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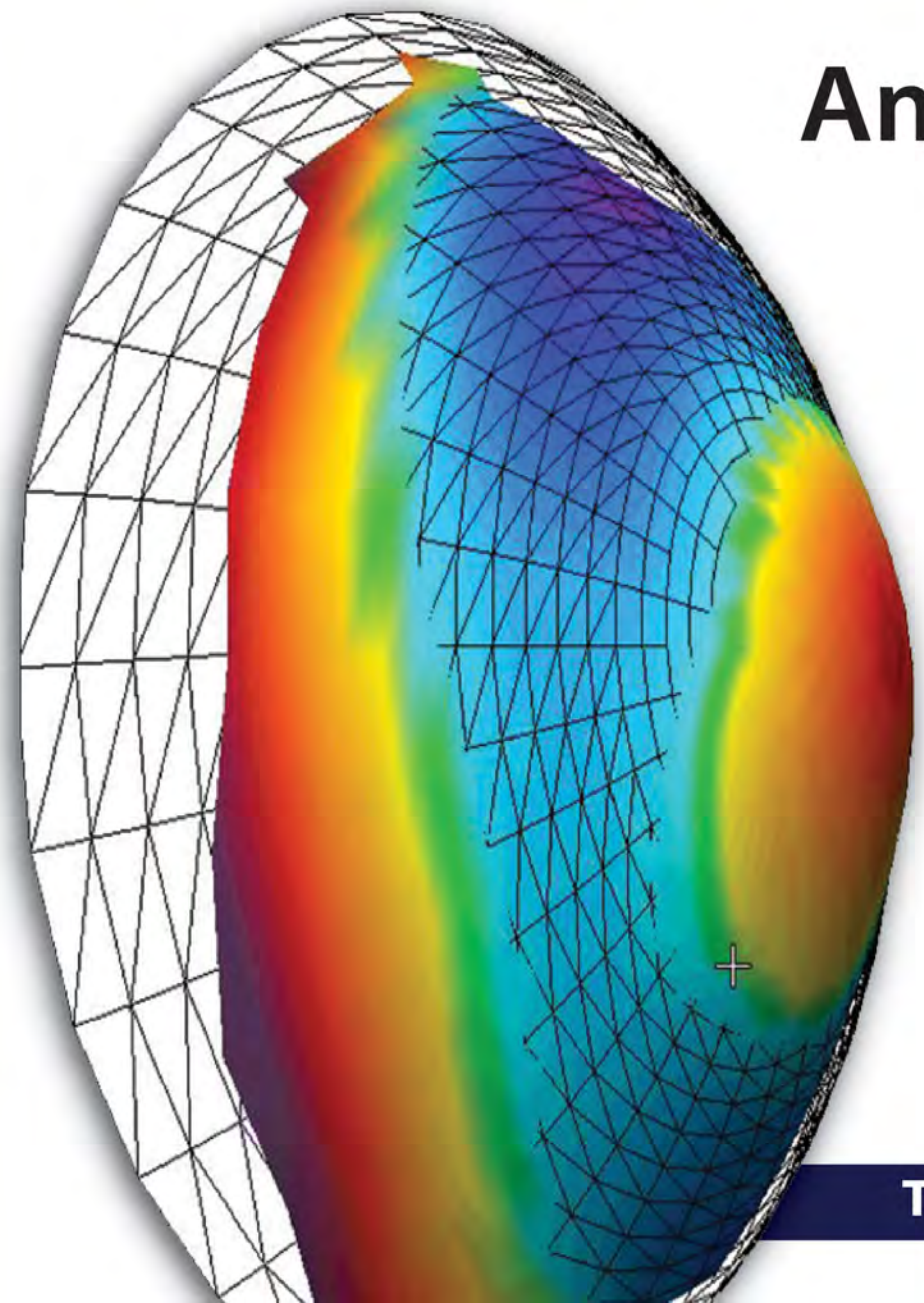
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CORNEAL TOPOGRAPHY

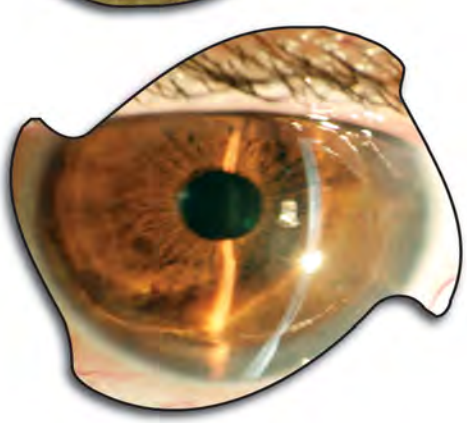
Including Pentacam and Anterior Segment OCT

Editor
Amar Agarwal

Foreword
Bonnie An Henderson







THIRD EDITION

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Chapter 4

The Orbscan IIz Diagnostic System and Zywave Wavefront Analysis

Gregg Feinerman (USA), N Timothy Peters (USA), Hoo Yeun Kim (USA), Marcus Solorzano (USA), Shiela Scott (USA)

INTRODUCTION

The combination of topographic and wavefront data is the foundation for customized ablation. The Zyoptix™ Diagnostic Workstation seamlessly integrates wavefront and topographical data for customized treatments **(Figure 4.1)**. It is ergonomic and easy to use, and provides surgeons with a platform for comprehensive diagnosis and treatment. The ORBSCAN® IIz uses slit scanning technology to measure corneal curvature. It also provides true three-dimensional elevation based on triangulation and curvature of both anterior and posterior surfaces of the cornea. The ZYWAVE™ II ABERROMETER provides wavefront measurements based on Hartmann-Shack technology. It measures higher order aberrations (HOAs) up to the 5th order.



Figure 4.1 The Zyoptix™ diagnostic workstation

ORBSCAN

Corneal topography has evolved overtime from a manual keratometer to simple Placido's disk topographers, to the Orbscan. The Orbscan uses a combination of Placido's disk images with 20 slit scans to the left and 20 slits scan to the right. This allows for forty overlapping scans in the central 5 mm zone that then allows for the four basic measurements listed below. The Orbscan measures four essential elements:

1. Corneal power
2. Corneal thickness
3. Anterior corneal elevation
4. Posterior corneal elevation.

QUAD MAP

The quad map is the most common and useful way to get an overall view of the cornea. It combines anterior elevation, posterior elevation, corneal power and pachymetry into one view **(Figures 4.2 and 4.3)**.

