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THE SUMMIT OF SPECIALTY CONTACTS

Sorrento October 14-16, 2022

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HIGHER ORDER ABERRATION CORRECTION WITH SCLERAL LENSES

GREG GEMOULES, O.D.


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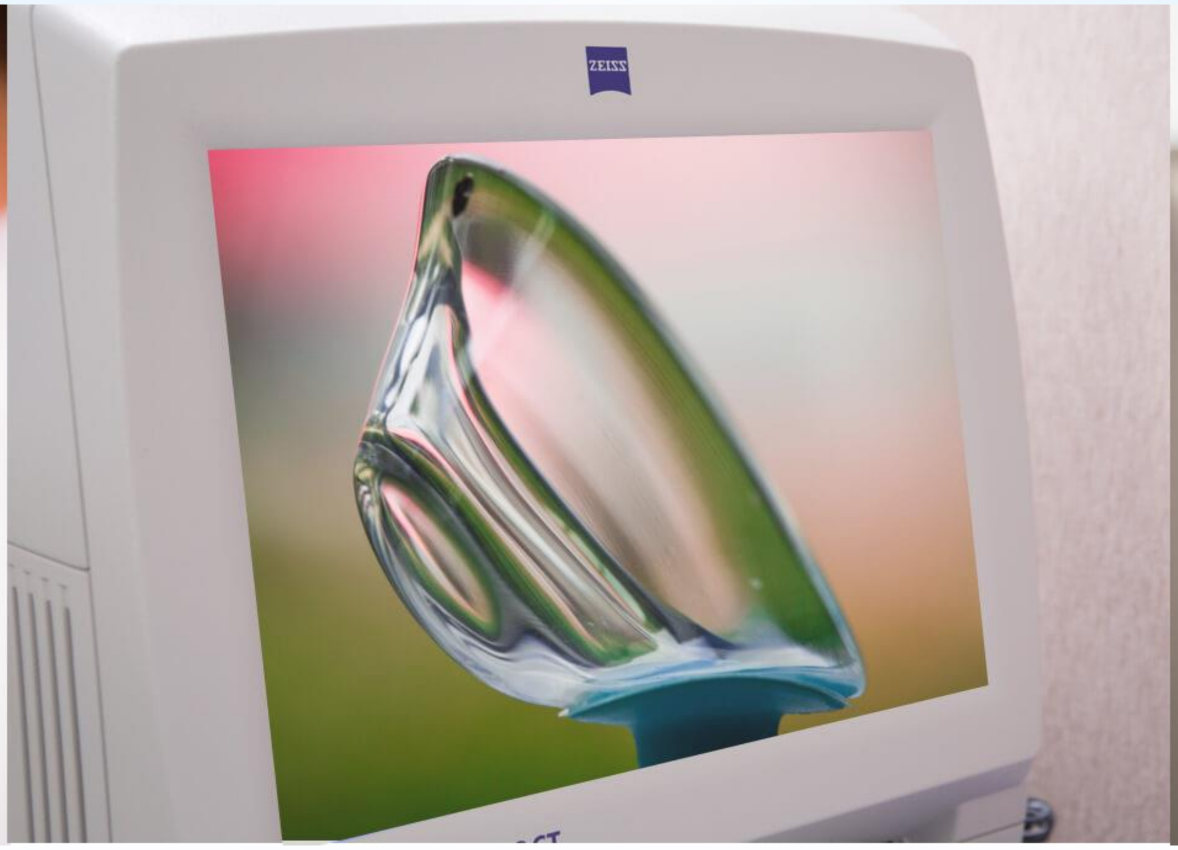
CELEBRATING 18 YEARS
WITH DIGITAL IMAGE-GUIDED SCLERAL LENSES SINCE 2007.

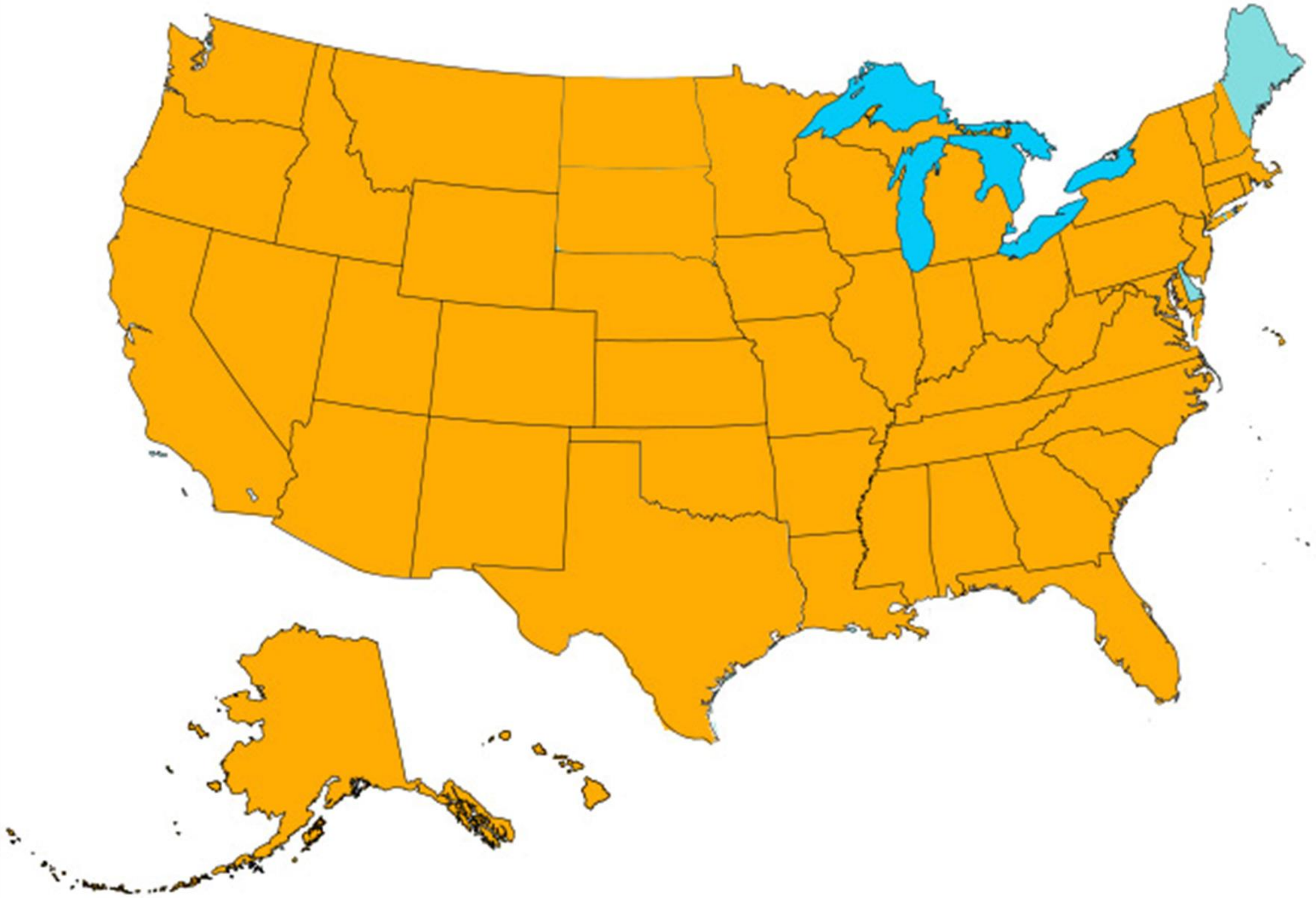
CELEBRATING 14 YEARS
WITH WAVEFRONT GUIDED-OPTICS IN SCLERAL LENSES SINCE 2011.

