BRIEF COMMUNICATION

Understanding Ocular Visual Function Beyond the Sphere and Cylinder Using Multimodal Imaging

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ABSTRACT
Multimodal imaging is the mainstay when diagnosing diseases of the retina. This same technique is applicable to the refractive surgeries including LASIK and refractive lens exchange. In the modern day, visual problems have moved beyond mere lower order aberrations and the Snellen chart. We present two interesting cases that demonstrate the use of multimodal imaging in refractive surgery cases. The first case demonstrates a simple capsular contraction causing immense problems of light spread in an otherwise normal trifocal implanted patient. The second is a case of a hidden and problematic refractive surgery that again complicated a trifocal lens surgery. We have made many advancements in understanding the eyes optical elements and must use this to our advantage to help our patients.

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INTRODUCTION
Multimodal imaging is the mainstay when diagnosing diseases of the retina. This same technique should be applied by refractive surgeons practicing modalities such as LASIK and refractive lens exchange. In the modern day, visual problems have moved beyond mere lower order aberrations and the Snellen chart.[1,2]

Nowadays, there are modalities to understand structure and function of the optical system. The anterior segment optical coherence tomography and the corneal tomography systems can help us understand corneal anatomy through cross sectional imaging and shape analysis.[3,4] Secondly, we have a variety of optical aberrometers, like the Hartman shack[5] and ray tracing[6], available that can map out the functional wave front errors of the eye. Additionally, these aberrometers can separate the corneal from internal aberrations and can map these while the patient has fixated at different distances like near, intermediate and far.[7]

This article aims to explain the benefits of multimodal imaging within the arena of refractive surgery using a case-based approach. We are presenting two cases to show how a patient's problems can be mapped using the variety of tools available at our disposal.

Case 1
A 60-year-old patient presented with a complaint of inability to see the oncoming lights at night. The complaint was so severe that he could not see a truck coming until it was about 1 meter away. This patient was previously implanted with a trifocal intraocular lens (AcrySof IQ PanOptix, Alcon Laboratories, Fort Worth, TX) and this was his 1-month postoperative checkup. There were no remarkable findings on slit lamp examination and his fundus was normal. The patient had an uncorrected distance visual acuity (UDVA) of 6/6 bilaterally with a refraction of 0, -0.25

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× 67 diopters (D) in the right eye and -0.50 × 0.25 × 91 D in the left.

He was put through several tests to elucidate the cause of his complaints. He underwent a spectral domain anterior segment OCT (AS-OCT; Optovue, Inc.) with epithelial mapping which were normal. His tomography scan (Pentacam HR; Oculus, Wetzlar, Germany) showed no evidence of corneal abnormalities. He underwent a ray tracing aberrometer examination (iTrace, Tracey Technology, Houston, TX), as shown in Figure 1.

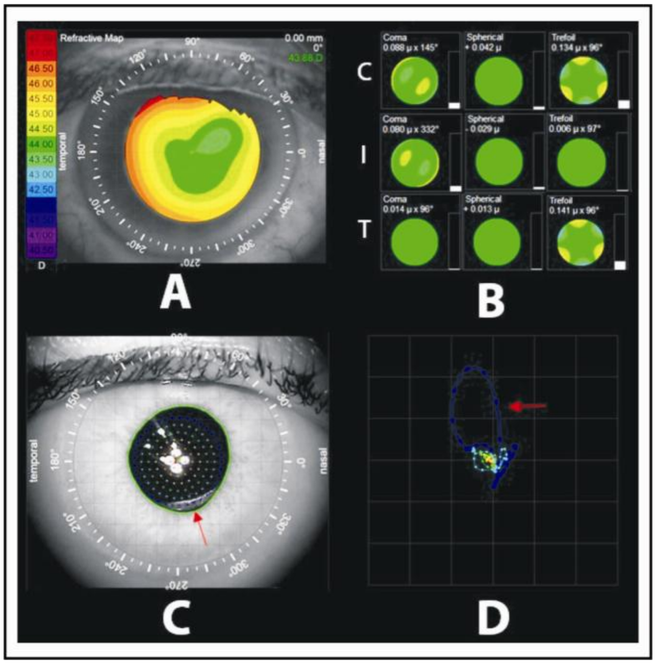

Fig. 1: **(A)** A normal axial map on a corneal topography. **(B)** Zernike polynomial divided in to corneal, internal, and total eye. The eye seems to be clear with mild trefoil present in the cornea that shows on the total eye. **(C)** Image of the eye showing scan points centered on the visual axis. The red arrow shows the contracted rhexis. **(D)** A retinal spot diagram with a bump in the visual function coinciding to the contracted rhexis. This was the source of the patient's problems.

Figure 1A shows a uniform anterior surface with progressive steepening in the periphery, like a normal cornea. Figure 1B shows the breakup of higher order aberrations, the first row being the anterior surface of the cornea, the second, internal minus the anterior surface and, the last, the total eye. This image would suggest a problem with the cornea as there is trefoil present that is shown on the total eye analysis. However, it did not correlate with the severity of patient's complaint.

Figure 1C shows an infrared image of the patients non-dilated eye with 256 points scanned centered on the visual axis. The red arrow shows a white opacification in the inferior region right above the pupil. Figure 1D shows a retinal spot diagram with a single large bump, shown by the red arrow.

The points on figure 1C and 1D showed that there was capsular contraction that encroached on the visual axis when the patient was dark-adapted, causing light spreading. This singular point caused the intense symptoms of the patient. He, subsequently, underwent a YAG capsulotomy, which relieved the patient of his symptoms.