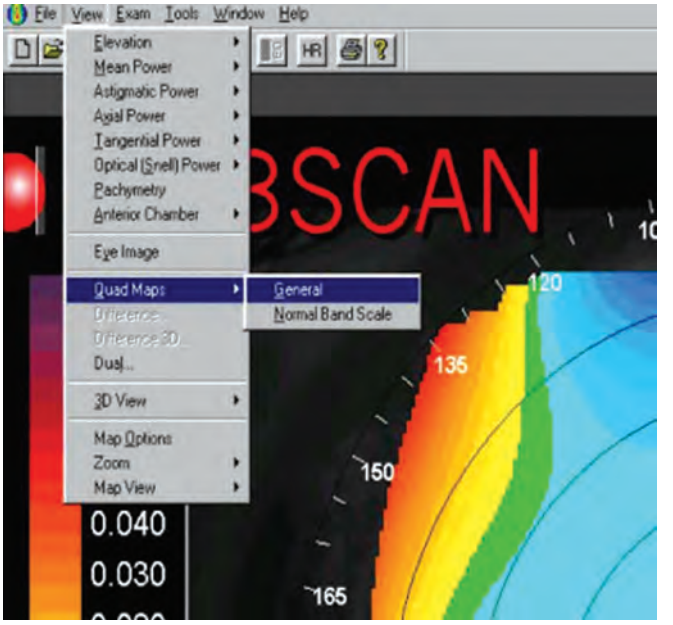


Figure 4.2 Selecting the quad map

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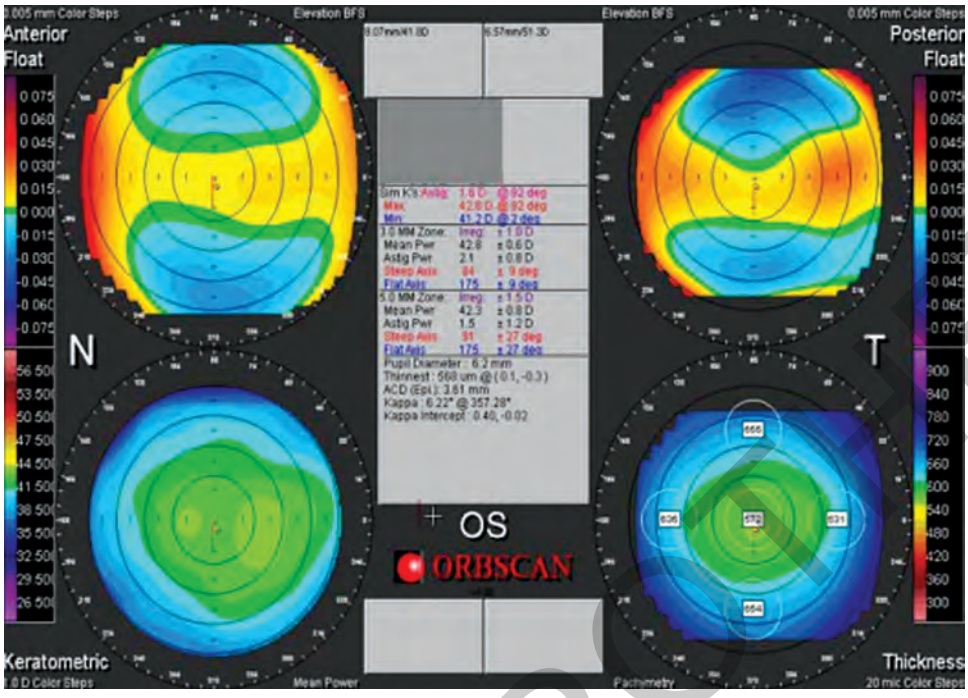


Figure 4.3 Normal quad map showing typical with the rule astigmatism

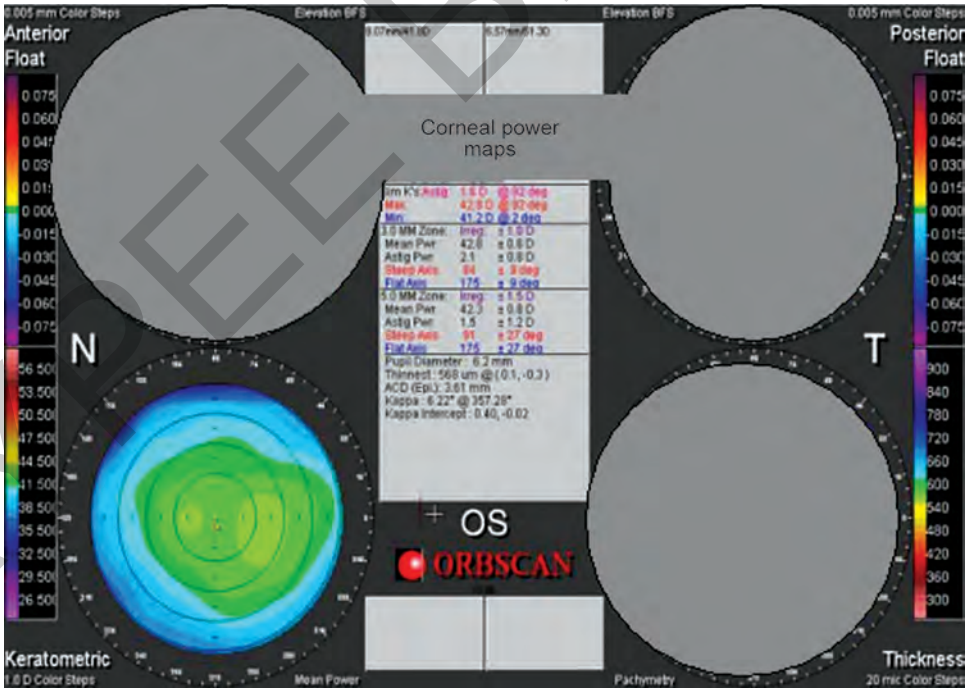


Figure 4.4 Mean power map

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POWER MAPS

One of the most confusing tasks in refractive diagnostic testing is deciding which corneal power maps to interpret. The Orbscan offers multiple ways to measure corneal power. The type of corneal power map to choose depends on what you are trying to interpret. The default setting is the mean power map **(Figures 4.4 to 4.6)**. It is most useful for eyes with extreme abnormalities. The mean power map determines the location of a surface abnormality. The axial power map is a familiar sagittal map from Placido systems **(Figures 4.7 and 4.8)**. It provides a comfortable transition for new Orbscan users; but only uses Placido rings. Normal astigmatism appears in a classic bow-tie pattern.

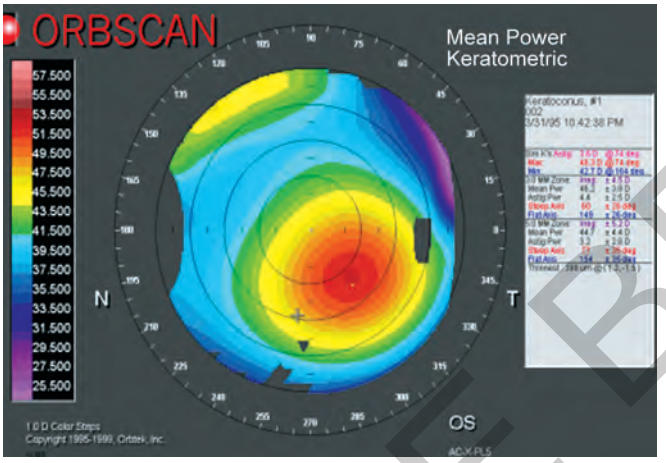


Figure 4.5 Mean power map demonstrating keratoconus

PACHYMETRY MAP

The pachymetry map **(Figures 4.9 to 4.11)** unquestionably makes the Orbscan diagnostic system unique. The Orbscan measures thickness from the tear film layer to Descemet's membrane, thus its pachymetry readings are thicker than those obtained with ultrasound pachymetry. However, the Orbscan has an adjustment factor called the acoustic factor, which can be set to replicate ultrasound pachymetry. The default setting is 92%, but each user may adjust this percentage to mimic what their own ultrasound reading show. The Orbscan not only provides a central pachymetry reading, but it also provides a superior, inferior, nasal, and temporal reading at the 6 mm zone. It also provides a reading showing the thinnest part of the cornea that may not necessarily be the central reading. The extra reading allows for the subtle interpretation of variable corneal thickness in conjunction with other topographic abnormalities, to aid in the detection of forme-fruste keratoconus as well as other corneal disease processes.

READING CORNEAL ELEVATION MAPS

Global Perspective

The map in the upper left of the quad maps **(Figure 4.12)** is the anterior elevation map. Understanding the usefulness of the map requires some background perspective. Think first from a global perspective. If we view the surface of the earth from a great distance it losses all of its relevant features and appears totally smooth, but if we change the scale then we can perceive significant height discrepancies. The cornea is the same way. When looking at a proper scale we can see height differences. To understand these differences we have to compare the height of the actual cornea to the heights of a best-fit sphere.