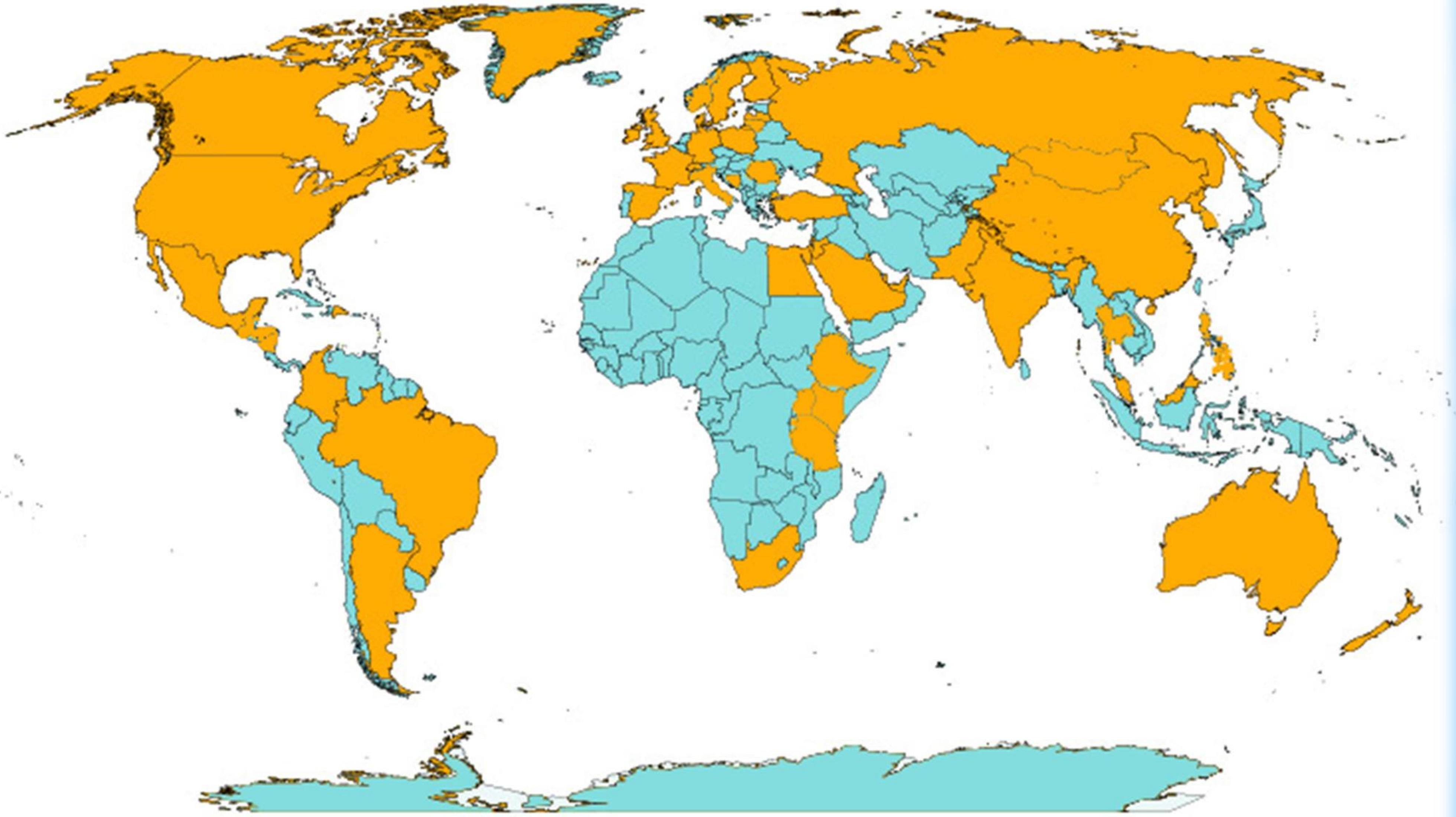


WORLDWIDE REPRESENTATION

PATIENTS HAVE COME FROM THE FOLLOWING LOCATIONS TO IMPROVE THEIR VISION WITH LASERFIT LENS

PLACES OUR PATIENTS HAVE COME FROM ARE REPRESENTED IN ORANGE





HISTORY OF HUMAN WAVEFRONT SENSING

Aberrations and retinal image quality of the normal human eye

Junzhong Liang and David R. Williams

Center for Visual Science, University of Rochester, Rochester, New York 14627

Received January 7, 1997; revised manuscript received May 12, 1997; accepted May 20, 1997

We have constructed a wave-front sensor to measure the irregular as well as the classical aberrations of the eye, providing a more complete description of the eye's aberrations than has previously been possible. We show that the wave-front sensor provides repeatable and accurate measurements of the eye's wave aberration. The modulation transfer function of the eye computed from the wave-front sensor is in fair, though not complete, agreement with that obtained under similar conditions on the same observers by use of the double-pass and the interferometric techniques. Irregular aberrations, i.e., those beyond defocus, astigmatism, coma, and spherical aberration, do not have a large effect on retinal image quality in normal eyes when the pupil is small (3 mm). However, they play a substantial role when the pupil is large (7.3-mm), reducing visual performance and the resolution of images of the living retina. Although the pattern of aberrations varies from subject to subject, aberrations, including irregular ones, are correlated in left and right eyes of the same subject, indicating that they are not random defects. [S0740-3232(97)00811-9]

Gemoules demonstrated a linear correlation between pupil area and spherical aberration in post-LASIK patients.

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Eye & Contact Lens 31(1): 12–22, 2005

Therapeutic Effects of Contact Lenses After Refractive Surgery

Greg Gemoules, O.D.

Purpose. Although highly successful, refractive surgery can have adverse effects, such as loss of best spectacle-corrected visual acuity, glare, haloes, monocular polyopia, and loss of contrast. Further surgical intervention may no longer be an adequate or appropriate response. The efficacy of rigid gas-permeable contact lenses and their therapeutic effects in managing these conditions are studied. **Methods.** A retrospective review of the records of 67 eyes of 37 patients fitted with contact lenses after different refractive surgeries was performed. The most successful lens design for each patient was evaluated. Klyce corneal statistics of surface regularity index and surface asymmetry index, mean keratometric values, and optical zone diameter were measured before and after contact lens wear using the Tomey TMS-2 topographer. Comparative wavefront aberrometry was obtained for five eyes of three patients. **Results.** The cohort had a mean uncorrected visual acuity of 20/40, a mean best spectacle-corrected visual acuity of 20/26, and a mean visual acuity with contact lenses of 20/20. Contact lens wear resulted in significant improvements in corneal regularity and symmetry, as indicated by Klyce corneal statistics, with concomitant improvements in visual acuity between wearing periods. The mean visual acuity on lens removal was 20/24. This lens molding effect lasted from several hours to several days. The lenses also had the effects of decreasing higher-order aberrations, as measured by wavefront aberrometry in three patients. **Conclusions.** Rigid gas-permeable contact lenses can dramatically improve visual acuity and higher-order aberrations in eyes of patients with unsatisfactory refractive surgery outcomes. Contact lenses can also have a measurable therapeutic effect on vision when the lenses are not being worn or cannot be worn full time.

Key Words: Corneal molding—Contact lenses—Refractive surgery—wavefront aberrometry—Reverse geometry—Rigid gas-permeable—Topography—Higher order aberrations.

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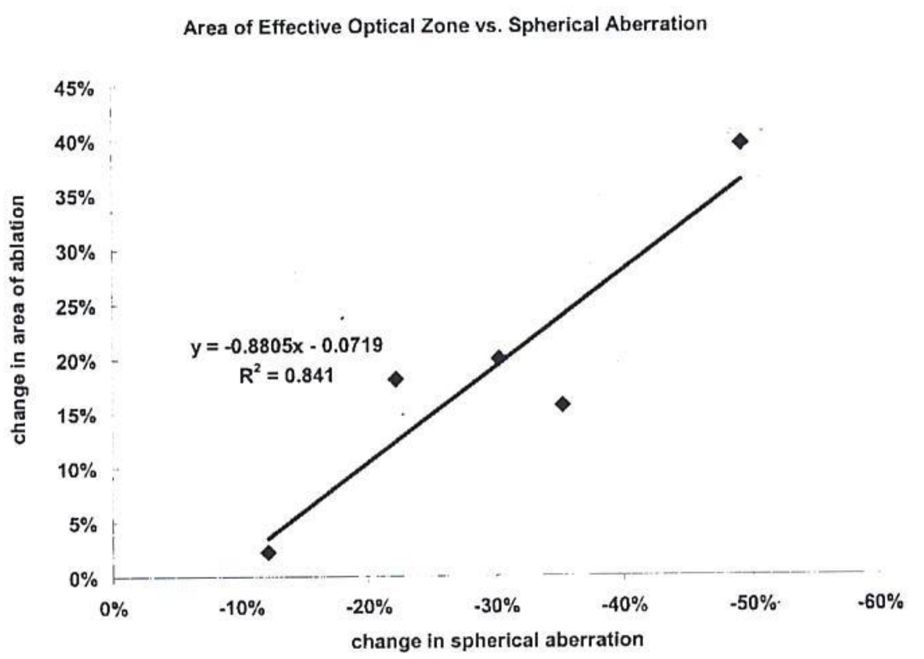

FIG. 20. The relationship between change in the area of effective optical zone (EOZ) and spherical aberration is fairly linear. As the EOZ was increased through the molding effects of the contact lenses, the spherical aberration decreased.

in the right eye and 20/30 in the left eye. A small nest of epithelial cells was noted under the right flap superotemporally. This nest later became active and then burned itself out without sequelae during the course of fitting. It is not known whether the contact lenses may have triggered that event.

