Contact lens measurement

Beyond refractive data

Metrology for the optical properties of contact lenses and intraocular lenses is an enabling technology for every lens manufacturer. The regulatory bodies request quality control and assurance so the customer can expect a high and constant quality. But lens manufacturers also strive for efficient and high-quality working processes, so feedback on the manufacturing process is important to improve yield. New equipment helps to provide more information in daily work and to make the measurement process safer.

By Johannes Pfund

Typically, in the full process of lens qualification the following parameters and properties are measured:

- **Refractive data**
  - Sphere, cylinder, cylinder axis
  - Prism
  - Add power
- **Geometric data**
  - Diameter, haptics diameter
  - Sag
  - Base curve, equivalent base curve
  - Center thickness, haptics thickness
- **Surface quality**
  - Cosmetic defects
  - Lens rim properties

In the first section of this this article we describe how multi-functional wavefront metrology can deliver fast results for several of these parameters at once. In the second section, we discuss what information wavefront metrology can deliver beyond refractive data.

MEASUREMENT PRINCIPLE

Traditional lens meters can only provide a subjective measurement of the refractive power of a contact lens. Figure 1 shows the observation screen of a typical lens meter, where the operator has to find the point of the best image on the screen and then reads the refractive power from a scale. This method is subjective and thus has high operator dependence in the measurement process.

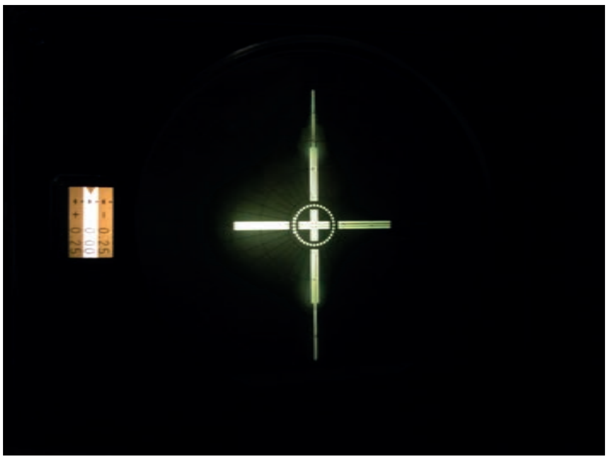

Fig. 1: Measurement screen of a lens meter.

Digital camera-based instruments provide objective results. An example of such an instrument is shown schematically in figure 2. It provides a high-resolution image of the lens, which is used to measure the diameter, position and orientation of the lens automatically and to perform visual qualification of cosmetic defects, see figure 3. In addition to this top-view image, some instruments provide a side-view image, which is used to measure sag, see figure 4.

Most importantly, these instruments measure lens power, power map and imaging quality of the lens. A typical 2D-map of the power distribution across the optical zone of a contact lens is shown in figure 5. Details on the measurement of wavefront and imaging quality are shown in the last section of this article.

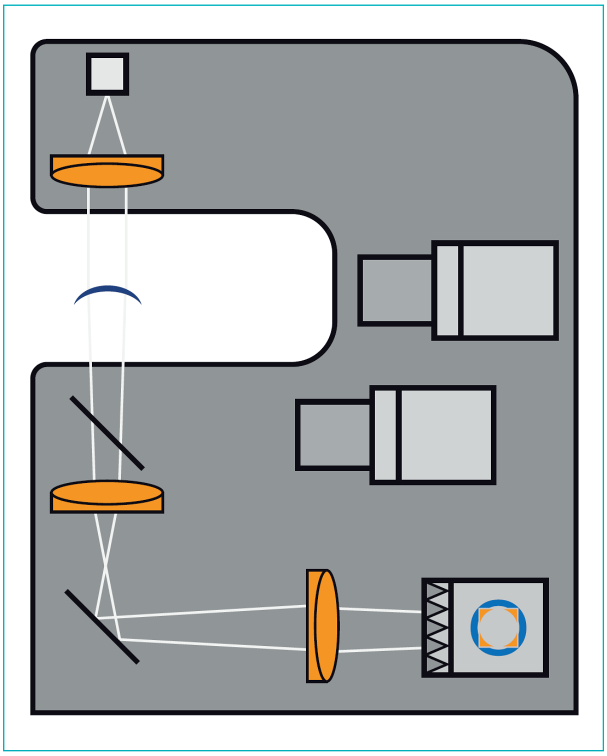

Fig. 2: Schematic of a digital camera-based instrument.