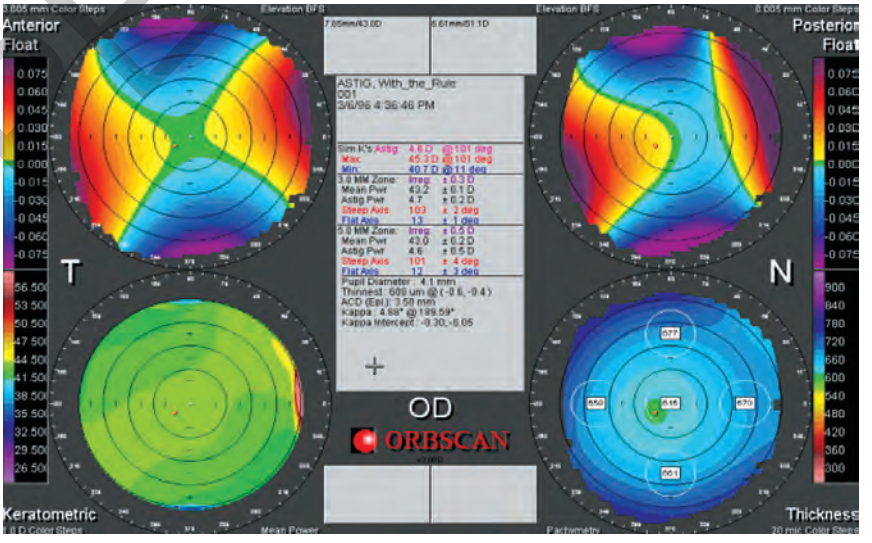


Figure 4.6 Mean power map demonstrating regular astigmatism

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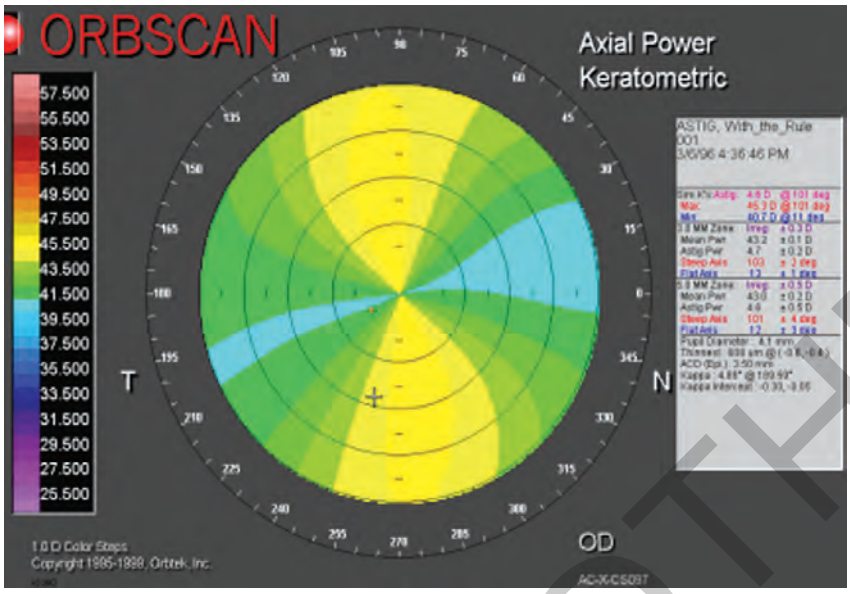


Figure 4.7 Axial power map

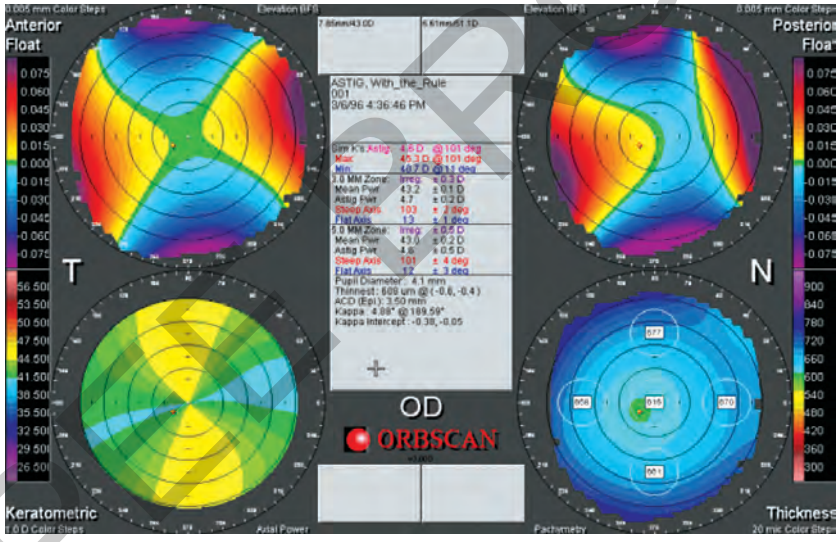


Figure 4.8 Axial power map demonstrating regular astigmatism

A normal prolate cornea is steep in the center, and flat in the periphery **(Figures 4.13 and 4.14)**. When this is overlayed with a best-fit sphere the center of the normal cornea is steeper than the best-fit sphere. Steep colors are red ones, and thus the central cornea is red on a normal elevation map. The mid-periphery of a normal cornea is flatter than our reference best-fit sphere and thus appears blue on an elevation map. Now consider a post-LASIK elevation profile on a previously myopic patient **(Figure 4.15)**. The reference sphere is best fit to the postablation shape, but the post-LASIK cornea is now oblate with a flatter center. This will appear as a blue central zone. The mid-periphery is now steeper than the reference sphere and appears as a red ring. The untouched peripheral cornea again then becomes flatter than the reference sphere and appears blue on our scale in a normal postmyopic LASIK elevation map. The anterior corneal elevation take home message is that:

- Elevation is measured relative to a "Best-fit Sphere"
- The elevation "is what it is" but may appear different depending how we look at it in relation to the best-fit sphere.

POSTERIOR CORNEAL ELEVATION MAPS

The posterior corneal elevation is another unique and defining feature of the Orbscan. As we recall from basic science, the

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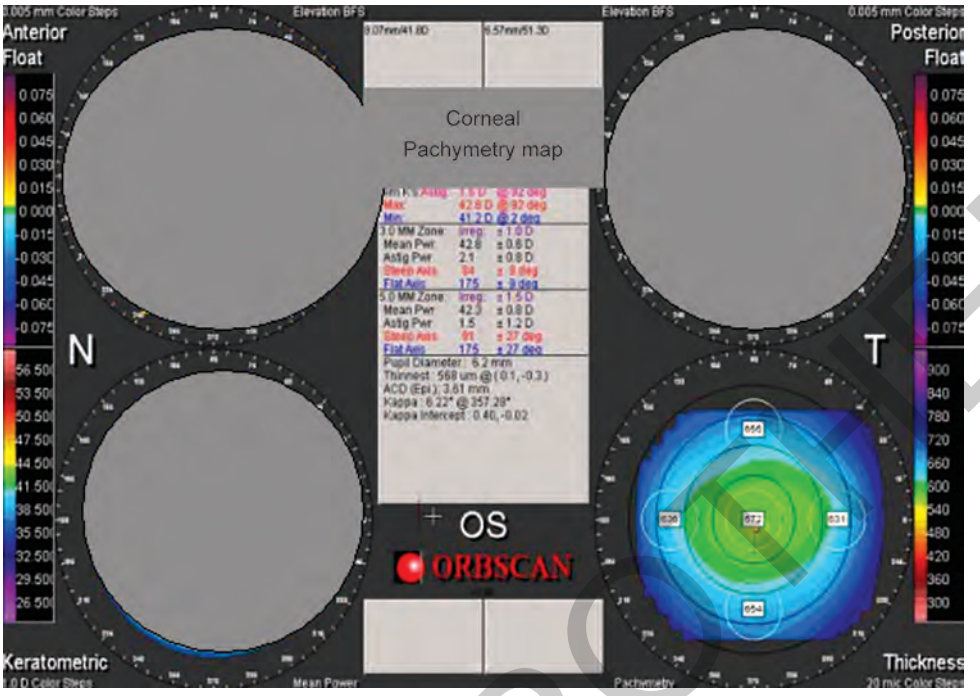


