



Figure 4. The patient still reports unchanged "poor vision" and headaches.

What would you recommend to the patient?

At the patient's first visit, BCVA with a contact lens correction was 20/20; however, we are not given the best spectacle-corrected visual acuity. The pachymetry

and topography show that the patient did not have keratoconus, and the topography does not suggest contact-lens-induced warpage. However, we are not told what kind of contact lenses the patient was wearing (i.e., soft, soft toric, or gas permeable), and we do not know how long the patient ceased wearing the contact lenses before LASIK was performed. If this patient did

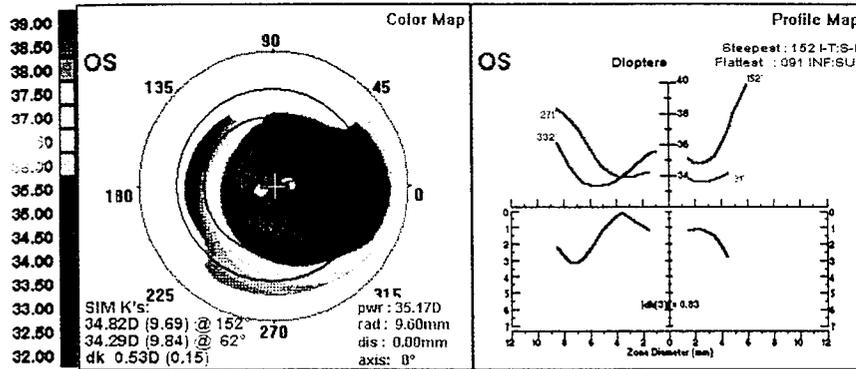
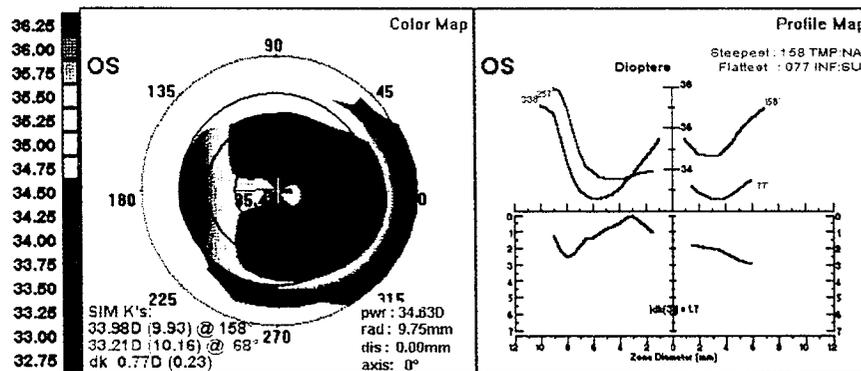
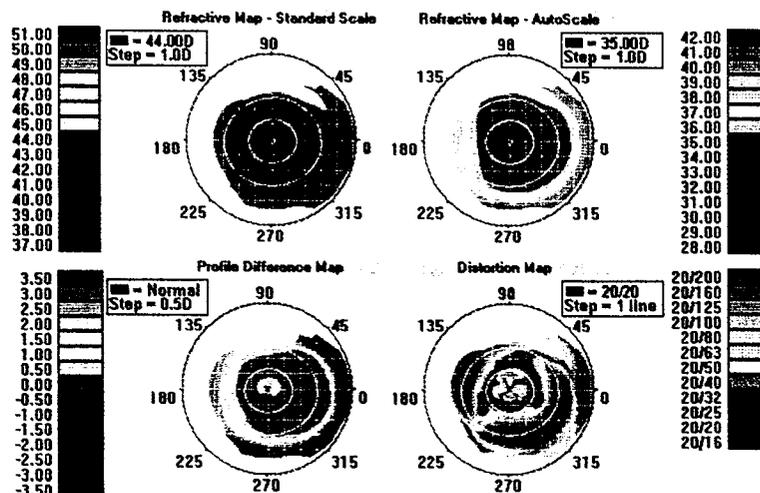


Figure 3. (Kohnen) Corneal topography of the left eye 3 months after LASIK, 1 month after "stromal smoothing" (EyeSys CAS, software version 3.04; axial [color] map).



