“The Wavefront Analyzer as a Part of the Routine Examinations will Enhance the Level of the Clinic.”

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“Providing Better Quality of Vision with Wavefront Analyzers”

“Using the Map, I Can Explain to My Patients their Condition to Help them Understand.”

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“The Wavefront Analyzer Enhances Clinical Decision Making in Determining the Best Timing to Move on with Cataract Surgery.”

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“We Can Obtain Very Useful Examination Data from These Maps.”

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Introduction

Dr. Maeda: With the advancements in the field of ophthalmology in recent years, treatments for previously incurable diseases are available, and also the treatments have been becoming more comfortable and less invasive. Concurrently, the demand for higher-quality treatment has been increasing, requiring ophthalmologists to provide higher quality of vision to their patients. Given current trends in instruments that can measure the optical properties of the eyes, such as wavefront sensors, are becoming indispensable tools for certain situations. Today, we have invited expert ophthalmologists who use the Topcon wavefront analyzer on a daily basis to discuss how they have been using this equipment in their clinics.

LASIK

Dr. Maeda: Wavefront analyzers first appeared as an optical instrument used in LASIK surgery. Refractive surgery is still a relatively new technology, with 10 years having passed since its widespread adoption in Japan. However, in this time, we have already achieved a record of more than 1 million LASIK procedures performed. Dr. Bissen-Miyaiima, I understand that you have extensive experience with refractive surgery. Could you tell us how you are utilizing the wavefront sensors and corneal topographer for LASIK surgery?

Dr. Bissen-Miyaiima: At my clinic, I use the Topcon Wavefront analyzer prior to LASIK surgery, not only for wavefront-guided LASIK patients, but for all patients who request treatment with LASIK surgery. Wavefront sensors with excimer lasers can only measure total ocular wavefront aberrations, but the Topcon wavefront analyzer is unique in its ability to measure both total ocular and corneal wavefront aberrations. This means that Topcon’s wavefront analyzer can distinguish whether the cause of blurred vision lies on the cornea or is due to other factors. (Figures 1, 2). This distinction has always been difficult to determine with other instruments. This is what makes Topcon’s wavefront analyzer intriguing, that it can tell us the cause of the patient’s complaint. I use the Topcon wavefront analyzer before surgery to determine whether or not wavefront-guided LASIK is suitable for that patient. There have been cases in which the patient asked, ‘Did I really achieve 1.0 visual acuity?’ after LASIK surgery. Using the wavefront analyzer, I can identify whether or not the blurred vision is coming from higher order aberrations (HOAs), such as in this example (Figure 3). There was another patient who visited us complaining of blurred vision after having surgery at another clinic. Even though patient’s visual acuity appeared normal, wavefront analyzer showed increased HOAs caused by off-center positioning of the laser during LASIK surgery (Figure 4).

Dr. Maeda: So you are using two different wavefront analyzers, one for evaluating pre- and post-LASIK surgery and another one for daily general examinations.

Dr. Bissen-Miyaiima: Wavefront sensors with excimer lasers measure the ocular refractive power data, while Topcon’s wavefront analyzer is beneficial in analyzing both corneal and ocular data. Therefore I use it as a pre- and post-surgery diagnostic instrument. My staff can also check the examination results and see if the data was measured accurately. The other wavefront sensors with excimer lasers used in my clinic cannot provide that level of detail.
**CORNEA – Keratoconus**

**Dr. Manda:** Keratoconus is the most common disease in corneal irregular astigmatism, and it is difficult to diagnose mild cases of keratoconus with conventional examinations such as slit lamp or standard visual acuity testing. However, there are cases in patients who still complain of blurred vision. Wavefront analyzers can show quantitatively how the patient’s vision is deteriorated by measuring HOA (Figure 6). Moreover, the simulation of Landolt ring is helpful to understand how the patient sees.

**Dr. Fujikado:** The Topcon wavefront analyzer can measure ocular aberrations according to the diameter of the pupil. It displays the HOA assuming that the regular pupil diameter is 4 mm for daytime and 6 mm for nighttime (Figure 5). Some patients who received LASIK surgery complain of haloes at night when driving, while almost no problems are observed during the day. I found an increase in the asymmetric ocular spherical aberration in an astigmatic patient with myopia (6 mm diameter pupil): HOA, there is very little reason to worry. However, the existence of asymmetric ciliary aberration can cause blurred vision and be much worse (Figure 5). Using the results from the wavefront analyzer, I can explain the condition to my patients using the map to help them understand. I think the availability of this map is very useful.

**Dr. Manda:** It’s true that the maps make it much easier to explain the causes behind a patient’s complaint.

**CORNEA – Dry Eye**

**Dr. Manda:** There are various corneal diseases other than keratoconus. Dr. Fujikado, could you share with us your experiences regarding dry eye?