Figure 4.9 Pachymetry map

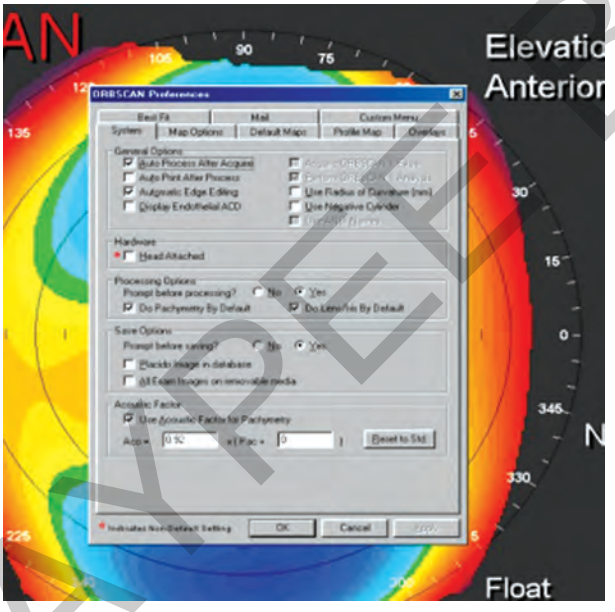


Figure 4.10 Adjusting the acoustic factor for pachymetry

posterior corneal power is negative and much smaller than anterior corneal power **(Figure 4.16)**. Thus, the posterior surface reduces corneal power.

There has been no prior experience with this information, and this surface is simply assumed to be normal by all other topographic systems. When interpreting the posterior float we need to put the posterior cornea in context. It is important to look for pattern recognition, and to look for related changes on other maps. Similar to the anterior elevation map, the posterior elevation map is related to a best-fit sphere. When reading this map two features are of greatest importance. One is the location of the steepest part of the posterior float. This should be relatively central, but is a more concern should it be located away from the center and in an area of corneal thinning. The second is the posterior float difference. This number is given in microns and is the difference between the steepest and flattest part of the posterior elevation. Much debate has centered over the magnitude that constitutes an abnormal reading, but 45 to 50 microns seems to be the maximum difference that is widely accepted. It is also important to keep in mind that while the posterior float difference appears to be clinically relevant, that isolated findings have limited value.

THREE STEP RULE

Dr Karpecki and Moyes have developed what they refer to as the three step rule when interpreting the posterior elevation. If there is one abnormal map **(Figure 4.17)** then it is okay to perform LASIK with caution. If there are two abnormal maps **(Figure 4.18)**, then it is still okay to proceed, but with concern, and if there are three abnormal maps **(Figure 4.19)** the LASIK is contraindicated. Below are some quad maps demonstrating the different levels of concern.

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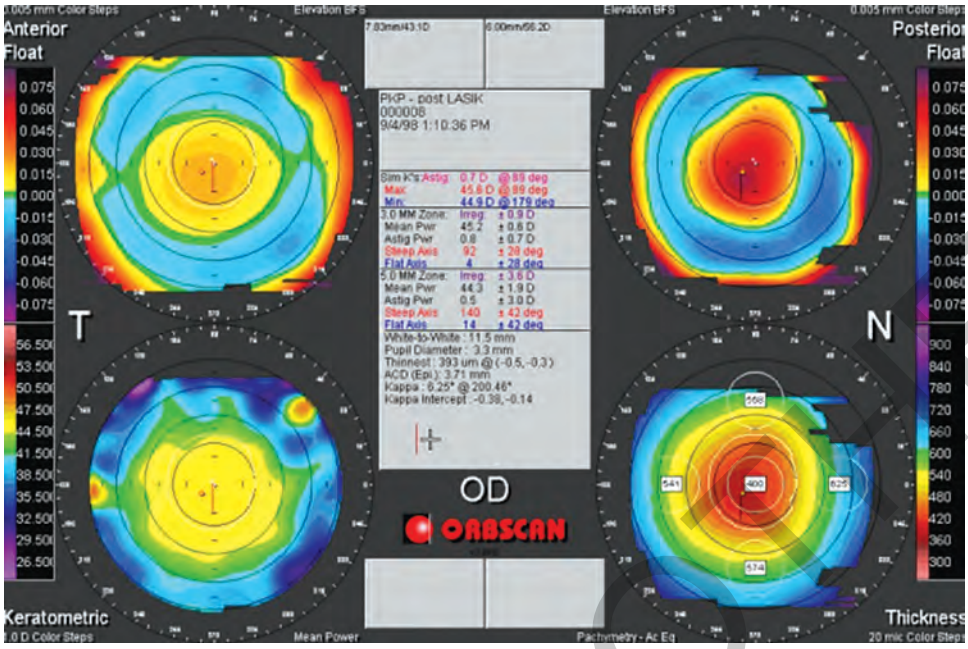


Figure 4.11 Pachymetry map of postoperative LASIK

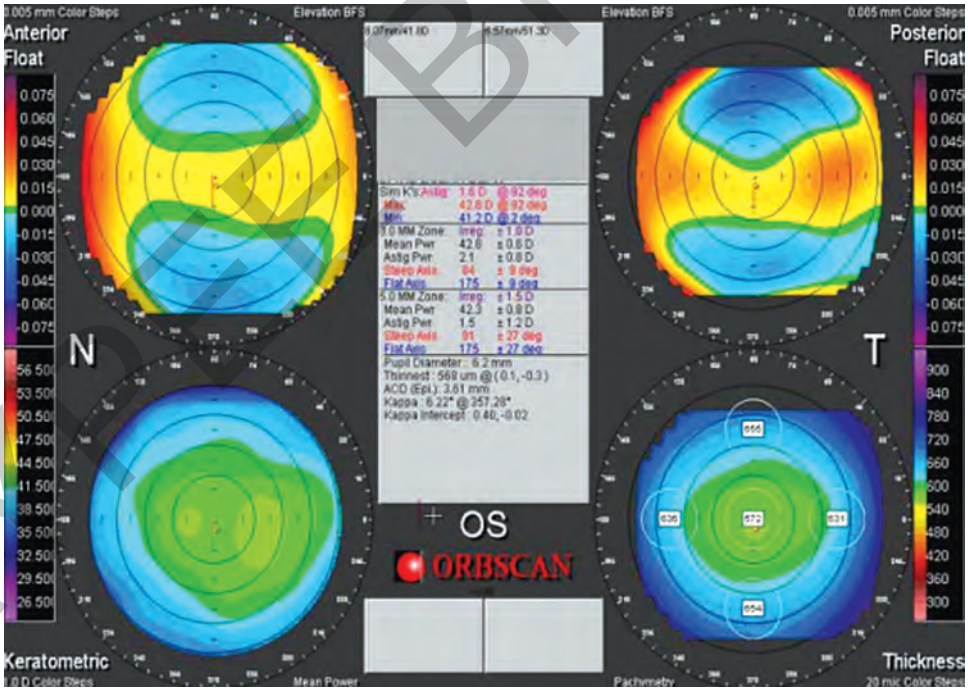


Figure 4.12 Quad map

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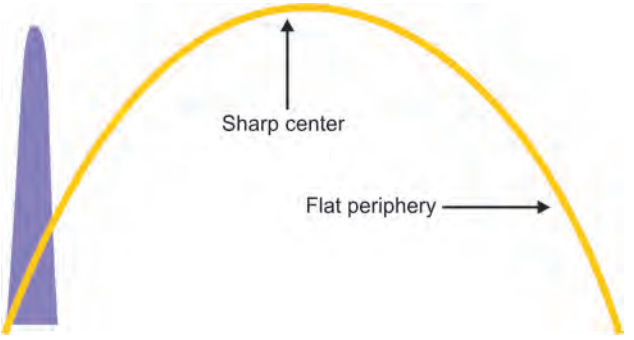