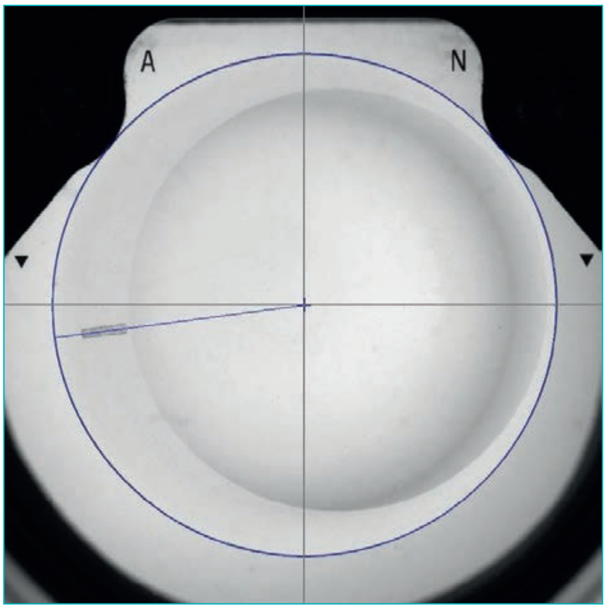

Fig. 3: Camera image (top-view) with automatic measurement of lens position and orientation.

Fig. 4: Camera image (side-view) with automatic measurement of lens sagittal height.

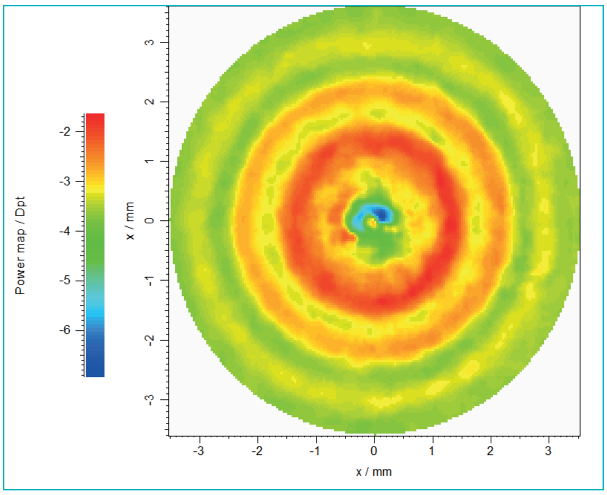

Fig. 5: Power map of a multifocal contact lens.

MEASUREMENT OF REFRACTIVE DATA

As soon as the lens is placed on the sample stage, the lens position and orientation as well as refractive data and imaging quality are measured. Thus, the operator only needs to adjust the lens position roughly, so the measurement process is extremely fast and easy. Some instruments achieve image acquisition and processing, power calculation and display in less than 0.25 seconds.

Accurate, objective results

We did a small study and compared the performance of a digital camera-based instrument (SHSOphthalmic cito) with a lens meter (Nikon PL-2). The refractive power of 5 soft contact lenses was measured 10 times on each instrument, with a time period of approximately one day between each single measurement. The lenses were stored in saline solution.

In order to avoid subjective influence on the readings, the measurements were executed with a "blinded scale" on the Nikon PL-2. The measurements were performed by an optician on either measurement system. While the variation of the measurements with the traditional lens meter was in the range of 0.3 to 0.4 Dpt, the SHSOphthalmic cito had a variation of well below 0.1 Dpt.

In order to achieve measurement results traceable to international standards, any measurement system needs to be calibrated. For the calibration of the power- and diameter-measurement, glass lenses and tools with properties certified by accredited institutes are used.

More than sphere and cylinder

Whereas the measurement of multifocal lenses is quite a challenge for a lens meter, digital camera-based instruments provide detailed information on the refractive power in each zone of a multifocal lens, see exemplary power map in figure 5.

The power map and corresponding evaluation methods will also show if the power profile of a lens is decentred with respect to the lens' optical zone. Figure 6 shows a lens with a decenter on the left, and on the right the modified power profile after a shift of 0.27mm of the power profile.