**Dr. Fujikado:** Dry eye is a disease that results in blurred vision induced by a decrease in tear film and corneal xerosis, and it is considered difficult to quantitatively assess. However, the Topcon wavefront analyzer can be useful in assessing patient visual performance by displaying the increase of HOA. To be more specific, right after blinking, the corneal surface is slightly flattened and HOA temporarily decreases, but as the surface dries, HOA begins to increase. These symptoms can be observed in mild cases of dry eye. I think the wavefront analyzer can determine the condition of blurred vision in patients quantitatively by observing HOA over time (Figure 7). On the other hand, patients with serious dry eye show increased HOA from the beginning.

**Dr. Manda:** So, if a patient has serious evaporative dry eye, it is easy to guess that their blurred vision is caused by corneal epithelial defects. However, in mild cases, such as those that ophthalmologists assume to be a minor problem, the patient may actually be having difficulty with their vision when the eye is kept open for longer periods. Dr. Fujikado, treating ocular symptoms associated with visual display terminal (VDT) use is also your specialty. What do you think about the relationship between frequent computer usage and dry eye?

**Dr. Fujikado:** VDT-induced dry eye can be observed as corneal xerosis caused by decreased blinking. During the corneal measurement, the eye may show an increase in HOA along with corneal xerosis. In that case, I would insist patients use eye drops or intentionally try to blink more frequently.
**CORNEA - Lacrimal Duct Obstruction**

Dr. Maeda: Even with lacrimal duct obstruction, the change in tear fluid on the corneal surface also influences vision, causing blurred vision especially when the tear volume increases contrary to dry eye. I heard that Dr. House is utilizing the wavefront analyzer in patients with lacrimal duct obstruction. Could you tell us about that in detail?

Dr. House: Patients are usually very grateful after being treated for lacrimal duct obstruction. Visual acuity tests do not show significant changes, but continuous measurement after surgery with the Topcon wavefront analyzer shows a stabilized pattern of ocular HOA right after blinking. This was not the case before treatment, at which point increased ocular HOA was shown first, gradually decreasing, which is the opposite of dry eye. We can suspect from these results that most patients can develop increased ocular HOA right after blinking, which could be the cause of blurred vision. Now we can easily understand what the patient means when they complain, “the more I blink, the harder it is to see” (Figure 8).

Dr. Maeda: Thank you. So you are also using the wavefront analyzer routinely to quantify HOA and to assess quality of vision objectively in the patients with lacrimal duct obstruction.

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**CATARACT - Pre-Surgery**

Dr. Maeda: It is necessary to measure HOA using wavefront sensors before cataract refractive surgery, but there is a new trend to utilize these analyzers before and after cataract surgery, and as a decision-making tool to determine the indication of cataract surgery. Dr. Fulka: I think the loss of vision due to cataracts is basically associated with scattering in the lens. So what kinds of merit are there to measuring aberrations with the wavefront analyzer?

Dr. Fulka: There are various types of cataract. If a patient has a cataract that can be diagnosed at a glance, of course you do not need to use a wavefront sensor. However, for an early stage cataract patient, especially those with cortical cataracts, it has been difficult to detect the presence of the cataract due to local changes in the refractive corneal power. These patients are hard to identify using slit lamp observation as well because the crystal lens optical deterioration can be difficult to detect, which may lead to misjudgment in the timing of cataract surgery at some clinics (Figure 9). The important thing is, among these patients, there are those who have cortical cataracts or nuclear cataracts and suffer from double or triple vision. One criterion I use for decision making is the ocular HOA. When it is higher than 0.3 μm or 0.5 μm (peak diameter 4 mm), I assume that the patient has some kind of visual impairment, and I consider an appropriate plan, including surgery. The Topcon wavefront analyzer can objectively simulate blurred vision and, I am sorry to repeat this again, can display corneal and ocular maps at the same time. Therefore, making it easier to determine that the cause of the blurred vision lies on the cornea when a pattern of corneal and ocular maps appear almost the same, and attribute it to cataract when ocular HOA shows more aberrations while corneal HOA shows less. So-called the “Component Maps” calculate internal HOA by subtracting corneal HOA from ocular HOA (Figure 10). The greater the figure is, the higher the rate cataract is causing blurred vision.

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**Figure 9**
Slit lamp anterior segment image

**Figure 10**
Cortical cataract (Component Maps)
Dr. Maeda: I see. Patients with cataracts usually develop the visual loss caused by opacity in the lens, but in mild cases, the visual disturbance is associated with HOA or lenticular irregular astigmatism. So, wavefront analyzers can be useful. Now, please describe how cortical cataracts and nuclear cataracts differ in their optical characteristics.