Figure 4.13 Elevation topology—normal cornea

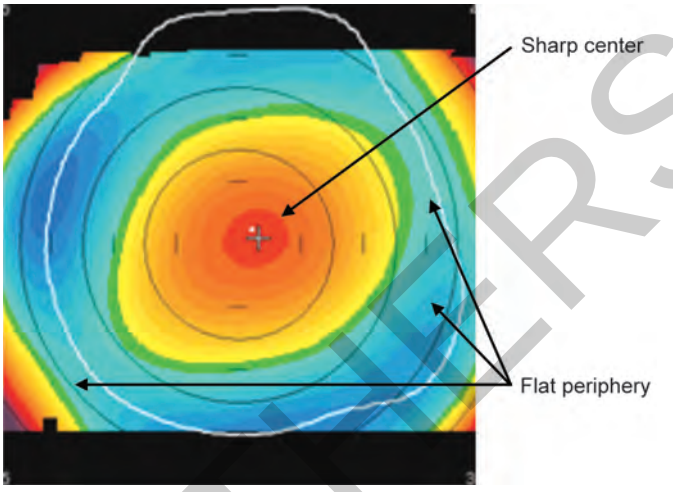


Figure 4.14 Anterior corneal elevation map

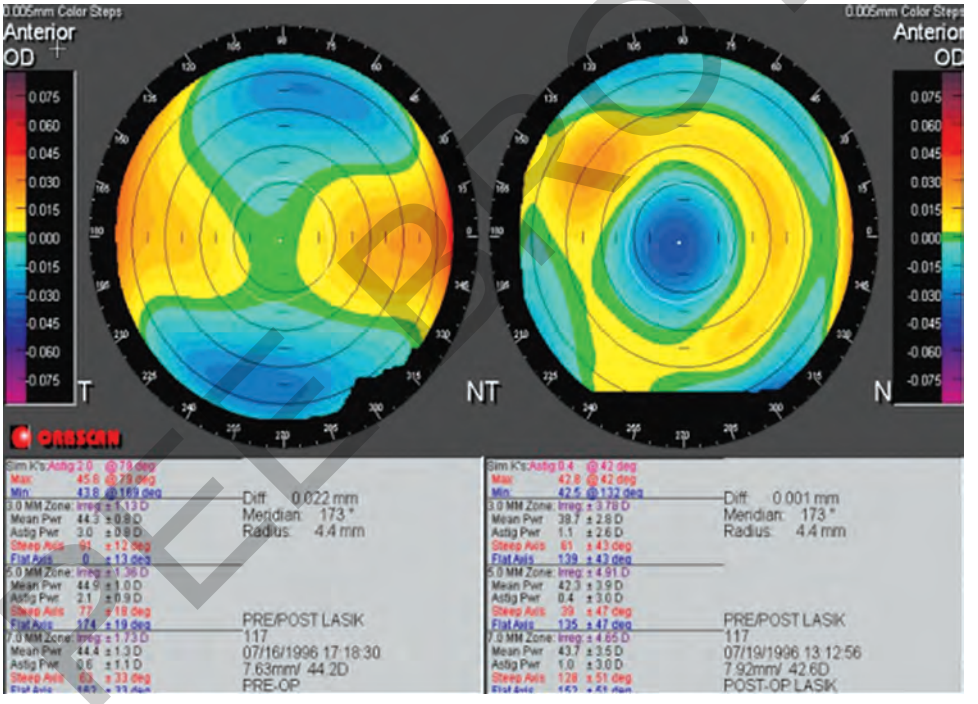


Figure 4.15 Elevation map pre- and postoperative LASIK

PREOPERATIVE LASIK SCREENING

Three Step Rule

- One abnormal map: Caution
- Two abnormal maps: Concern
- Three abnormal maps: Contraindication.

This quad map shows three normal maps, but the posterior float is abnormal because the difference reading is greater than 50 microns.

This quad map shows two normal maps, but the posterior difference is again over 50 microns. This quad map, however, also shows an abnormally thin central pachymetry. This thinning has good correlation with the steepest location of the posterior elevation map.

This quad map has three abnormal maps. The posterior difference is greater then 50 microns, there is a well-correlated steep area on the anterior elevation map, and a well-correlated area of high power on the mean power map. This is an absolute contraindication for LASIK.

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MIDDLE BOX

When reading the quad maps try not to forget the information in the middle box **(Figure 4.20)**. This box provides standard keratometric readings, white-to-white distance in millimeters, angle kappa readings, and more. The thinnest area of the cornea is displayed here as well as the amount of corneal irregularity within the central 3 and 5 mm zones. These irregularity indices are considered abnormal if they exceed 1.5 and 2 diopters respectively. This extra information combined with the quad maps provides the most complete screening tool available to detect preoperative corneal abnormalities to reduce the risk of iatrogenic induced keratoectasia. Dr(s) Karpecki and Moyes have compiled a list of Orbscan risk factors for keratoectasia based on extensive retrospective case reviews. This is a guideline that other users may want to consider when screening LASIK candidates.

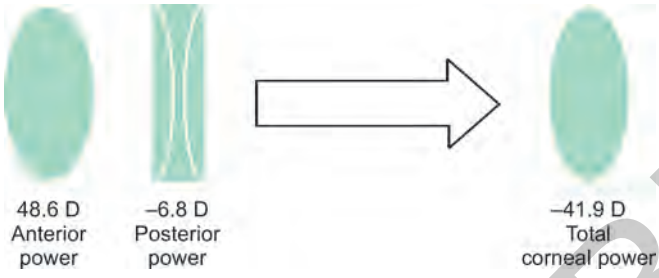


Figure 4.16 The posterior corneal surface reduces corneal power

ORBSCAN RISK OF ECTASIA INDICES

- Number of abnormal maps
- Posterior surface float (difference) >0.050 D
- 3 and 5 mm irregularity
- Peripheral thickness changes
- Astigmatism variance between eyes
- Steep K's—mean power map.

The first item is the number of abnormal maps. As stated earlier in the three-step rule, one abnormal map is a caution sign, two is of concern, and three is an absolute contraindication. The second item is the posterior float difference **(Figure 4.21)**. A difference of greater than 50 is generally accepted as abnormal, but other physicians have suggested that 50 is the limit in normal corneas, but in corneas that are thinner than normal to start with a difference over 40 should be considered abnormal.[1] The third item is the amount of irregularity in the central 3 and 5 mm zones **(Figures 4.22A and B)**. Greater than 1.5 and 2.0 diopters respectively is considered abnormal and cause for concern. The fourth item is how the central pachymetry reading compares to the peripheral 6 mm reading and to the thinnest reading **(Figure 4.23)**. These numbers are considered abnormal if the peripheral 6 mm readings are not at least 20 microns thicker than the central reading, especially if they are correlated with abnormalities on other quad maps. The thinnest reading is also considered abnormal if it is less than 30 microns thinner than the central reading, again if it is also correlated with an abnormality on another quad map. The fifth item is a difference of greater than