BEYOND STANDARD QUALITY CONTROL

The wavefront measured by digital camera-based instruments carries information on the wave aberrations of the lens under test. This information can be used to measure influences of the production process onto the quality of the lens, or to compare the quality of the manufactured lens to its design. Especially, the imaging quality can be evaluated in detail.

In order to analyse the wavefront and to detect typical aberrations contained in the wavefront, a Zernike polynomial is fit to the wavefront. The Zernike expansion is commonly

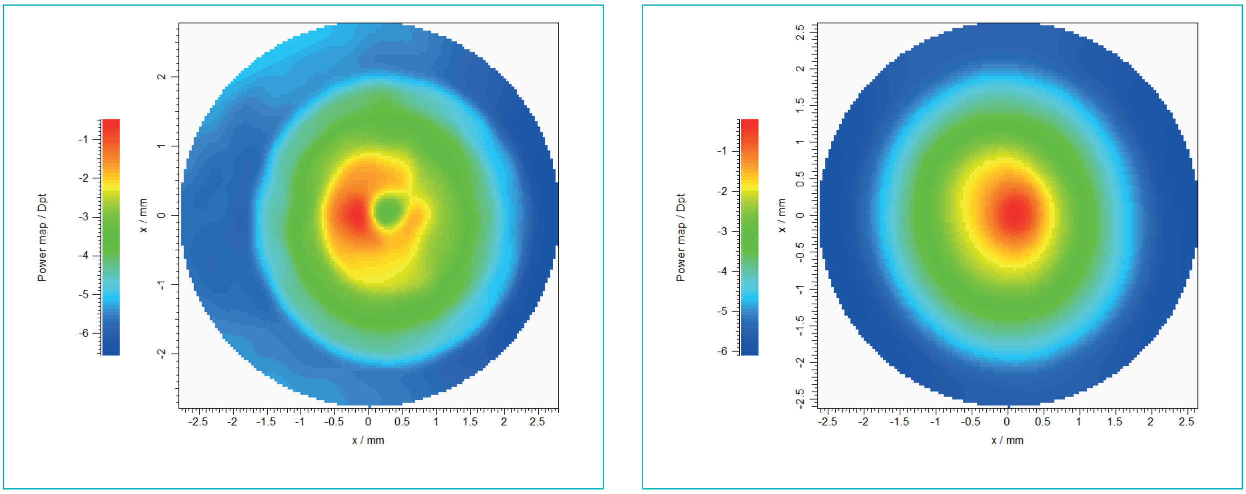

Fig. 6: Power map of a lens with decentered power profile (left) and same power map with decenter removed by software (right).

used to categorize the aberrations, and it typically contains tilt and defocus and the low order aberration (LOA) coefficients astigmatism, coma, spherical aberration. Beyond that the aberrations are called higher order aberration (HOA).

Figure 7 shows the wavefront of a spherical RGP lens. The total wavefront contains the refractive power which shows up the tilt (equivalent to the prism) and the uniform defocus term, equivalent to the spherical power. After subtraction of tilt and defocus, primarily the LOA are revealed (Fig. 8) which in the example are dominated by the spherical aberration (donut shaped aberration). A comparison to the simulation of the lens with nominal data would have to tell whether this spherical aberration is a manufacturing issue or not.

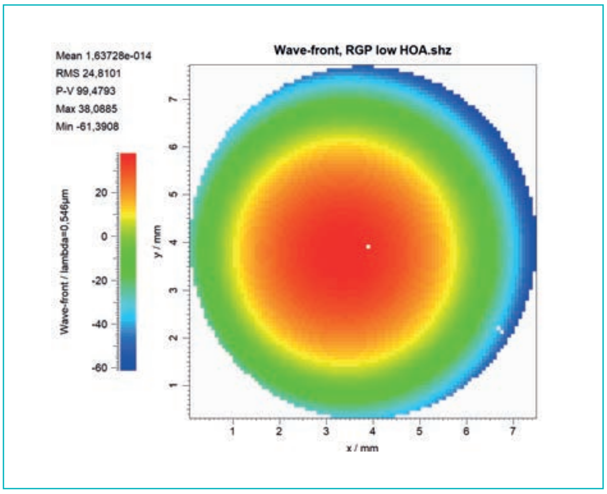

Fig. 7: Total wavefront of a RGP lens.