Because the patient was strongly right eye dominant and because the right eye was more symptomatic, she was fitted with a reverse-geometry corneal lens on the right eye only. The EOZ of the right eye increased from 4.84 to 6.0 mm. The SRI improved from 1.13 to 0.93, and the SAI improved from 0.49 to 0.23 (Fig. 16). With lenses, the BVA improved one line to 20/30, with marked subjective improvement in contrast and elimination of the secondary image. A small amount of against-the-rule astigmatism was induced when the lens was worn. An attempt was made to neutralize the astigmatism with a prism-ballast front-toric reverse-geometry lens, which resulted in a BVA of 20/10. Unfortunately, the patient found that the acuity fluctuated and preferred the lesser but more consistent VA of the spherical-effect lens.

A significant therapeutic effect was achieved on lens removal and was reported by the patient to have a duration of approximately 3 days, during which time lens wear was unnecessary except for demanding situations, such as surgery. This proved to be an important benefit. Because of climate, the patient found it difficult to tolerate the lens on a daily basis.

Patient 3

A 30-year-old man underwent bilateral primary LASIK 30 months earlier and bilateral wavefront re-treatments 8 months before his visit. His chief complaint was severe low-light glare and loss of contrast. Clinical findings were UCVA of 20/80 in the right

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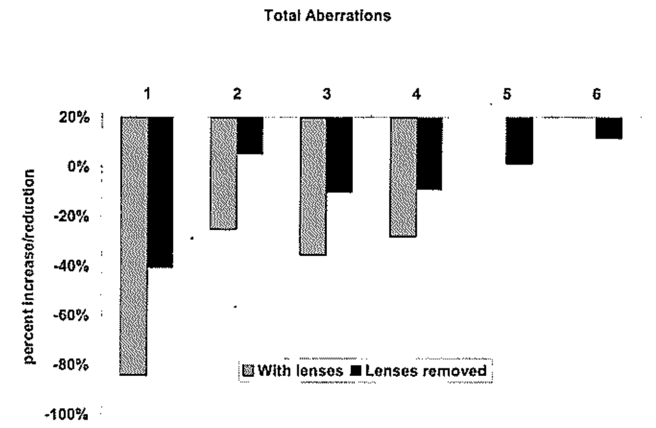

FIG. 17. Change in total aberrations during and immediately after contact lens wear. Wavefront aberrometry data was not obtained for one patient while lenses were being worn.

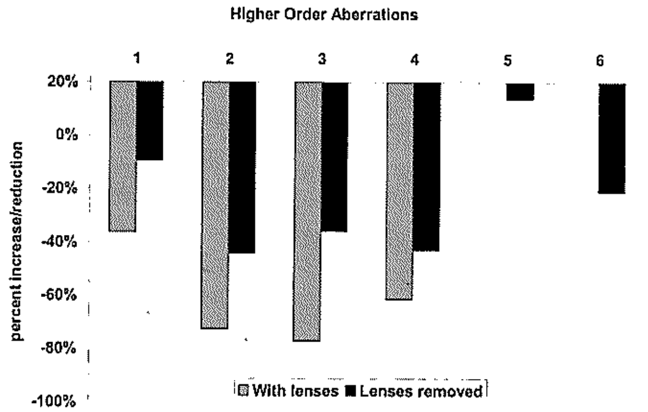

FIG. 18. Change in higher order aberrations during and immediately after lens wear.

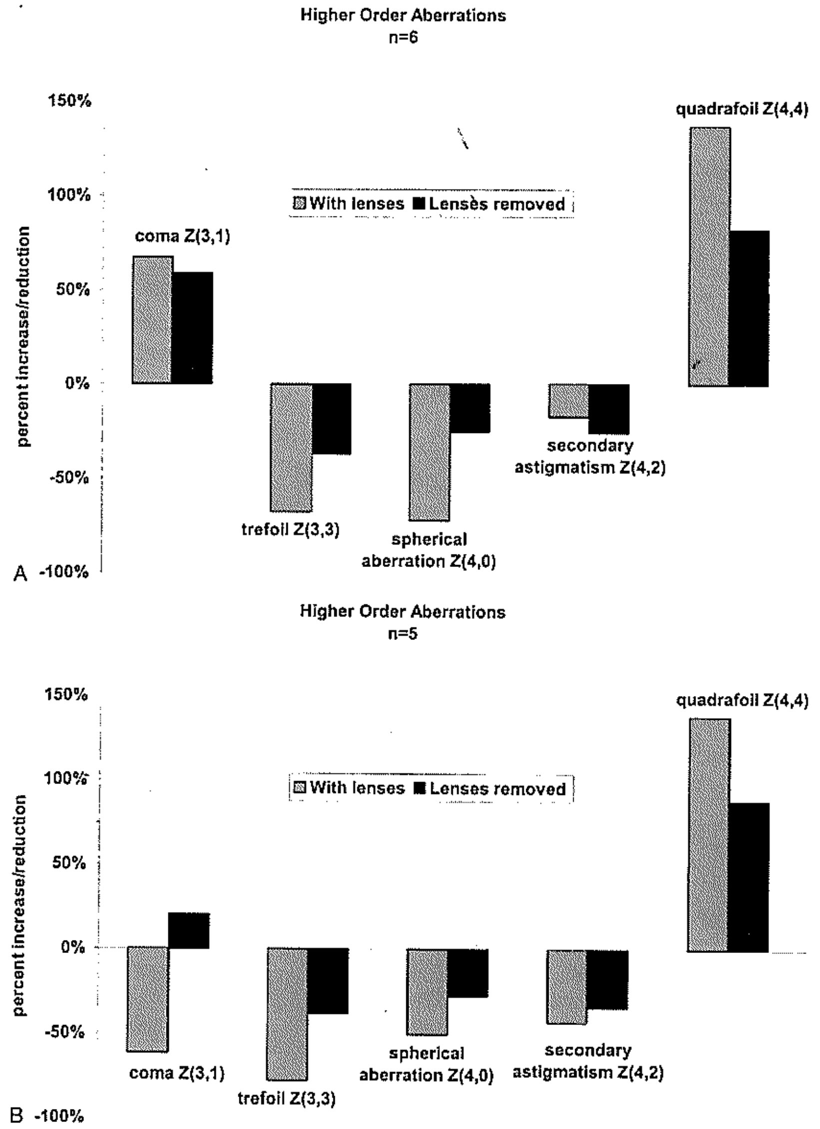

FIG. 19. (A) Changes in individual higher order Zernicke terms during and immediately after lens wear. The increase in coma was not anticipated, and is primarily due to one eye of one patient. Quadrafoil was also increased. (B) The same data as in A, excluding the one eye with the large increase in coma. There was still a slight increase in coma for the group after lens removal.

Further analysis of 6 eyes of post-LASIK patients demonstrated effects of corneal changes induced by the reverse geometry lenses in temporarily reducing higher order aberrations post-wear.

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Eye & Contact Lens 33(6): 304–307, 2007

Rigid Gas-Permeable Contact Lenses and Severe Higher-Order Aberrations in Postsurgical Corneas

Greg Gemoules, O.D. and Kim M. Morris, B.S.