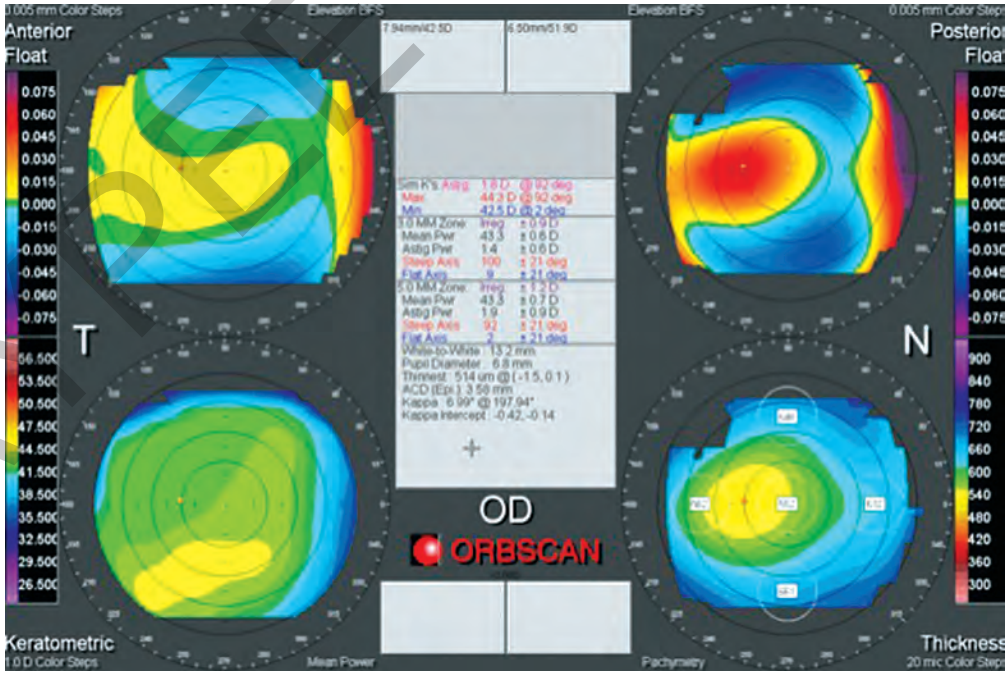


Figure 4.17 Caution—one abnormal map

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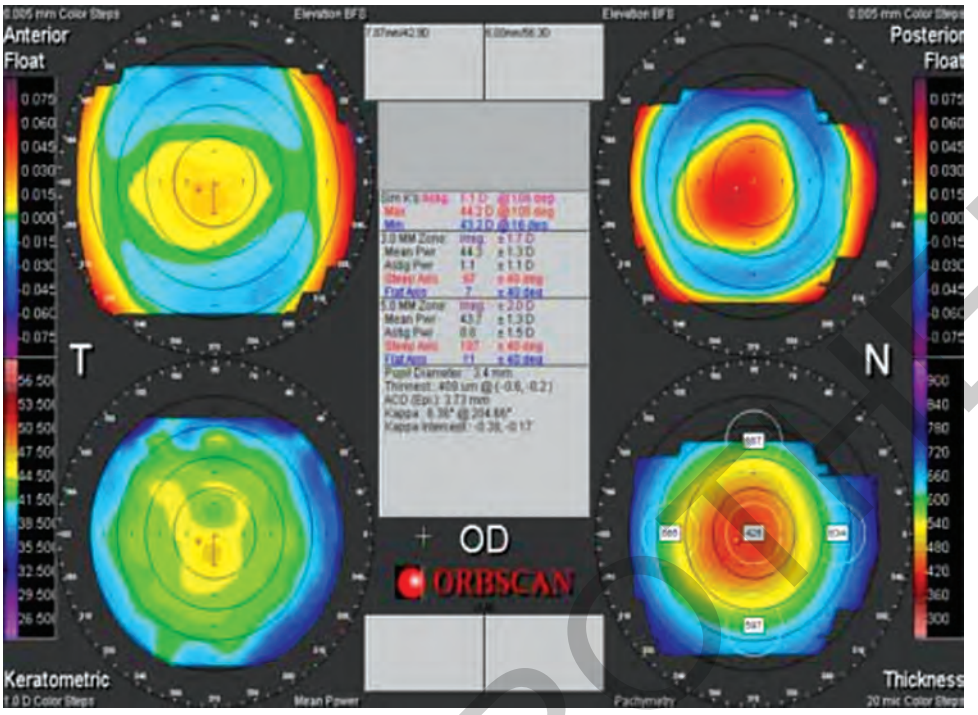


Figure 4.18 Concern—two abnormal maps

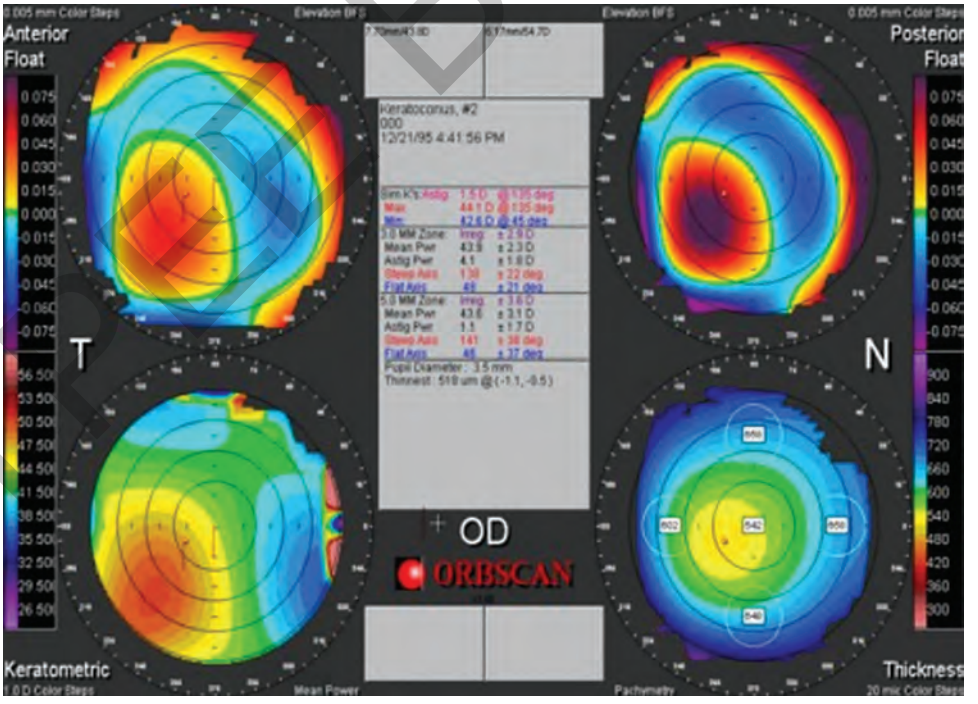


Figure 4.19 Contraindication—three abnormal maps

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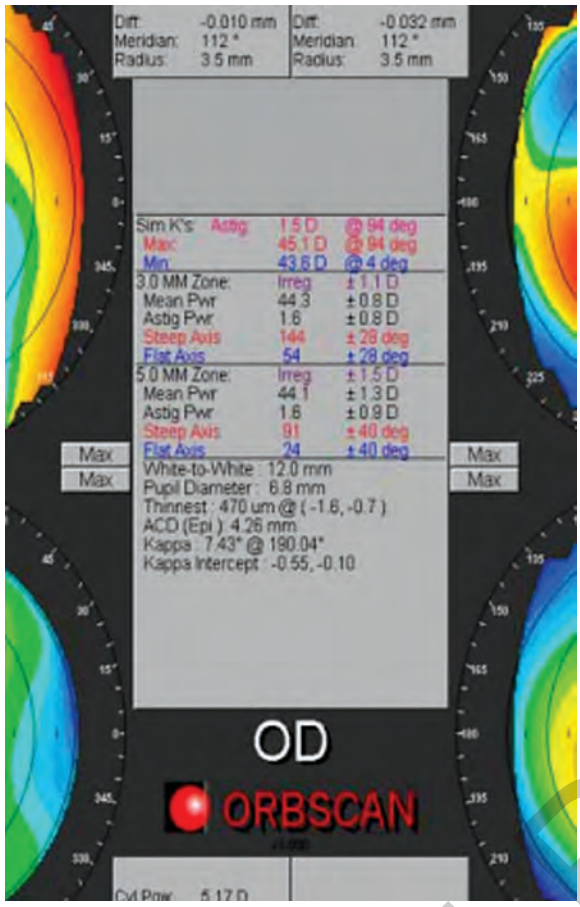


Figure 4.20 Orbscan middle box data

1.00 diopter in the amount of corneal astigmatism between eyes **(Figures 4.24 and 4.25)**. The last item is a localized steep area on the mean power map, especially if correlated with other abnormalities **(Figure 4.26)**.

