Principles and clinical applications of ray-tracing aberrometry (Part II)

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APPENDIX

CLINICAL CASES

Several real clinical cases are analysed below in order to obtain greater understanding of the iTrace system for clinical exploitation.

Normal Eyes

The emmetropic eye (refractive map)

![Refractive map of the WF Summary Display](image)

Refractive map of the WF Summary Display

Here we analyse an emmetropic eye with VA correction not surpassing 20/20. The first map solely takes LOA into account (which affect the total quality of vision) and therefore appears entirely in green. The second map appears in blue, green and yellow but all with refractive values close to 0 in accordance with the colorimetric scale in D. We can therefore deduce that this eye is more greatly affected more by HOA, which have little influence on vision. This is corroborated by Total LO and HO RMS values (right-hand side values) which result in good VA without correction values.

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The astigmatic eye (refractive map)

The Total Refractive map shows a with-the-rule astigmatism of approx. 2.12 D, which is what predominantly affects the poor vision of this patient as seen in the PSF and Total Snellen E.

With this system we can go further and analyse exactly where the astigmatism shown in the total refraction comes from. To this end, we can use corneal topography, as its axial map (bottom right) corresponds to the refractive map (analysed previously). However, the value of the astigmatic corneal aberration (bottom left) is lower than the total (top right). The remaining aberrations come from the internal optics of the eye (top left). Separating corneal, internal and total aberrations we can also see that the lens compensates for part of the defocus and the spherical aberration of the cornea.
As previously explained, by combining WF and CT in one screen we can study corneal topography by selecting a map of choice, in this case the axial map. We can also study corneal aberrations based on the cornea as well as those induced by the internal optics and subsequently, total aberrations of the eye. In keratoconus, predictably, the cornea is responsible for the main aberrations. It is very useful to undertake an overall study in order to decide the exact implantation of the segments and gain the best result. For example, the internal optics generate a total spherical refraction of approx. 5.00 D in myopia, while compensating for part of the corneal astigmatism. In this case, the astigmatism and coma axes coincide, facilitating the decision-making process and allowing us to treat both sphero-cylindrical refraction and coma.

It was noted that both measurements, before (left) and after (right) were taken from the entrance pupil with a similar diameter (under mesopic lighting conditions). Only one segment with an optical zone of 6 mm was implanted. On the top right-hand side image we can clearly see the location of the ring, not yet in the pupil zone. The patient therefore does not report the usual halos or glares caused by the ring. As the implantation of the segment has changed the structure of the cornea, the RSD that we now obtain (right) is much less aberrated than prior to the procedure (left).
If we analyse the axial difference map (left), we can quantify the effect of the ring as well as its placement, which is perfectly in line with the previous image. Comparing the pre (bottom) and post (top) topographic axial maps, we see the changes in corneal morphology. The keratometry of the most curved axis has decreased; the cone has centred in relation to the pupil and therefore the spherical aberration of the cornea is more negative.

At this point, after ring implantation, we checked the total aberrometric status and compared pre and post implantation RMD values.

Changes induced in the cornea reduced astigmatism and defocus by half a point. In terms of refraction there was 2.00 D of reduction of myopia and 2.37 D of reduction of astigmatism.
Cataracts

The cornea is practically spherical, creating a quite homogeneous wavefront map which is almost entirely green. It can be observed that the WF Map Total (top right) is due to the opacification of the lens as the two top maps (WF internal optics and Entire Eye Total) are very similar.

Lasik

For a 26-year-old patient who underwent surgery 6 months ago optimized Lasik treatment with an aspheric ablation pattern was used.

If we focus on the axial map prior to (top) and post surgery (bottom) as well as the values obtained from them, we see that after Lasik the cornea is more oblate. However, the positive corneal spherical aberration induced after myopic ablation is practically non-existent, i.e. the previous positive value is maintained. This is due to the pattern of spherical ablation produced, taking into account the previous Q value and that expected after Lasik.
A comparison between the total spherical aberration maps (Z 4.0) pre and post Lasik was made. Maintaining the positive spherical aberration of the cornea prevents an increase in total aberration as the patient is young and the lens compensates with a negative spherical aberration to keep the total close to 0 and to obtain good quality of vision. This is evidenced in the VFA of the bottom image.

**Multifocal lens**

The case of a 56-year-old post-phacoemulsiﬁcation patient with implantation of a toric refractive multifocal IOL of aspheric design.

The previous refraction of this patient was +5.00 (−4.00) 175° with a +2.00 addition. In line with this, implantation of the aforementioned IOL design was decided. If we solely compare the aberrometric maps for astigmatism, we see that the WF generated by the IOL (top right) is similar to the WF of the cornea (bottom left) with a 90° rotation. This is ideal for compensating overall corneal astigmatism. However, IOL compensation in turn induces astigmatic aberration in a different orientation, which is reﬂected in the Total WF Total (top right) and, of course, in the patient’s vision. On the other hand, the IOL of aspheric design compensates corneal spherical aberration correctly as it shifts from a value of +0.279 microns to nearly zero (+0.050 microns), as reﬂected in the total aberration (top right).
Corneal transplant

We describe the case of a 62-year-old patient who underwent keratoplasty after Fuchs’ dystrophy 2 years ago. Cataract surgery was performed 6 months ago in the same eye with implantation of a monofocal IOL of an aspheric design.

In spite of the irregularity of the cornea, the iTrace system allows us to take correct measurements with very reliable data; out of the 256 points projected through the entrance pupil, none were rejected. The cornea is responsible for a large number of aberrations, causing the irregularity in the morphology of the RSD.

We performed a more detailed aberrometric study, combining the CT and WF and decomposing each WF into the Zernike polynomials shown in the bar graph.

On the bottom left side we analyse corneal aberrations (according to the axial topographic map on the right); both low and high order aberrations appear very altered. On the other hand, we can see that the internal optic, i.e. the IOL (top left), to a large extent, compensates corneal aberrations (same size bars but with different sign, shown in another color). This greatly decreases total RMS values (top right), particularly those of high order. We can therefore assert that the IOL successfully contributes to the sight of this patient.
Phakic lens

A 29-year-old patient with refraction in her RE of −9.00 (−6.00) 175 and VA 0.4. We analysed topography using CT, detecting corneal astigmatism of nearly 3.00 D. The other 3.00 D are therefore derived from the internal optics.

Implantation of an anterior chamber phakic toric IOL to compensate overall sphero-cylindrical refraction.
Once this IOL was implanted, we analysed aberrometric status and the visual quality of this patient. Combining the WF with CT we noticed a corneal aberrometric map typical of astigmatism, neutralised by the IOL. It should be noted that both WF maps are symmetrical but present inverted colours, this makes the WF total map very homogeneous, with colours close to green and with a total RMS of 0.361 microns. For a more comprehensive study, we chose the option of decomposing each map into the different Zernike polynomials through a bar graph. The IOL compensates overall corneal astigmatism but to a certain degree also induces this, evident in total refraction (–0.75 to 99°). It also induces a mild comatic aberration.