Purpose. Even in the absence of significant residual refractive error, patients can be highly symptomatic after corneal refractive surgery. The presence of glare, halos, monocular polyopia, and loss of contrast are principally caused by the presence of higher-order aberrations. This study investigated the efficacy of rigid gas-permeable contact lenses in reducing these higher-order aberrations. **Methods.** In a prospective study, 20 eyes of 10 consecutive, highly symptomatic patients who had undergone refractive surgery were fitted with semiscleral rigid gas-permeable lenses (Macrolenses). The most successful lens design for each patient was evaluated by using ray-tracing aberrometry (iTrace). **Results.** The cohort had a mean uncorrected visual acuity of 20/30 and a mean best spectacle-corrected visual acuity of 20/25. The mean visual acuity with the treatment lenses was 20/20. The contact lenses reduced the combined higher-order aberrations by a mean of 65% (range, 30%–77%), combined coma by 71% (range, 39%–93%), spherical aberration by 82% (range, 41%–100%), and trefoil by 44% (range, 90% reduction to 727% increase). Multiple linear regression showed a high correlation with preoperative levels of myopia and mesopic pupil area as independent variables and postoperative spherical aberration as the dependent variable (R^2 = 0.82, SE = 0.09, F = 31.08, $P<0.0001$). **Conclusions.** Rigid gas-permeable contact lenses were shown to reduce elevated total higher order aberrations to normal levels in all cases following corneal refractive surgery. The mean reduction was 66% for total higher order aberrations and 83% for spherical aberration. Correlation was shown between high preoperative refractive error and pupil size in relation to postoperative spherical aberration.

Key Words: Higher order aberrations—Spherical aberration—Contact lenses—Pupil size—Refractive surgery—Wavefront.

these symptoms with additional surgery have met with only limited success.[5,6]

Many studies have been published on the use of contact lenses for postsurgical vision correction, with results measured in terms of improved Snellen acuity and residual refractive error. Only a scant number of studies on the effects of contact lenses on wavefront aberrometry have been published, and only for virgin eyes.[7–10] Those studies show that soft contact lenses tend to increase higher-order aberrations slightly and that rigid gas-permeable (RGP) contact lenses reduce them. In January 2005, the authors published a small case series involving the effects of RGP lenses on the aberrations of postsurgical eyes.[4] In that study, the higher-order aberrations were reduced as much as 77%. Symptomatic patients with significantly increased higher-order aberrations and little or no refractive error after undergoing surgery pose a difficult clinical challenge. The authors' materials and methods continue to evolve in their efforts to treat this group.

MATERIALS AND METHODS

Patients

The current study involved 20 eyes of 10 patients, eight men and two women, whose age ranged from 24 to 48 years. All patients had undergone photorefractive keratectomy (PRK), laser in situ keratomileusis (LASIK), or a combination procedure. One patient had bilateral penetrating keratoplasty as a result of postsurgical ectasia, and another patient had an aborted buttonhole flap. Elapsed time since the original surgery ranged from 5 months to 9

Analysis of 20 eyes of 10 symptomatic post-LASIK patients with elevated HOA achieved normal levels of HOA during semi-scleral lens wear.

Lens requirements for HOA correction

- Rotational and translational stability
- Optical zone centration
- Excellent optical properties
- Ability to make fine adjustments
- Scleral lenses = ideal vehicle for WFG

Scleral shape measurements

- IMAGE BASED TOMOGRAMS
  1. OCT (Laserfit)
  2. Scheimpflug camera (Pentacam)

- Scleral Topography (ESP)

- Impression molds (Eyeprint)

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Anterior Eye Capture - OCT

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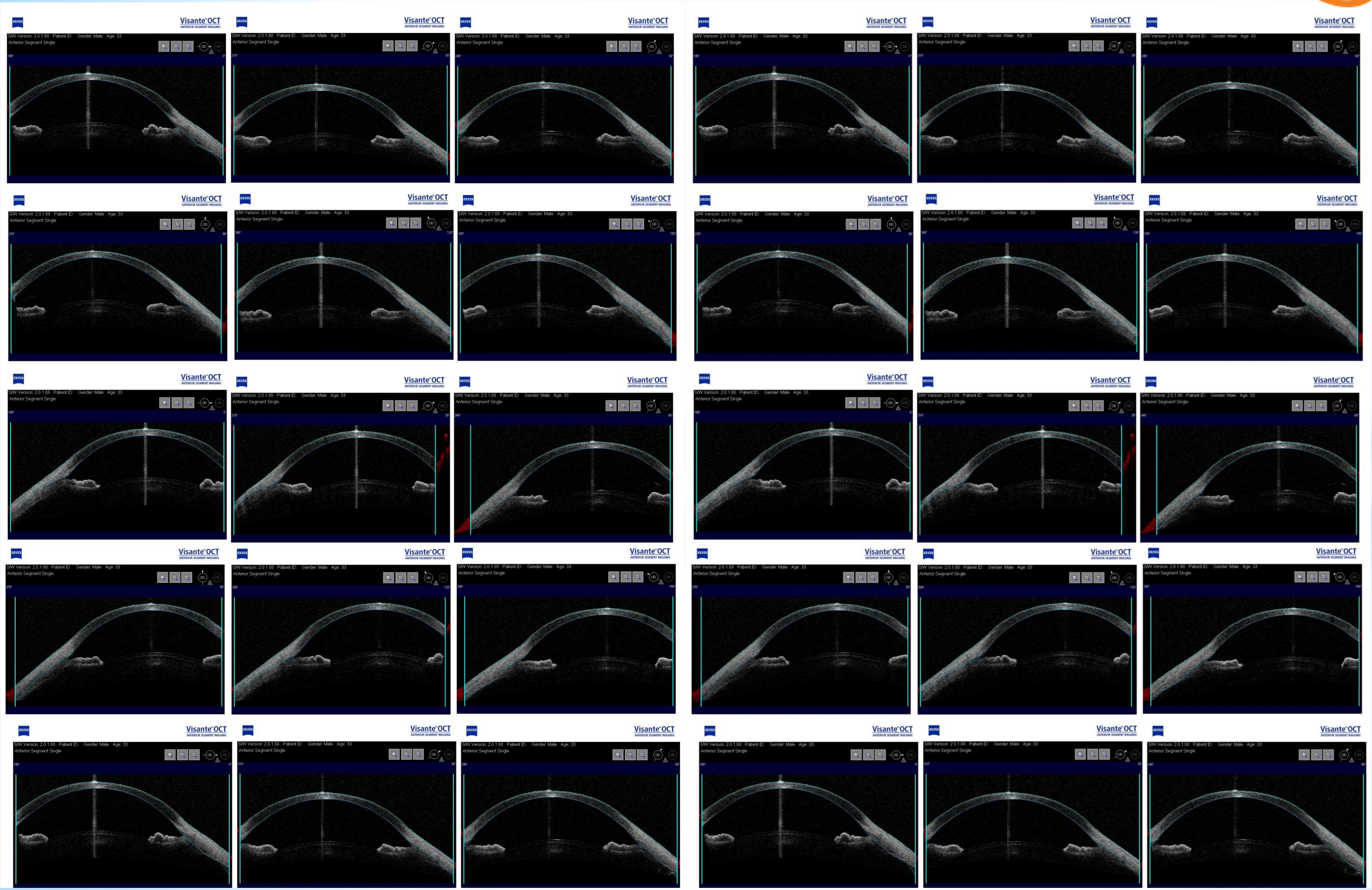
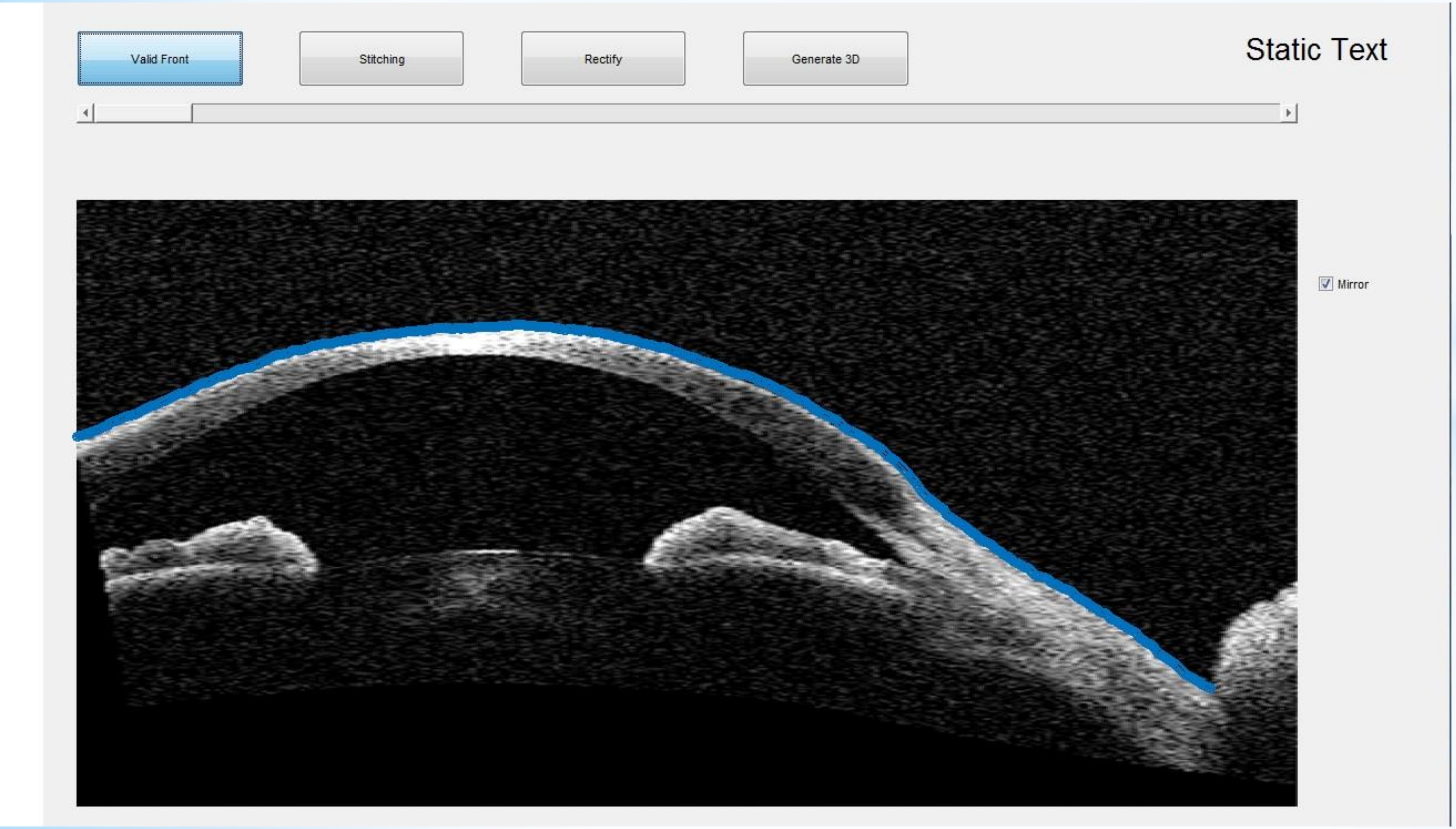


