3.00 D corresponds to a corneal vertex power of -2.90 D with a 12-mm vertex distance and -2.71 D with a 35-mm vertex distance, a difference of only 0.19 D over this range, possibly clinically insignificant. However, as we increase the lens power, the differences become larger and more meaningful.

### Table
### Effect of Vertex Distance on the Corneal Plane Dioptric Power With Increasing Refractor Lens Powers

| Lens Power (D) | Vertex Distance (D) 12 mm | 25 mm | 35 mm |
|---|---|---|---|
| -3.00 | -2.90 | -2.79 | -2.71 |
| -6.00 | -5.60 | -5.22 | -4.99 |
| -12.00 | -10.49 | -9.23 | -8.45 |
| -15.00 | -12.71 | -10.90 | -9.84 |
| +5.00 | +5.32 | +5.71 | +6.06 |

Consider what happens when we assume an average unmeasured vertex distance of 12 mm that is really 25 mm. In a -6.00-D myope, we will try correct -5.60 D at the corneal plane when we should have corrected -5.22 D, resulting in an overcorrection of 0.38 D. In the cases of -12.00 D and -15.00 D of myopia, we will theoretically overcorrect by 1.26 D and 1.81 D, respectively. Similarly, we can calculate that for a +5.00-D hyperope, we will undercorrect by 0.39 D. These differences are significant.

Likewise, using an average unmeasured 12-mm vertex distance that is really 35 mm will result in larger theoretical inaccuracies; overcorrecting -6.00 D, -12.00 D, and -15.00 D by 0.61 D, 2.04 D, and 2.87 D, respectively, and undercorrecting +5.00 D of hyperopia by 0.74 D. Parenthetically, it is of clinical interest to note that current software versions of many excimer laser systems do not allow entry of vertex distances greater than 25 mm, a subgroup consisting of 24 or 12.4% of our patients.

These examples illustrate that underestimating the refractor vertex distance will result in overcorrecting the myope and undercorrecting the hyperope. We believe that inaccuracy of vertex distance measurements at the refractor may account for some of the unpredictability of refractive outcomes in previously reported studies, specifically, overcorrections in higher myopes and undercorrections in higher hyperopes.

A crucial question is whether direct measurement from the cornea to the posterior presenting lens surface is the true vertex distance in all cases. Reichert Ophthalmic Instruments confirms that all lenses in their Phoroptor are referenced to the posterior lens surface (closest to the eye) of the lenses in the strong sphere lens plane. Figure 4 is an internal schematic of the lens placements within the Phoroptor.

Inside the Phoroptor, the lenses are divided into planes that correspond to different rotary dials that hold different power lenses; one each for an

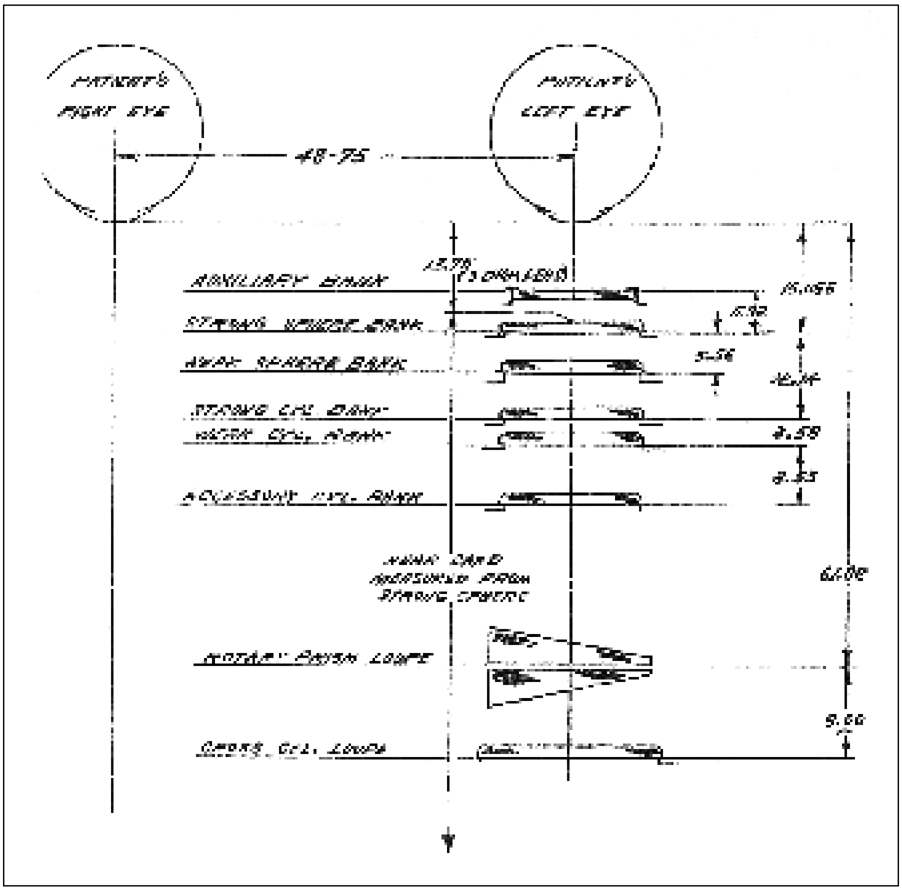

**Figure 4.** Internal schematic of the Reichert Ultramatic RX Master Phoroptor. Vertex distance of 13.75 mm assumes headrest is set properly for cornea to be aligned with zero sighting line.