A



B

Figure 4. (Kohnen) Corneal topography of the left eye 1 year after LASIK, 10 months after "stromal smoothing," and 1 month after "central island treatment" A: EyeSys CAS, software version 3.04; axial (color) map. B: Holladay Diagnostic Summary including refractive and distortion maps.

not have a period without contact lens use, some irregular corneal astigmatism could have been induced by the LASIK procedure.

The first laser treatment did not appear to include pretreatment or treatment incorporated in the laser algorithm to limit the possibility of central islands. Topography 2 months after LASIK shows marked irregular astigmatism in the central zone. There is also a flat, peanut-shaped area nasally. The rather flat keratometry preoperatively may have predisposed the cornea to a small flap, and it is possible that the nasal part of the ablation was on the cap surface. It is also possible that the ablation itself was slightly nasal to fixation.

Two months after LASIK, the patient has significant irregular astigmatism, which is causing the loss of BCVA. Refraction is difficult in these patients. If the patient did have a  $-2.00$  diopter (D) cylinder at 125 degrees, I would have expected a better improvement in visual acuity than from 20/50-1 to 20/40-1.

Once the patient developed the irregular astigmatism and loss of BCVA, I would have waited for at least 6 months before considering retreatment. When planning retreatment, it is best to be wary of trying to correct all the cylinder in the patient's apparent spectacle correction, particularly when it is not present topographically. I think it is inappropriate to do an astigmatic retreatment for irregular astigmatism as polyopia will likely result. Regarding retreatment, it has been my experience with the Summit Apex Plus that the ablations most likely to lead to central islands are myopic astigmatic corrections without any correction of spherical myopia. These patients require a significant pretreatment of about  $-1.00$  D at a 2.5 mm OZ. The retreatment itself can cause a hyperopic shift. I would have done a  $-1.00$  D, 6.5 mm spherical ablation as the patient's significant irregular astigmatism was certain to be made worse by a large astigmatic ablation.

The patient then developed a significant central island. The axis of the island is at nearly 90 degrees to the planned treatment, which is fairly typical. The island is steeper on the nasal side and is possibly related to fluid at the hinge of the LASIK cap; it also appears as though this ablation may have been decentered slightly temporally.

The central islands are not maximal centrally, but rather 1.0 to 2.0 mm off fixation. There is also irregular astigmatism.

The central island treatment of  $-1.00$  D and a 3.5 mm OZ will not resolve these central islands, which, if anything, required a 1.0 to 2.0 mm ablation of a few spots on either side of fixation. This would be a difficult procedure with a strong possibility of failure.

The final topography 1 month after this treatment shows a cornea with marked central islands. Just as important is the irregular astigmatism, which is shown best in the profile difference map on which the nasal half of the central area is significantly steeper than the temporal half. With the current technology, I believe this is not treatable with the excimer laser. One should wait at least 6 months, if not longer, before contemplating further treatment. The corneal topography, corneal uniformity index, and potential corneal acuity should significantly improve with time.

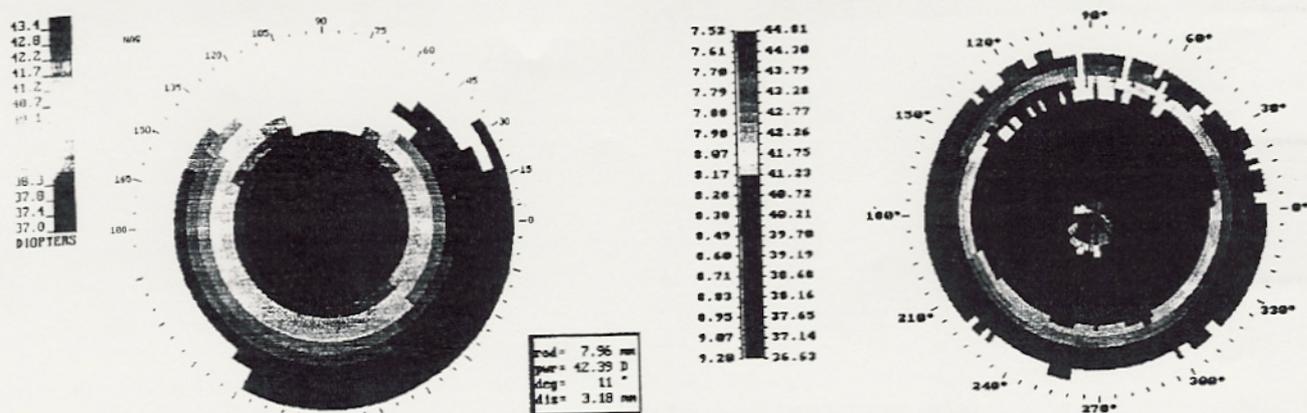
It is also probable that the degree of hyperopia will diminish. These corneas may benefit from topographic-based excimer laser treatment customized to the corneal shape.