These guidelines are meant to help alert the clinician to a poor candidate. The example below is an actual patient who preoperatively had a steep posterior difference, a thinnest spot of the cornea greater than 30 microns thinner than the central reading, and a higher amount of irregularity in the central 3 and 5 mm zones **(Figure 4.27)**. As you follow this patient's course postoperatively you can see progressive steepening and topographic irregular astigmatism at the 4 and 17 month visits indicating keratoectasia **(Figures 4.28 and 4.29)**.

CLINICAL EXAMPLES

As with all topographies, an abnormal tear film layer can significantly distort the readings. Below is an example of normal topography on a patient, and then a repeat topography taken after 3 minutes of drying **(Figures 4.30 and 4.31)**. Note the significant change is surface quality and validity of the dry eye reading. The next example is that of a keratoconus patient **(Figure 4.32)**. Note the larger posterior float difference, the well-correlated steep anterior float, the well-correlated steep power reading on the mean power map, the thinnest spot of the cornea not being central and being greater than 30 microns thinner than the central reading, and the large amounts of irregularity in the central 3 and 5 mm zones. The final example is of pellucid marginal degeneration **(Figure 4.33)**. Note the classic large amount of against the rule astigmatism, the large posterior float difference,

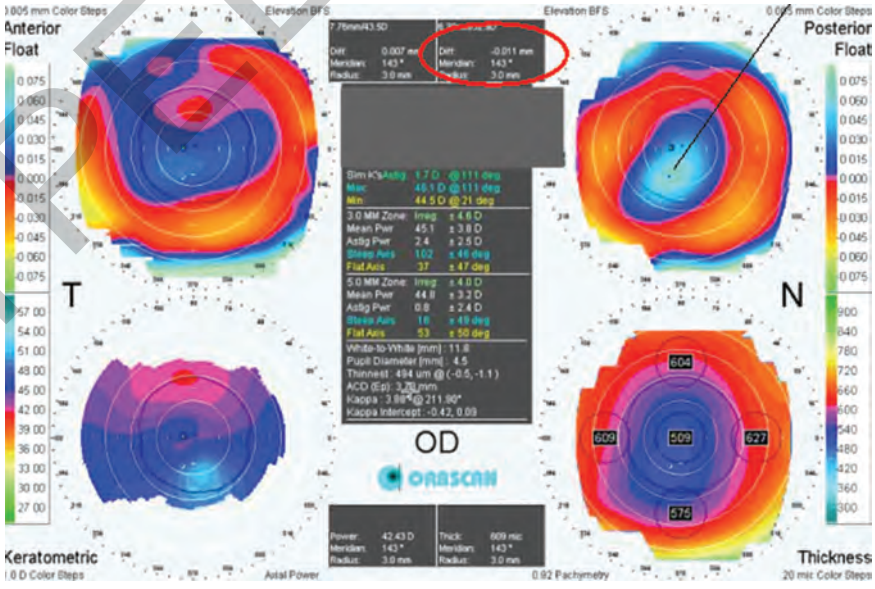
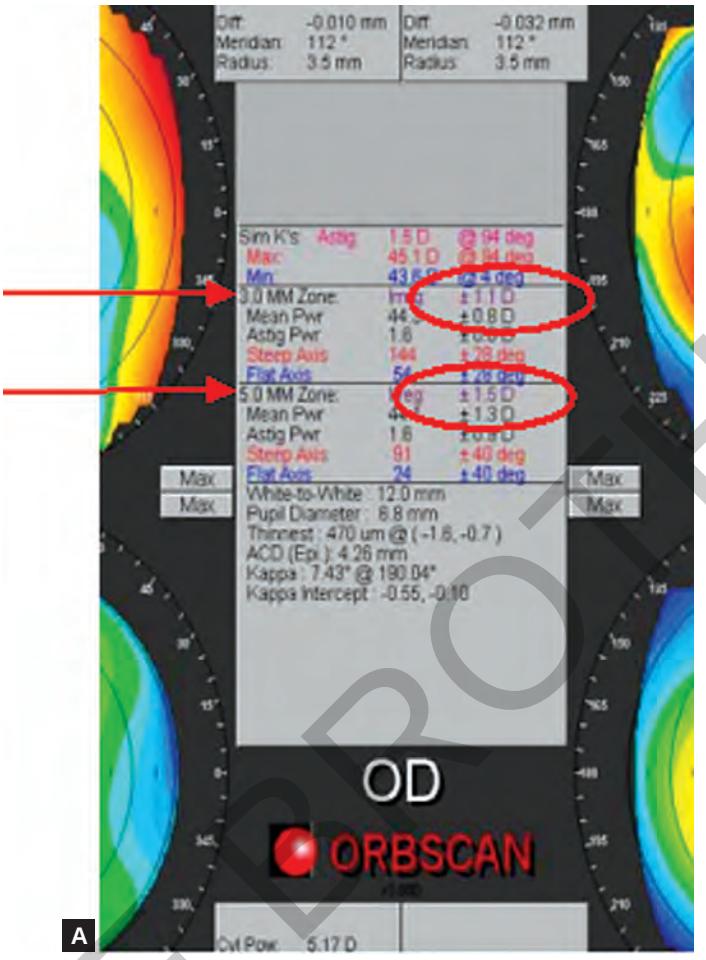
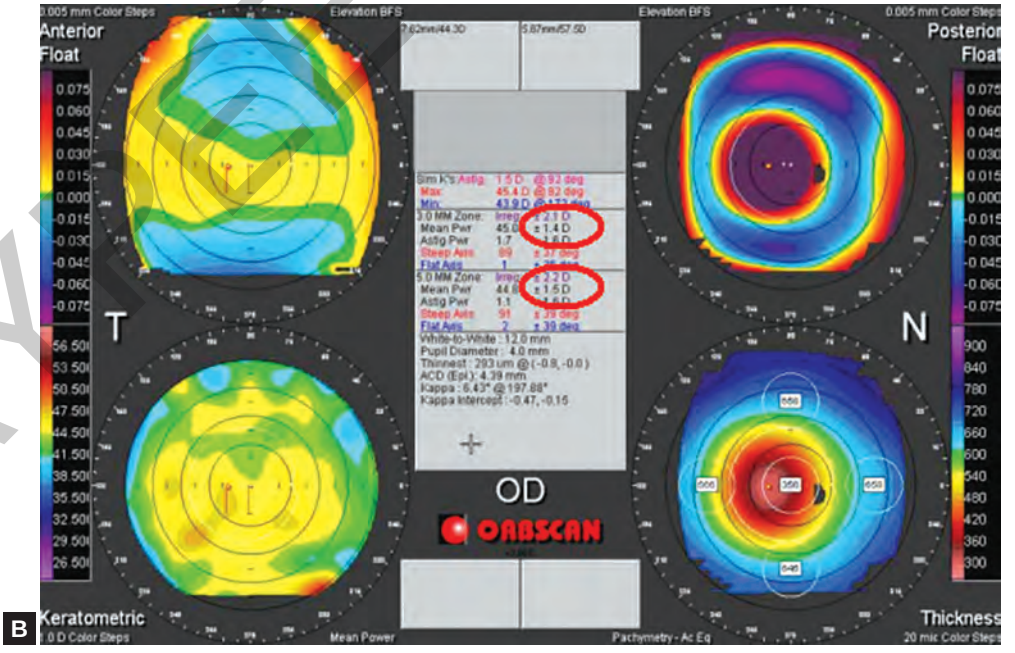


Figure 4.21 Posterior float difference

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Figures 4.22A and B 3 and 5 mm irregularity