3-D Image Stitching Algorithm



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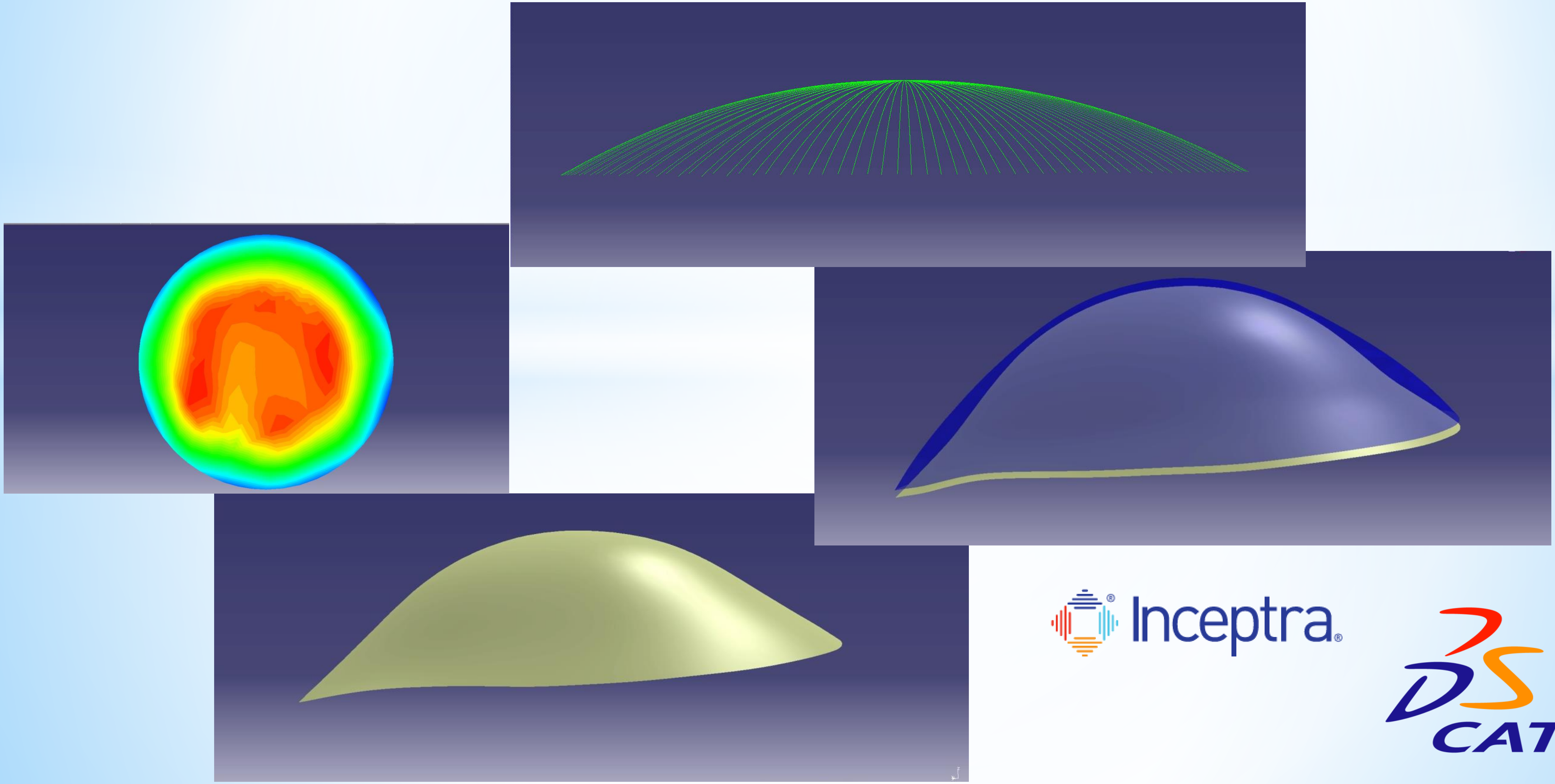
RAY-TRACING ABERROMETRY (iTrace)

Integrating scans and optical files into software

Lens design using state-of-the-art software from our partners
Inceptra and Dassault Systemes using best engineering practices.