In the meantime, the patient's options are to (1) continue with a contact lens in the right eye and leave the left eye uncorrected; (2) try a contact lens, probably a rigid gas-permeable lens, which may significantly relieve the headaches and poor vision; however, I doubt this would make the patient asymptomatic, nor do I believe he would tolerate it.

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■ This 47-year-old man with unilateral myopic LASIK poses a unique challenge to the refractive surgeon because of his multiple retreatments and hyperopic refraction. There are several points to consider in evaluating this patient throughout the course of his treatments as well as his current stage of requiring further intervention. First, his preoperative K-readings are relatively flat (40.00 D). This, together with an 8.00 D myopic correction, would intuitively lead to rather flat K-readings postoperatively. This patient shows significant flatness in keratometry and topography values, which seem to continue getting flatter with each retreatment.

Initially, the 2 month postoperative topography showed a semicircular ablation pattern nasally. The surgeon then performed an unknown smoothing pat-



**Figure 5.** (Kohnen) Videokeratography of a steep central island after excimer laser photorefractive keratectomy. *Left:* The EyeSys CAS provides insufficient central information to identify the island (only 0.50 D of steepening). *Right:* A Technolas C-scan clearly delineates the magnitude of the island (>4.00 D of steepening). (Topographies reprinted with permission from the *Journal of Refractive Surgery* [1997; 13:215-218].)

tern resulting in a central island, the magnitude of which is essentially unknown because of the inaccuracy

of the EyeSys system centrally. The surgeon then treats the central island with a 3.5 mm zone, which appears larger than the size of the island. After the second retreatment, the topography shows another semicircular pattern, this time noted temporally with an associated keyhole-like pattern 1 month after the last retreatment.

I would wait at least another 1 or 2 months for outcome stability and then re-evaluate the patient to see whether 1 more retreatment might be attempted. However, further diagnostic information must be gathered:

1. *Improved topography.* Because of superior central resolution, a Technomed C-Scan topography would offer more accurate central information, which is especially important in evaluating a steep central island, as shown in Figure 5.<sup>1</sup> Ray-tracing analysis can also be used to correlate the potential acuity to the clinical acuity tested to verify that a proper refraction is being done.

2. *Ultrasound versus optical pachymetry.* Because multiple retreatments have been performed in this patient, careful assessment should be made of the actual stromal thickness beneath the area of central elevation (seen as a steep central island). Very high frequency ultrasound has recently been shown to adequately resolve a 2-dimensional map of corneal epithelium thickness, flap thickness, and underlying stromal depth with good accuracy.<sup>2</sup> Also, optical pachymetry could be considered as derived from the Orbscan topography

system. This may be helpful in evaluating the posterior surface to see whether an ectasia exists.

3. *Hard contact lens over-refraction.* To achieve BCVA (beyond spectacles), a hard contact lens refraction would be helpful. Because there is no mention of haze in this report, one must evaluate any opacity or reason for loss of BCVA with a contact lens.

After these additional diagnostic tests, further evaluation can be done. First, the hard contact lens over-refraction could determine that a rigid contact lens worn by the patient may solve the problem by correcting the corneal irregularity. If this fully corrected the visual abnormalities, it could provide an immediate solution.

If a hard contact lens over-refraction fails or the patient is unmotivated to wear a contact lens, it may be possible to perform a topography-assisted corneal ablation. Although this is still investigational, recent progress has been made in this area. This includes the TopoLink system provided by the Technomed C-scan, which can be coupled to a Technolas laser. The TopoLink program estimates the amount of tissue to be removed by subtracting the C-scan's elevation map from the desired spherical outcome. This can then be linked with the Technolas laser to selectively correct areas of greater elevation along the map. Thus, an irregular cornea can be treated, which may even correct the hyperopic refraction recorded after the last retreatment.

Finally, if all else fails (rigid gas-permeable contact lens versus custom retreatment), a homoplastic lamellar

or penetrating keratoplasty can be performed, especially if haze, uncorrected distortion, or ectasia exists.