Case 2

As this patient had similar findings in both eyes, we shall only discuss the left eye. A 65-year-old female came with a complaint of double vision and a ring around lights. In general, she was unhappy with her vision. She was implanted with trifocal intraocular lenses one month prior to this visit at another hospital. She gave no history of co-morbidities. Slit lamp examination was un-remarkable and the fundus was within normal limits. Manifest refraction of the right eye was -0.50, -0.25 x 160 D and of left eye was +1.00, -2.75 x 168 D. The left eye had a UDVA of 6/12.

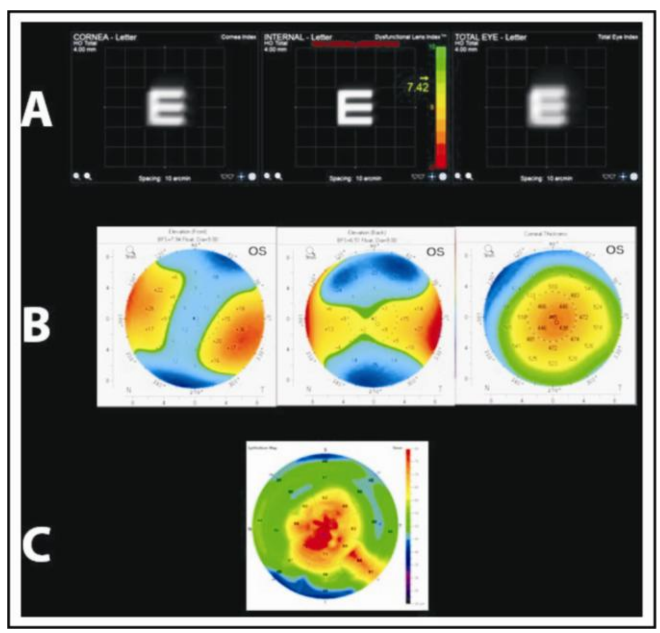

Fig. 2: **(A)** A simulated vision showing problems arising in the cornea. **(B)** A corneal tomography showing normal elevation points with a thinned-out cornea. **(C)** An epithelial map with a central epithelial hypertrophy.

Figure 2 shows the test findings of the left eye. In figure 2A, we can observe that even in its best corrected form, the vision has blurriness originating in the cornea. In figure 2B, we see a tomography image showing normal elevation points, but a relatively thinned cornea with a slight inferotemporal dislocation. Figure 2C shows a hypertrophied corneal epithelium.

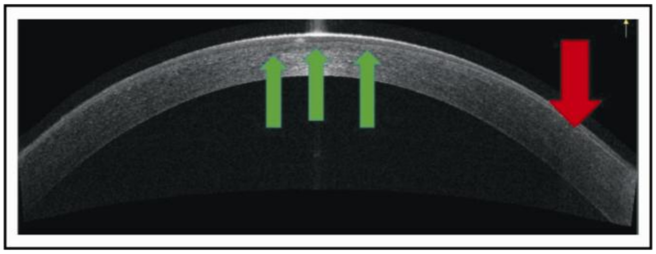

Fig. 3: An anterior segment OCT B Scan showing central undulations at the LASIK flap interface (green arrows). The periphery shows a meniscus style flap that proves this was a LASIK performed with a microkeratome (red arrow).

Figure 3 gives the final diagnosis. This is anAS-OCT scan image. Two points can be seen: a meniscus style flap can be seen in the periphery (red arrow), and the multiple undulations seen in the center (green arrow). This is a post refractive surgery case complicated by an irregular flap.

DISCUSSION

First case indicates the importance of ray tracing aberrometer and its ability to provide clues into the true optical elements of the eye. We always think of higher order aberrations in terms of Zernicke's polynomials[8] but it should be noted that not all wave-front patterns fit into this model. Relying solely on this model, we would have suspected a problem in the cornea. There are elements in the eye other than the cornea and the lens, that can cause monochromatic aberrations; these must be considered before we make a final diagnosis.

In the second case, the patient herself claimed that no surgery was performed on her eye. Performing any type of IOL calculation is problematic in such eyes, as different formulas are to be utilized in such cases.[9] If no corneal tomography or AS-OCT facilities are available at the hospital, it is not possible to provide these patients with an accurate IOL power. The error in IOL power calculation along with the astigmatism can be explained by two variables: 1. Unreported refractive surgery and 2. Irregular flap. Additionally, the epithelial hypertrophy can be explained by the irregular flap; the epithelium hypertrophied due to the sudden stromal curvature changes.[10]

Even in its best-corrected form, the resolving power of the cornea was reduced due to a prior problematic refractive surgery. This had magnified the limitations of the trifocal lens. Secondly, there arises a question whether this patient was fit for a non-toric tri focal implantation? In our practice, we exclude patients with a significant corneal astigmatism. The corneal tomography showed us a -3.5 D astigmatism and thus should have been excluded. Significant lower orders impair image quality to a large degree, and divide light into different foci. Therefore, they would amplify all the shortcomings of a trifocal lens.

The challenge to treat this patient remains. The first option would be to treat the cornea with a regularization procedure like topography guided photorefractive keratectomy. However, this would worsen hyperopia. Only two other options remain: Lens exchange with a recalculation of power or to wear glasses. At this time, the patient has opted for the latter.

Conflicts of Interest

There are no conflicts of interest to note.

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Authors' Designation and Contribution

Nauman Hashmani: Consultant Ophthalmologist: *Data acquisition, manuscript write-up, final review.*

Sharif Hashmani: Consultant Ophthalmologist: *Data acquisition, manuscript write-up, final review.*

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