Inceptra

CATIA

LASERFIT WFG and Keratoconus

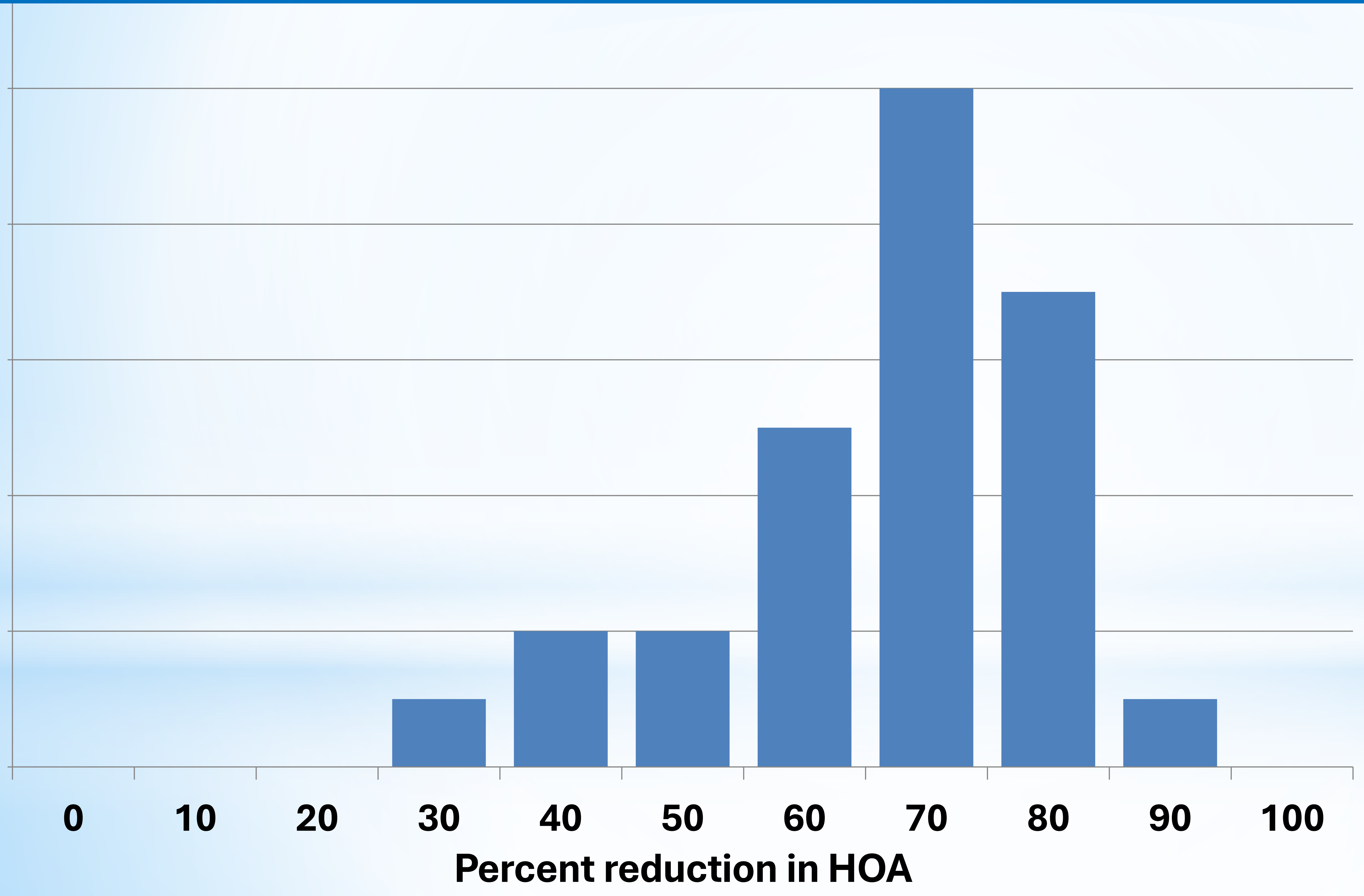
Consecutive Series From 2021 Compared To 2018 Rome Poster

Demonstrating Process Improvements Achieved.

SCLERAL TYPE	TOTAL HORMS µ 2018 (N=31) (SCARS INCLUDED)	TOTAL HORMS µ 2021 (N=34) (SCARS INCLUDED)	TOTAL HORMS µ 2021 (SCARS ONLY)	TOTAL HORMS µ 2021 (SCARS NOT INCLUDED)
Conventional	0.755	0.605	0.729	0.579
WFG	0.407	0.250	0.447	0.208
Change	-46%	-59%	-39%	-64%

FREQUENCY HISTOGRAM

WFG LENS PERCENT HOA IMPROVEMENT COMPARED TO STD SCLERAL LENS IN KERATOCONUS PATIENTS



PUPIL-CENTERED OR CORNEAL APEX?

- SURGEONS PREFER LINE OF SIGHT OR CORNEAL APEX
- WE PREFER USING THE PUPIL CENTER

Centering the wavefront optics on the corneal vertex may not be the better option for several reasons:

1. **For one, the cornea has been surgically altered and the light reflex may not properly indicate the intersection of the line of sight with the cornea.**
2. **A wavefront surface can also shift the location of the apical reflection.**
3. **Also, centering the treatment at a point that is decentered from the pupil may have the undesired consequence of under-correcting the spherical aberration or coma.**
4. **For patients suffering from very large scotopic pupils, one should always strive to achieve the maximum area of aberration-free vision.**

“One And Done” or ITERATIVE?

For highly aberrated eyes, Sabesan used a large-stroke deformable mirror in a closed-loop system to reduce the higher-order aberrations after 30-40 iterations to produce an almost perfect image quality using phase plates. (Sabesan, Ahmed, and Yoon, 2007, pp. 947-952).

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Normal-eye Zernike coefficients and root-mean-square wavefront errors

Thomas O. Salmon, OD, PhD, Corina van de Pol, OD, PhD

Table 3. Mean RMS values ± 1 standard deviation (μm) for polar and combined Zernike modes, Zernike orders, and total HDAs (orders 3 to 5) for 4 pupi diameters. Pooled from all right eye and left eye data.

	Pupil Diameter (mm)			
Root Mean Square	6.0	5.0	4.0	3.0
Polar modes				
Z_{31}	0.185 ± 0.118	0.109 ± 0.069	0.061 ± 0.039	0.029 ± 0.018
Z_{33}	0.147 ± 0.091	0.095 ± 0.058	0.055 ± 0.035	0.026 ± 0.017
Z_{40}	0.128 ± 0.096	0.064 ± 0.049	0.028 ± 0.022	0.010 ± 0.008
Z_{42}	0.060 ± 0.039	0.034 ± 0.023	0.018 ± 0.013	0.007 ± 0.005
Z_{44}	0.063 ± 0.042	0.038 ± 0.025	0.020 ± 0.013	0.008 ± 0.005
Z_{51}	0.039 ± 0.025	0.017 ± 0.011	0.006 ± 0.004	0.001 ± 0.001
Z_{53}	0.033 ± 0.022	0.014 ± 0.010	0.005 ± 0.003	0.001 ± 0.001
Z_{55}	0.037 ± 0.025	0.016 ± 0.011	0.005 ± 0.004	0.001 ± 0.001
Z_{60}	0.024 ± 0.020	0.008 ± 0.007	0.002 ± 0.002	0.000 ± 0.000
Z_{62}	0.023 ± 0.017	0.008 ± 0.006	0.002 ± 0.002	0.000 ± 0.000
Z_{64}	0.025 ± 0.018	0.009 ± 0.007	0.002 ± 0.002	0.000 ± 0.000
Z_{66}	0.030 ± 0.022	0.010 ± 0.008	0.003 ± 0.002	0.000 ± 0.000
Combined modes				
Coma-like ($Z_3^{\pm 1}+Z_5^{\pm 1}$)	0.192 ± 0.115	0.112 ± 0.068	0.062 ± 0.039	0.029 ± 0.018
Spherical aberration-like ($Z_4^{0}+Z_6^{0}$)	0.133 ± 0.094	0.065 ± 0.048	0.029 ± 0.021	0.010 ± 0.008
Zernike order				
3	0.251 ± 0.123	0.153 ± 0.075	0.087 ± 0.043	0.041 ± 0.021
4	0.169 ± 0.090	0.090 ± 0.046	0.043 ± 0.022	0.016 ± 0.008
5	0.067 ± 0.034	0.030 ± 0.016	0.010 ± 0.005	0.002 ± 0.001
6	0.057 ± 0.030	0.020 ± 0.011	0.005 ± 0.003	0.001 ± 0.001
Total higher order (orders 3–6)	0.327 ± 0.130	0.186 ± 0.078	0.100 ± 0.044	0.045 ± 0.021

For 3rd through 5th-order aberrations, n = 2205 for 6.0 mm and n = 2560 for 5.0, 4.0, and 3.0 mm; for 6th-order aberrations, n = 1871 for 6.0 mm anc n = 2008 for 5.0, 4.0, and 3.0 mm