Dr. Fujikado: Cortical cataracts can sometime present triple vision, but generally, it is a combination of coma aberration and other HOAs, which present distorted Landolt rings. I think triple vision is observed in younger patients with nuclear cataracts due to less lens scattering and more pronounced aberration. This is because I think nuclear cataracts harbor more, causing increased spherical aberration. Probably the third symmetric component that lenses originally possess, what we call the Y Suture and A Suture (Figure 1), slowly increases refractive power along with age, and when these two get mixed, it can lead to triple vision.

I think this is a really good optical instrument for judging the timing of surgery during the early stages of cataracts.

Dr. Maeda: Are you actually showing the Landolt ring simulation to your patients to explain their condition?

Dr. Inoue: Yes, I am. Patients can quickly and easily learn to understand the situation just by looking at the internal aberration on component maps.

Dr. Fujikado: Since I handle pediatric ophthalmology as well, one experience I would like to share is that when I measure the HOA of congenital cataract patients and observe opacity in the surrounding areas while the center of the pupil is clear, it is easy to determine whether the patient is the type capable of gaining up to 1.0 visual acuity with an eye patch or the type who cannot. That is to say, I can use the wavefront analyzer to build a live vision training target for a congenital cataract patient who maintains transparency but has irregular aberration.

Dr. Maeda: So, Dr. Biszen-Miyajima uses the Topcon wavefront analyzer before surgery to determine whether or not a premium IOL should be implanted on that particular patient. How about you, Dr. Inoue?

Dr. Inoue: At my clinic, we still have a few cases in which multifocal IOLs are selected. However, when deciding on this type of lens, we make sure to at least check for corneal irregular astigmatism using the “IOL Selection Maps”. I select multifocal IOL when a patient has low corneal HOA, astigmatism less than 0.5 D or 0.75 D, and is under the age of 60 years.

Dr. Maeda: So you also check the corneal topography and confirm that there is no corneal irregular astigmatism prior to selecting multifocal IOLs. How about your IOLs? Dr. Inoue, do you have any comments on selecting IOLs and how to examine the patient when considering this modality?

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**CATARACT - Selecting Premium IOL**

Dr. Maeda: We can use variable IOLs with different optical features, such as aspheric, multifocal, and toric IOLs, which are the so-called new technology IOLs or premium IOLs and currently a hot topic. I think it is difficult to choose these IOLs. But Dr. Biszen-Miyajima, could you explain some pearls for selecting patients who will be suitable matches for multifocal IOLs?

Dr. Biszen-Miyajima: The Topcon wavefront analyzer can produce total ocular wavefront analysis and corneal topography analysis results which enable us to judge the stage of the disease by looking for regular and irregular corneal astigmatism in the corneal topography data. The important thing to remember is that even if we proceed with IOL surgery, the cornea itself will not be corrected in a patient with corneal HOA, so that may lead to blurred vision and leave the patient dissatisfied with their treatment (Figure 12). In general, I choose premium IOLs for cases in which the patient does not have irregular or severe regular astigmatisms. Still, if these patients ask specifically for premium IOL surgery, I make sure to explain to them before surgery that even after the IOL surgery, the regular or irregular astigmatism will still remain, and we need to discuss whether to leave it as it is or to move on to the next step and perform laser surgery touch-ups to remove the astigmatisms.

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![Figure 13](image-url)

Even with the correct IOL implantation procedure, blurred vision remains due to corneal astigmatisms.

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![Figure 12](image-url)

Commeal astigmatism and corneal irregular astigmatism
Dr. Inoue: I do not have many cases indicated for toric IOLs as well as multifocal IOLs, however, the basics are the same. I check for corneal irregular astigmatism with the wavefront analyzer and measure the astigmatic diopter. I usually select toric IOL for inverse astigmatism.

Dr. Maeda: So in other words, rather than applying toric IOLs to every patient who has enough astigmatism measured by kerometer, you first check the corneal topography, and if corneal irregular astigmatism is observed at a certain level, you choose IOLs that are matched with toric IOLs. How about you, Dr. Bissen-Miyajima?

Dr. Bissen-Miyajima: I always measure with an autokerometer as well as use the wavefront analyzer to obtain corneal topography. I have not examined many patients with irregular astigmatism yet, but if there is mild asymmetry in the eye and there seems to be no problem, I select toric IOLs. In my practice, I choose toric IOL not only for inverse astigmatism but also for direct astigmatism: inverse astigmatism for 0.75 D to 1.00 D or higher, and direct astigmatism 1.00 D or higher.

Dr. Maeda: Thank you. I understand that in cases in which premium or new technology IOLs are planned for implantation, you also check the corneal topography for all cases with the Topcon wavefront analyzer before proceeding with the surgery.