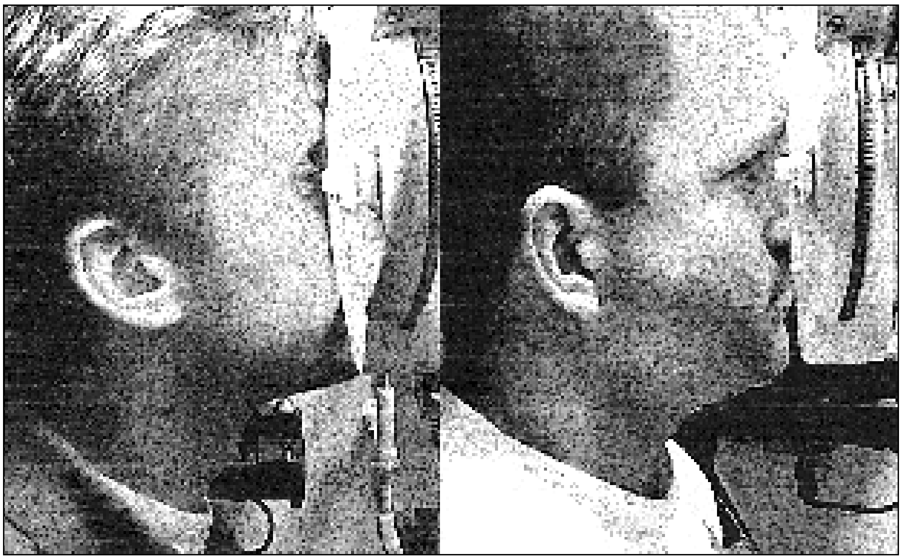

**Figure 5.** Patients with different vertex distances (Left: 14 mm vs. Right: 26 mm) due to differences in forehead anatomy. Same investigator, refractor, and headrest setting. (Courtesy of William Berke, OD)

auxiliary bank, strong sphere bank, weak sphere bank, strong cylinder bank, weak cylinder bank, accessory cylinder bank, rotary prism loupe, and cross cylinder loupe, with successive planes being located further from the eye, in the above order.

As mentioned, all lenses in the Phoroptor are referenced to the back surface of the plane of the strong sphere. For all lenses in this plane (+3.00 D, +6.00 D, +9.00 D, +12.00 D, +15.00 D, -3.00 D, -6.00 D, -9.00 D, -12.00 D, -15.00 D, -18.00 D) the marked power is the same as the actual lensometer power.

Thus, direct measurement of vertex distance to the back surface of lenses in the strong sphere plane is valid. By direct measurement, we found that the strong sphere lens plane is always in this position for marked powers of greater than -1.00 D and greater than +2.00 D, as long as the auxiliary bank is not in place at the time of measurement, as it usually is not. The only exception when direct measurement is not valid is for plano-cylindrical powers in an open tube phoropter (without a lens aperture cover), in which case the direct measurement would be to the more distant cylinder plane, an overestimation of the vertex distance.

With this exception in mind, we excluded five patients with plano-cylindrical refractions from our series. In retrospect, these were not valid vertex measurements. Interestingly, the largest vertex measurement in the entire series was taken at a closed tube phoropter.

Weak sphere and all cylinder lenses are also referenced to the posterior surface of the strong sphere plane. For example, the actual lensometer power for a marked +5.00-D cylinder lens is +4.674 D, which corresponds to the 12.14-mm distance from one lens plane to the other.

The above confirms the validity of the fact that two lenses in combination correspond exactly to the marked Phoroptor power, with a vertex distance being referenced to the back surface of the strong sphere lens plane (closest to the eye), which can then be directly measured for moderate and higher refractive errors.

Accuracy of individual refractive results requires accurate vertex distance measurements in each patient because this distance varies in each patient. We should be less complacent about entering the vertex distance into the laser. The average vertex distance should not be applied to everyone, and has no clinical usefulness.

A more significant finding is the wide range (10 to 34 mm) of measured vertex distances even among patients of the same investigator, which again emphasizes the need for accurate individual measurements. This relatively wide range was due in part to anatomic variations, differences in baseline phoropter headrest position, posture, and effort. There is certainly no uniformity about the starting position of the refractor headrest among different examiners. Figure 5 shows two patients with markedly different vertex distances, the farthest measuring 26 mm and the nearest measuring 14 mm.

The average vertex distance in this study was 20.4 mm (range of 10 to 34 mm). This is substantially larger than commonly used values and may be responsible for certain cases of overcorrected myopes and undercorrected hyperopes in previous studies.

Accurate refractor vertex measurements in every patient are essential in producing predictable refractive surgical results, especially in patients with moderate to severe refractive errors. This may be especially relevant with increasing demands for accuracy of refractive results.

## REFERENCES

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2. Cogger TJ. Correction with hard contact lenses. In: Duane TD, ed. Clinical Ophthalmology. Hagerstown, MD: Harper & Row; 1980: chapter 54, p 22.