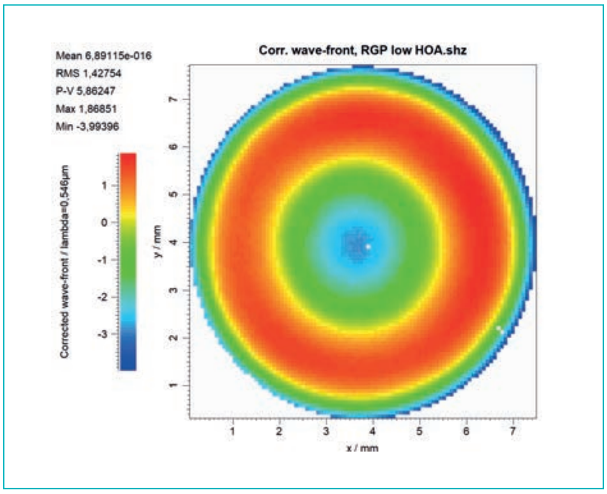

Fig. 8: Wave aberrations of a RGP lens after subtraction of tilt and defocus.

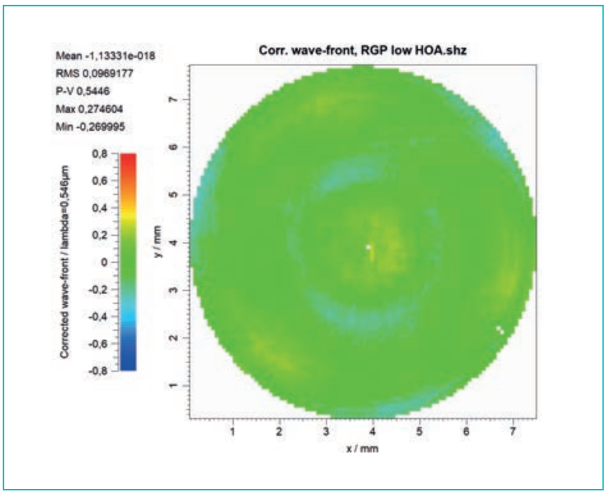

Fig. 9: Wave aberrations of a RGP lens with low HOA.

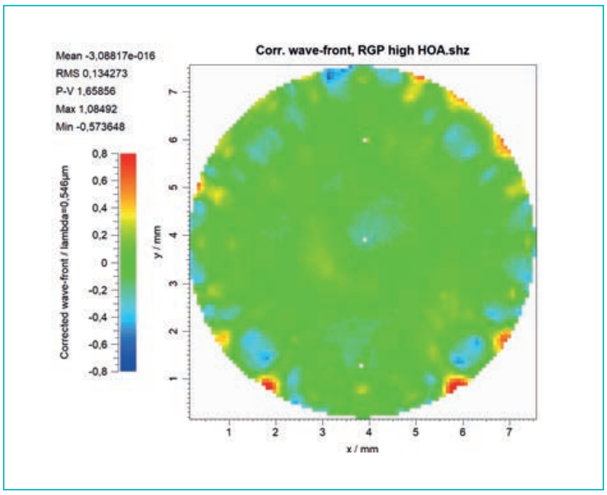

Fig. 10: Wave aberrations of an RGP lens with high HOA.

After subtraction of the LOA it can be seen that the lens has a neglectable amount of HOA, i.e., the wavefront plot shows up quite uniformly green (Fig. 9), i.e. has a low peak-to-valley value. In comparison, figure 10 shows the HOA of a different lens where something has gone wrong because of instabilities in the lathing process. The wavy structure is clearly visible and the amount of the HOA is significant.

The low quality RGP in figure 10, even though the refractive data is in specification (sphere power of -5.75dpt), would perform badly in terms of visual acuity when inserted in the eye. The patient would most probably not be satisfied.

This type of measurement combined with a proper interpretation can easily be used to improve efficiency in the production process and will increase customer satisfaction when used in final quality control.

SUMMARY

We have shown how digital, camera-based instruments can provide fast and reliable measurement results and also can help to learn more about the quality and performance of a lens. This will help the lens manufacturer to work more efficiently and to create more customer satisfaction. ■

Literature

[ref1] J. Lamprecht and J. Pfund in GlobalCONTACT 1-14, p16-p19.

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