This scenario poses a difficult problem. However, with further careful analysis of the refractive status of the eye, it is possible to use 1 of the above modalities in ascending order until you find a solution.

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■ The last topographic map of the left eye (after the second retreatment) shows a temporally decentered key-hole ablation pattern. The blurred vision is caused by the multifocality of the cornea overlying the entrance pupil. Any treatment must be designed to get rid of this multifocality.

The least invasive approach would be to fit a rigid contact lens. Surgical treatment is another option. The most invasive would be a penetrating graft, which should be considered the last option. Surgical techniques that "mask" part of the cornea during a subsequent excimer ablation to achieve a more regular surface may work but represent art rather than science, which means very poor predictability.

I believe the only treatment option currently available is topographically guided LASIK,<sup>1</sup> which uses the actual topographic map to calculate the ablation. A recent study reported a success rate of 70 to 80% in similar cases. Possible limitations include the thickness of the remaining stromal bed. As the corneal thickness was 608  $\mu\text{m}$  initially and only moderate myopia was corrected, there should be sufficient thickness to perform another ablation.

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■ A rigid gas-permeable contact lens is the best treatment option for this 47-year-old patient, who presents with "poor vision," hyperopic astigmatism,

and an irregular central island after repeated LASIK reoperations. A few corrective surgical options, such as topography-assisted LASIK retreatment<sup>1</sup> or laser thermokeratoplasty (LTK) applications in the stromal bed,<sup>2</sup> may be available in the future. The theoretical benefits of these approaches should be substantiated in future clinical studies before being considered for this particular patient.

Analysis of the events leading to the patient's present eye condition suggests that current surgical modalities may not be very beneficial in correcting the LASIK complications. In addition, several lessons can be learned from this case:

#### 1. Initial decentration and irregular astigmatism.

This case illustrates the importance of treatment centration in LASIK, as in other keratorefractive procedures. Treatment centration relies predominantly on patient cooperation. Several factors may interfere with patient fixation including an uneven optical surface after the corneal flap is raised, leading to a blurred appearance of the fixation light; blurred vision after retinal reperfusion upon intraocular pressure drop; relatively high patient anxiety, particularly during LASIK. Other factors leading to decentration include misalignment of the laser beam and the optical system and nasal decentration of the pupil secondary to the microscope light or to pharmacologic miosis.

The pattern of decentration in this patient is suggestive of intraoperative drift.<sup>3</sup> In the postoperative evaluation and management of decentrations, it may be useful to distinguish between the effects of laser drift and laser displacement. Laser displacement (shift) is a direct consequence of misalignment of the laser beam with the center of the entrance pupil from the start of treatment; laser drift occurs with intraoperative movement of the eye, resulting in a relatively nonuniform distribution of surface powers within the treated zone. Intraoperative treatment drift appears as an uneven ablation area with the flatter zone shifted peripherally, leaving the central area of the ablation zone with a higher corneal surface power difference (Figure 2). We believe that it is this central corneal nonuniformity that is responsible for the loss of BCVA. We have observed that the degree of drift correlates strongly with loss of BCVA.<sup>3</sup> The observed topographical pattern in Figure 2 is consistent with the scenario of poor initial centration with intraoperative correctional eye movement. This

results in an irregular astigmatism that is often associated with BCVA loss and double vision.

The drift pattern may be the result not only of nasal intraoperative movement but also of treatment of the nasal hinge. It is interesting that the flattest area in this patient is confined to the nasal portion of the cornea, where the flap hinge is localized (Figure 2). This occurs when the laser treatment is delivered to both the stromal bed and the posterior face of the flap, producing double treatment of this area. Such a phenomenon may be encountered more frequently in flat corneas, as in this patient.

2. *Disadvantages of diametrically opposite retreatment of decentration.* The second treatment of this patient is not specified in detail. It is likely that the surgeon attempted to correct the nasal decentration by performing a diametrically opposite treatment.

The predominantly temporal treatment has resulted in marked improvement in UCVA and BCVA. This could have been achieved by simple intentional decentration or by using modulating agents to cover the nasal area.

Although preoperative astigmatism was WTR, the astigmatic central island after the second treatment was against the rule (ATR). This may be induced by more tissue ablation in the horizontal paracentral areas, responding to the initial nasal decentration and the subsequent temporally decentered retreatment.

3. *Disadvantages of central island treatment after LASIK.* Treatment of the ATR astigmatic central island may have been excessive, resulting in hyperopic astigmatism. This case illustrates the difficulty in determining the point at which sufficient surgical correction is achieved in a symptomatic patient.