Total higher order (orders 3–6) 0.327 ± 0.130 0.186 ± 0.078 0.100 ± 0.044 0.045 ± 0.021

For 3rd through 5th-order aberrations, n = 2205 for 6.0 mm and n = 2560 for 5.0, 4.0, and 3.0 mm; for 6th-order aberrations, n = 1871 for 6.0 mm and n = 2008 for 5.0, 4.0, and 3.0 mm

HABITUAL VS WFG (iTRACE)

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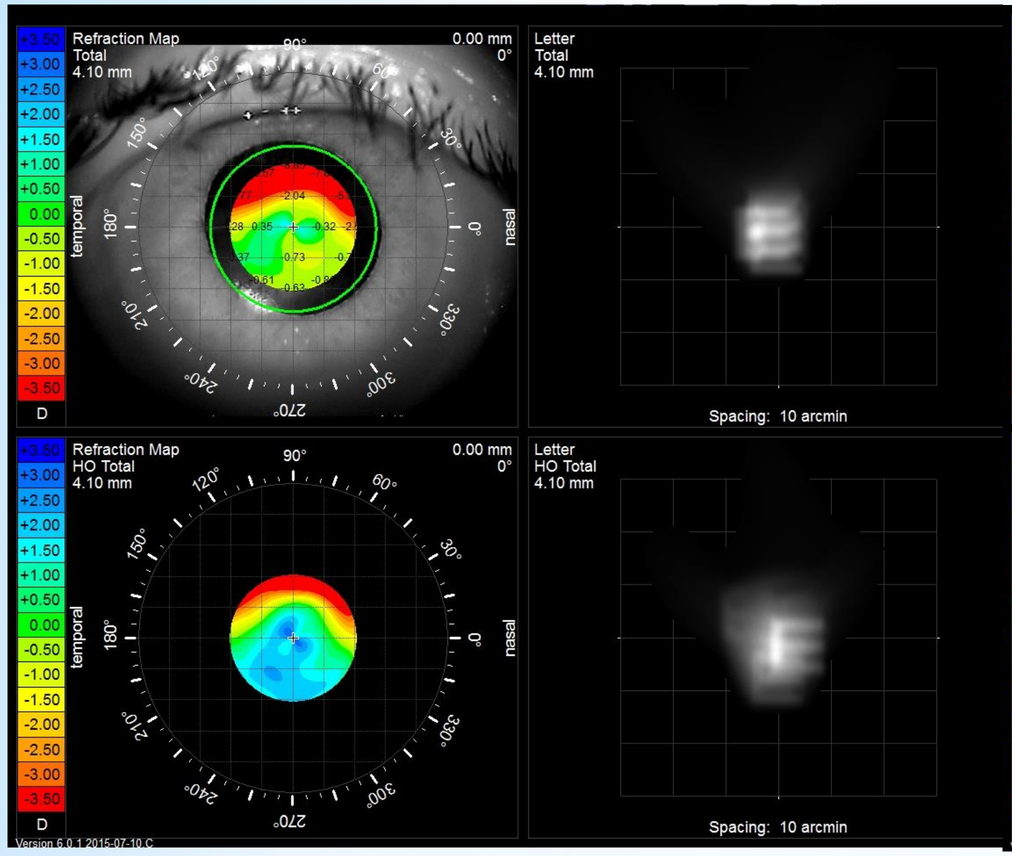
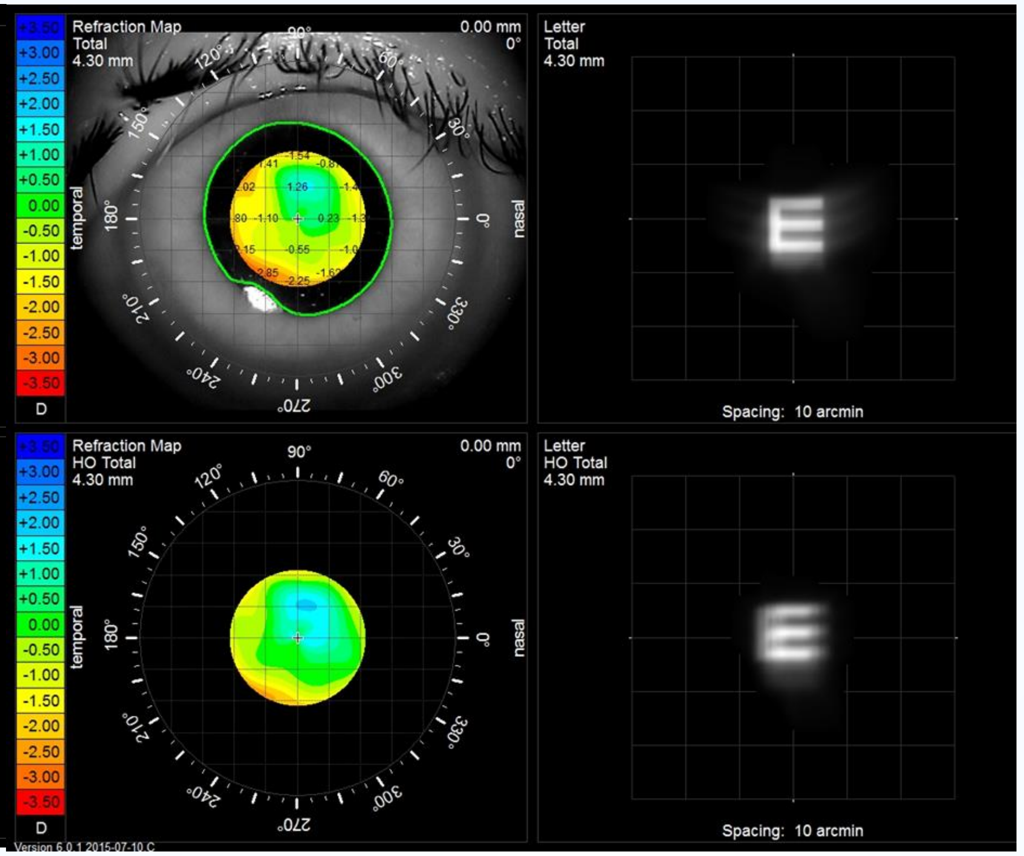
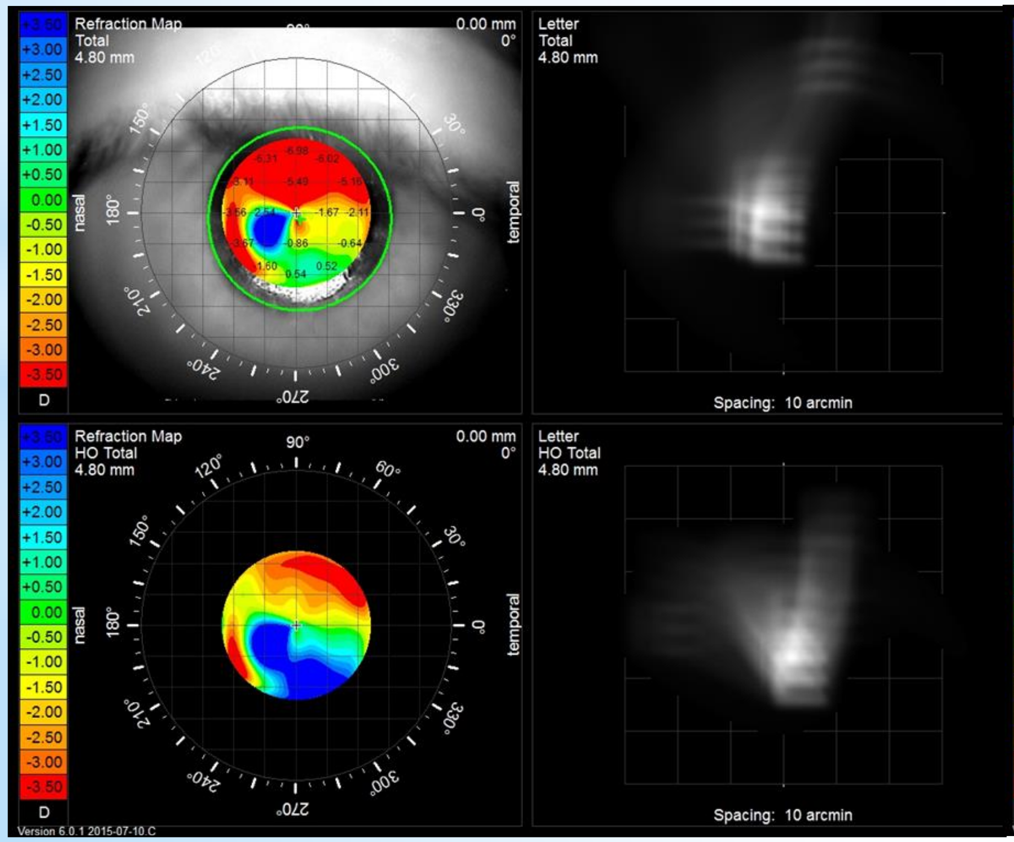
HABITUAL