Dr. Maeda: Generally speaking, it is well known that the conventional LASIK surgery could markedly alter corneal spherical aberration after the procedure. We nearly all have spherical aberration to some extent; however, LASIK surgery for myopia can increase positive spherical aberration substantially, so it is better to insert an aspherical IOL with negative spherical aberration for cataract surgery. We still have very few LASIK cases for hyperopia in Japan. In such cases of hyperopia, the LASIK procedure decreases corneal spherical aberration. Therefore, if you implant an aspherical lens into these types of eyes, negative spherical aberrations will increase. In this way, the corneal spherical aberration differs based on the patient’s corneal condition, so the question remains how we should differentiate it with conventional instruments before surgery. However, I think that wavefront analyzers can be used to determine whether a spherical or aspherical IOL should be inserted by measuring corneal spherical aberrations.

Dr. Bissen-Miyajima: Yes, indeed by using the wavefront analyzer, we can determine a patient’s LASIK history from the results of corneal topography without having to ask, so measuring with the wavefront analyzer is very useful.

CATARACT - Post-Surgery

Dr. Maeda: I would like to ask how you utilize wavefront analyzers for cataract patients after surgery. Dr. Bissen-Miyajima, could you share your experience with us?

Dr. Bissen-Miyajima: After cataract surgery, I measure almost all of my patients with the Topcon wavefront analyzer. I would particularly like to talk about the IOL selection maps, which were developed under the suggestion of Dr. Maeda for diagnosis in post-toric IOL surgery. We can obtain very useful examination data from these maps. Before the availability of IOL selection maps, we needed to take anterior segment photographs of the dilated pupil and then measure the toric IOL axis mark using a protractor. However, this wavefront analyzer can even measure internal astigmatisms, so it is no longer necessary to take the photographs as had been required previously (Figure 13). In fact, before I check post-surgery visual acuity, the first thing I am interested in is checking the results from the wavefront analyzer to see how much the overall astigmatism was corrected. If a total ocular astigmatism map shows only green, I can assume that uncorrected vision will improve to about 1.5 visual acuity. Because of this, I have been looking forward to seeing the results after every surgery.

Dr. Maeda: Thank you for your positive comments. So you have been using wavefront analyzers not only before surgery but also after surgery. How about you, Dr. Inoue?

Dr. Inoue: At my clinic, I too, measure all of my patients after surgery. One reason I measure with the wavefront analyzer is to answer complaints after surgery even with single focus lenses. To explain the cause of blurred vision, I show my patients the HMA map, axial map, and Landolt ring simulation map. Another reason is that, as Dr. Bissen-Miyajima said, in toric IOL cases it becomes harder to find the toric IOL axis after a certain amount of time has elapsed, so I measure with the wavefront analyzer to determine the astigmatic axis.
Dr. Maeda: The wavefront analyzer is indeed useful in assessing astigmatism of the IOL after toric IOL implantation, and I would say not only for toric IOLs, but also for investigating the cause of complaints after surgery and determining a procedure for correcting them. For example, in case of IOL tilting or decentration, I think sutured IOLs tend to tilt. When this occurs, the HOA shows higher values with blurred retinal images, and this can be a cause of complaint in cases where the surgeons actually believe the surgery to be a success. So, how about after multifocal IOL surgery? Is it possible to assess an eye with a multifocal IOL using wavefront sensors?

Dr. Fujikado: The wavefront analyzer uses infrared light with a narrow wavelength when measuring, so we cannot assess whether a patient can see a near or far image. However, we can say that during measurement, patients are measured with a far image, so we can consider multifocal IOLs to be assessed with a far image, which should still be useful.

Dr. Maeda: Wavefront sensors are not magical instruments that can handle everything, so I understand that there are certain limitations after multifocal IOL implantation. We need to understand that when assessing a different type of multifocal IOLs, only the far vision is being assessed with the wavefront analyzer.

Dr. Bissen-Miyajima: I measure this using the wavefront analyzer, as well, and as Dr. Fujikado does, I measure patients using far vision conditions. However, I can see another dim dot indicating near vision next to the clear dot indicating far vision in the Hartmann-Shack image. Satisfied patients can observe the Hartmann-Shack image beautifully, but patients with persistent complaints are mostly impossible to measure. Of course, from this you can notice whether the blurred vision is attributable to the cornea or not, and then you can assume that the blurred vision is coming from the internal multifocal IOL.

Dr. Maeda: To summarize, we ophthalmologists are working hard to improve vision or to prevent the deterioration of vision of our patients, but I feel we are likely to face more and more patients complaining of blurred vision after surgery, even with improved visual acuity. In such cases, corneal topographers and wavefront sensors are useful in assessing the cause of blurred vision, and understanding why the patient is having difficulty quantitatively and objectively. Previously, identifying the cause of blurred vision with ordinary examinations was very difficult, and I think introducing the wavefront analyzer as a part of the routine examinations will enhance the level of the clinic. And with that, we would like to close the round-table discussion. Thank you very much for taking the time to attend the discussion today.