4. *Future intervention.* Our preferred approach in this presbyopic patient would be conservative and nonsurgical. However, if rigid gas-permeable contact lens correction cannot be tolerated, other surgical options may be considered including hyperopic LASIK. This may result in worsening of the central island and in visual symptoms similar to those following small-diameter hyperopic photorefractive keratectomy (PRK). Astigmatic keratotomy under the flap may also be considered (to benefit from the coupling effect). However, the efficacy of this technique remains to be determined.

There may be a place for recently developed tech-

niques in the treatment of this patient's eye condition. Preliminary results of LASIK assisted by corneal topography in irregular corneas showed undercorrection and regression of treatment.<sup>1</sup> Holmium:YAG LTK has been used to treat PRK overcorrections below +2.00 D.<sup>2,4</sup> The use of this technology for LASIK overcorrections has not been reported. We expect that LTK would be less likely to correct the corneal irregularity than the spherical component in this patient.

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■ This case demonstrates how an initially straightforward spherical myopic LASIK procedure can become a complex LASIK complication. The left eye has had primary LASIK and 2 enhancement procedures. The first and most important step in treating this patient is preoperative counseling. To ensure that the patient had realistic expectations, I would explain that the problem is complex and full correction may take 2 or more procedures. To alleviate the despair associated with these types of complications, I would explain that new technology is constantly becoming available that could help correct unresolved problems in the future.

Although the postoperative corneal pachymetry values in the left eye were not provided, current corneal thickness is extremely important when planning another corrective excimer ablation.<sup>1</sup> Given that the initial correction was 8.20 D and the amount of laser applied during the second enhancement is unknown, it is possible that the central corneal thickness may be approaching 400  $\mu\text{m}$  and further excimer ablative therapy could result in a loss of corneal integrity and possible iatrogenic keratoconus.

The primary LASIK in the left eye suggests potential problems. The preoperative K-readings are listed as less than 41.00 D with the flat K at 40.12 D. If the Chiron ACS is used with the 160  $\mu\text{m}$  depth plate, the flap will be thin and small and there is a significant risk of a free cap. Although there are no flap problems described, I would take a careful look at the flap for signs of irregularity or striae, which would suggest a thin flap. In cases with flat K-readings of this nature, I would use the Chiron ACS with a 200  $\mu\text{m}$  depth plate or the Chiron Hansatome.

The 2 month postoperative topography (Figure 2) shows an irregular ablation pattern with excessive treatment nasally. This is the topographic pattern of a decentered ablation. Poor excimer beam homogeneity or a major flap problem can also cause this pattern. The first enhancement procedure was presumably done to correct this decentered ablation. The follow-up topography suggests that an excessive enhancement ablation was performed temporally that resulted in a central island. The danger of performing phototherapeutic keratectomy (PTK) smoothing procedures on the stromal bed is that we are really guessing how much ablation to perform. In this case, I would have lifted the flap, ablated the astigmatic refractive error alone, and carefully refloated the flap. I have found that the smoothing effect of the corneal flap is helpful in these cases, often giving excellent results.

After the first enhancement procedure, the left eye developed a central island (Figure 3). Central islands are less common with LASIK; however, they tend not to resolve unless treated, as in the case of central islands after PRK.<sup>2</sup> The EyeSys CAS version 3.04 indicates that the central island is small with a diameter of less than 3.0 mm and a height of only 1.00 to 1.50 D. The Munnerlyn formula suggests that this island has a maximum height of only 4.5  $\mu\text{m}$ . The second enhancement procedure involved a central island treatment of  $-1.00$  D at 3.5 mm, which would have a depth of approximately 4.10 D. Therefore, this treatment should have eliminated the island. Unfortunately, the follow-up topography (Figure 4) indicates the central island is still present and the patient is now hyperopic.

There are a number of possible explanations for the persistence of the central island. The EyeSys system cannot analyze the central 0.5 mm of the central cornea because of its centering system,<sup>3</sup> making it less ideal for

central island analysis. The EyeSys system has also been shown to produce excessive smoothing, which could lead to underestimation of central corneal elevations.<sup>4</sup> These 2 limitations suggest that the height and perhaps the size of the central island may have been underestimated. The treatment performed was a refractive ablation of  $-1.00$  D at 3.5 mm with the VISX Star excimer laser. I prefer to treat central islands with a PTK ablation for the calculated depth and diameter using the Chiron Technolas 116 or 217 excimer laser.