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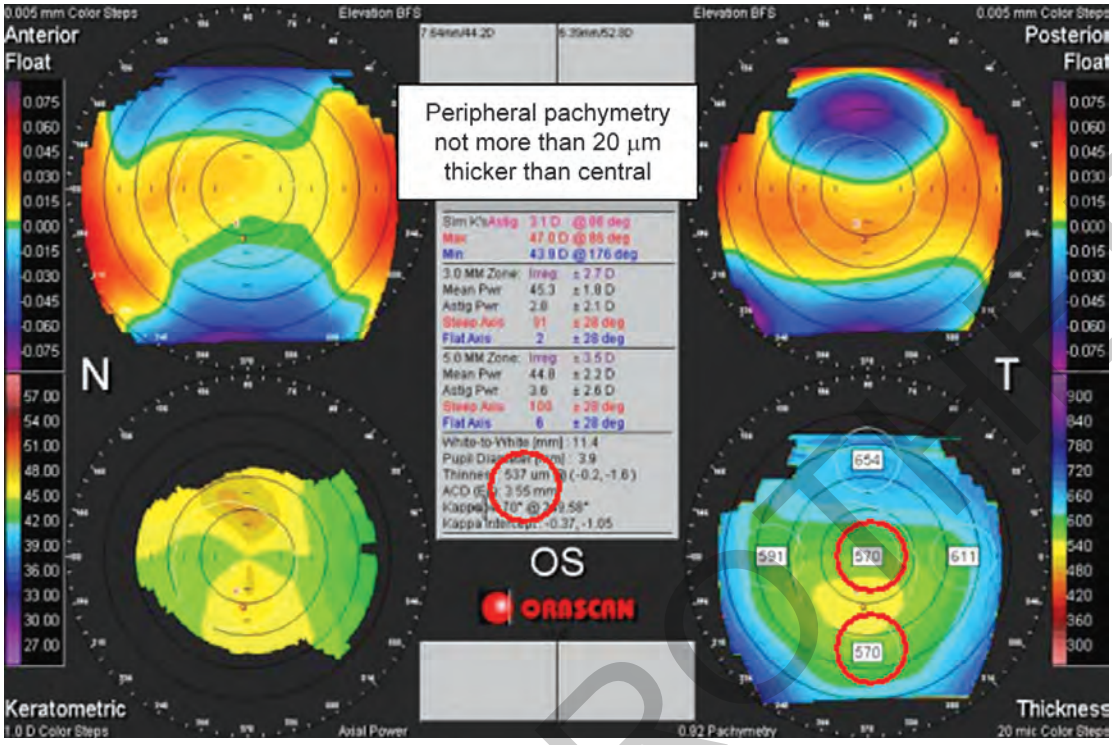


Figure 4.23 Peripheral thickness comparison

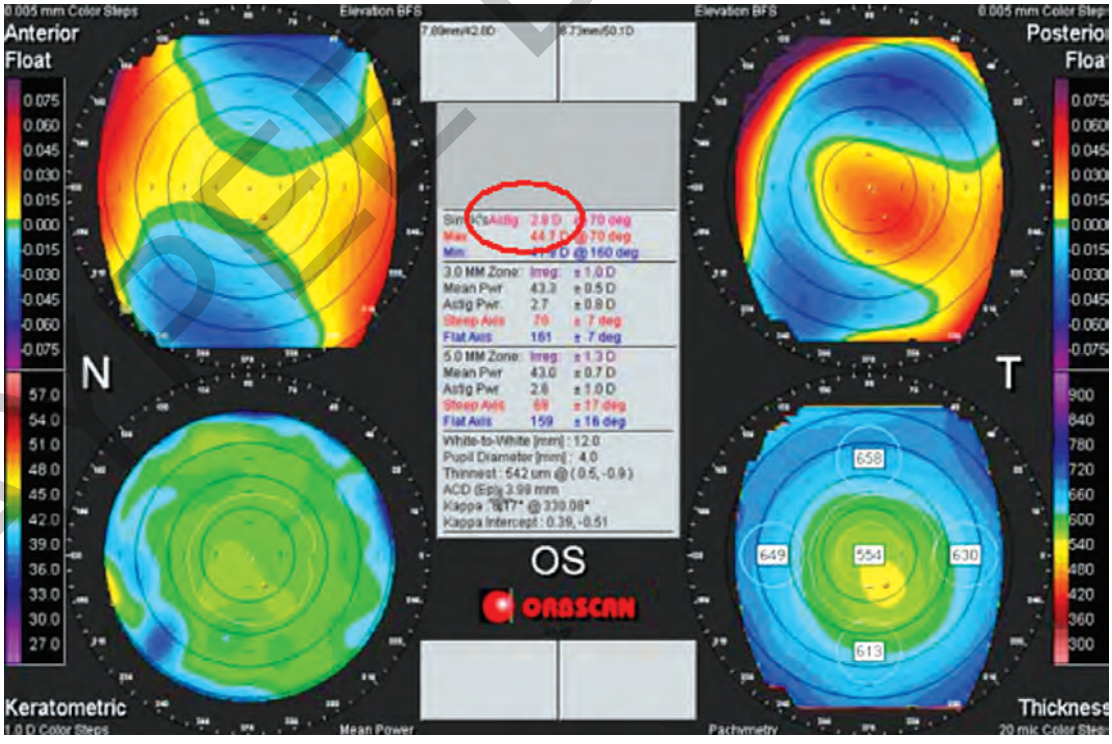


Figure 4.24 Astigmatism variance between eyes

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Amar Agarwal MS FRCS FRCOphth is the Chairman and Managing Director, Dr Agarwal's Group of Eye Hospitals and Eye Research Center, Chennai, Tamil Nadu, India. He is the Past President, International Society of Refractive Surgery (ISRS) and Secretary General, Indian Intraocular Implant and Refractive Society (IIRSI), India. He is the pioneer of Phakonit, which is Phaco with a Needle Incision Technology. This technique became popularized as bimanual phaco, microincision cataract surgery (MICS) or Microphaco. He is the first to remove cataracts through a 0.7 mm tip with the technique called Microphakonit. He has also discovered no anesthesia cataract surgery (NACS) and fallen vitreous (FAVIT) technique, a new technique to remove dropped nuclei. The air pump which was a simple idea of using an aquarium fish pump to increase the fluid into the eye in bimanual phaco, and co-axial phaco has helped prevent surge. He has discovered a new refractive error (Aberropia) and the first-to-do a combined surgery of microphakonit (700 micron cataract surgery) with a 25-gauge vitrectomy in the same patient. He is also the first surgeon to implant a new mirror telescopic IOL (LMI) for patients suffering from age-related macular degeneration. He has also been the first in the world to implant a Glued IOL, in which a PC-IOL is fixed in an eye without any capsules using fibrin glue. Dr Agarwal's Eye Hospital has done for the first time, an anterior segment transplantation in a 4-month-old child with anterior staphyloma. He has combined Glued IOL and IOL scaffold in cases of PC rupture where there is no iris or capsular support and termed the technique Glued IOL Scaffold. His hospital has done a glued endocapsular ring in cases of subluxated cataract.

He has started pre-Descemet's endothelial keratoplasty (PDEK), in which pre-Descemet's layer and the Descemet's membrane with endothelium are transplanted en bloc in patients with diseased endothelium. His hospital has also introduced contact lens-assisted collagen crosslinking (CACXL) for the first time, a new technique for crosslinking thin corneas, and has also worked on E-DMEK, in which an endoilluminator is used to assist in Descemet's membrane endothelial keratoplasty (DMEK) surgeries.

He has received many awards for his work done in ophthalmology, most significant being the Casebeer Award, Barraquer Award and the Kelman Award. He has performed more than 150 live surgeries at various conferences. His videos have won many awards at the film festivals of the ASCRS, AAO and ESCRS. He has also written more than 60 books, which have been published in various languages (English, Spanish and Polish). He also trains doctors from all over the world in his center on phaco, bimanual phaco, LASIK and vitreoretinal surgeries.

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