When evaluating and treating central islands, we must always remember that the Placido disk technology used by the common videokeratography machines can present a central divot as a central island. In a 1996 Ocular Surgery News article, Ray Stein, MD, described a case that presented as a central island on Alcon and Tomey topography, but both PAR and Orbscan systems showed a central divot. Undercorrections with a central divot should be treated with wide-zone refractive ablations rather than the central PTK ablation for the central islands.

My current recommendations would be to wait until refractive or topographic stability has been achieved. I would suggest that topography be performed monthly, on a different topography machine, and I would wait at least 6 months before considering other surgery. If possible, I would also arrange for analysis with the PAR or Orbscan system to confirm the presence and size of the central island. Corneal pachymetry should also be done.

Once these steps have been completed, I would consider treating the central island. I would perform a PTK ablation based on the height of the central island calculated with the Munnerlyn formula and island diameter. I would tell the patient to expect a further hyperopic shift after surgery and that enhancement hyperopic LASIK can be performed in the future once refraction is stable and BCVA restored. Persistent problems with the irregular ablation could be corrected with topography-assisted LASIK, which should be available in the near future.

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■ A review of the clinical history would be helpful before discussing treatment options. Two months postoperatively, the flap was relifted to "correct the stromal cylinder." However, we do not know which procedure was done or its specific goal. I question the indication for relifting the flap at that time since refraction was not yet stable and the symmetry of the topography did not reflect the degree of BCVA loss.

The result of this "smoothing" procedure is what I call a central island cylinder. Attempting to correct it with a spherical ablation, as was done here with the PRK laser, will drive the refraction toward overcorrection with the same amount of cylinder—and this is precisely what occurred.

My experience suggests that the only way to correct this difficult problem is first, do not let the patient push you into another hasty retreatment. In other words, wait until the topography and refraction are stable (usually 3 to 5 months). The topography shows a remarkably regular astigmatism, so I strongly suspect that the "BCVA" of 20/40 could be improved by pushing the cylinder. For retreatment, my colleague, Marc Mullie, MD, and I favor recutting using the same keratome with the same footplate without decentration of the ring. The astigmatism can best be treated by a scanning laser programmed to correct the full topographical cylinder in the negative cylinder mode. (The Schach & Lomb Keracor 116, 117, and 217 are excellent in this regard.) Any spherical component of the refraction—in this case residual hyperopia—can be treated at the same time.

This case demonstrates how an unhappy patient will sometimes make the surgeon feel compelled to "do something" even when it is not in the patient's best interest. When a problem occurs, it is best to be totally honest and get the patient to agree to a

treatment plan that may involve a long delay before an acceptable optical solution can be reached. This may sometimes require referral to a colleague who has access to the appropriate technology to correct a specific problem.

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■ Examining the preoperative topography reveals a corneal power that is much flatter than normal ( $40.71 \times 40.03$ ). There is a much higher chance of a short flap or cap with these flat corneas. At the 2 and 3 month postoperative visits, the treatment is decentered temporally by at least 1.0 mm. After the stromal smoothing, the decentration increased temporally, creating a very sharp transition at the nasal aspect of the optical zone at 3.0 mm. There are also 2 prominent central islands.

On the last topography (Figure 4), the Holladay Diagnostic Summary shows that the hinge side of the flap is just 2.0 mm nasal to the center of the pupil. It is elevated and has a peninsula crossing into the visual axis. As the distortion map shows, this is a terrible central optic that is consistent with the patient's poor vision and multiple images. I am sure both the patient and surgeon are having headaches at this time.

At this point, the only choices for good vision are hard contact lenses or a custom ablation. As the goal was to eliminate contact lenses, I doubt whether the patient would be happy with this alternative.

At this point, I would re-cut the flap using the Moria or Hansatome, slightly decentered nasally, to ensure a stromal treatment bed of at least 3.5 to 4.0 mm to allow for an adequate treatment area. The goal of the ablation would be to flatten the nasal ridge and peninsula to match the light blue of about 34.00 D. I would not worry about the "valley" superotemporally at this time. Flattening to this level would leave the patient too hyperopic. The patient will still have some minor distortion with pupil sizes over 6.0 mm but should have good daylight vision and only mild distortion at night.

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