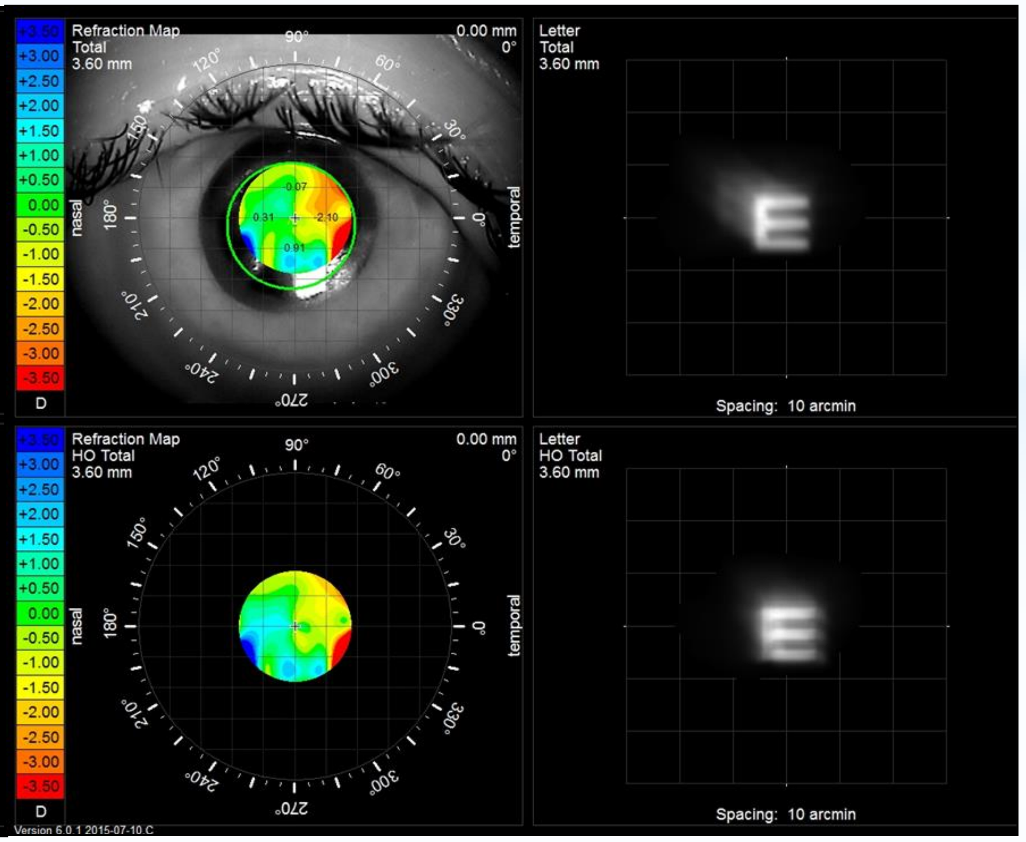
WFG



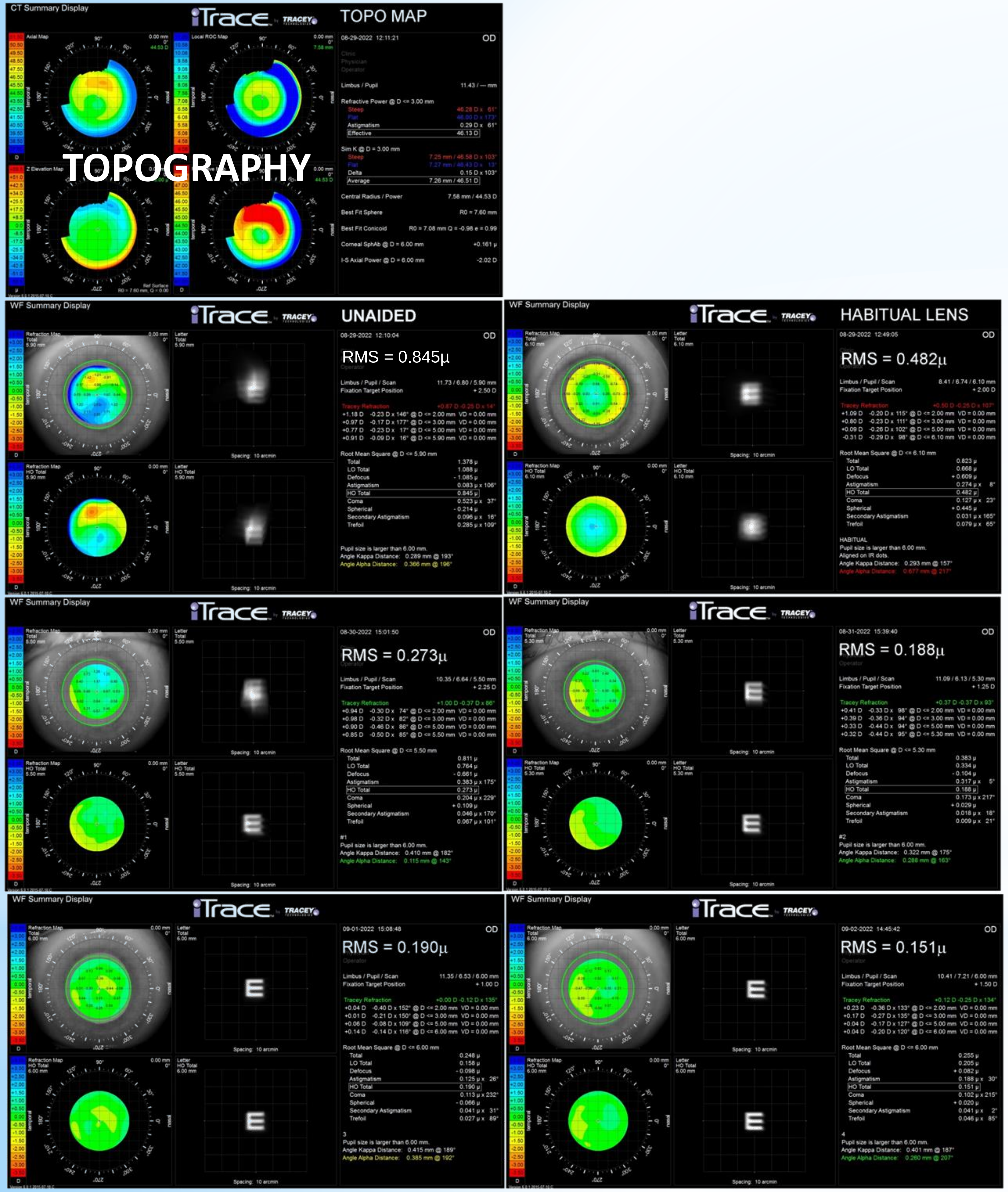


HABITUAL OD = VA 20/60
WFG OD = 20/30
Upper image = TOTAL
Lower image = HO only





HABITUAL OS = VA 20/40-
WFG OS = 20/30
Upper image = TOTAL
Lower image = HOA



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Series of 6 lens wavefront iterations of the right lens of one patient demonstrating iterative reductions in the HOA <u>until the patient was happy.</u>

1. **NO LENS HOA = 0.845μ**
2. **PATIENT'S OLD LENS HOA = 0.482μ**
3. **FINAL WFG LENS = 0.151μ**

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RMS = 0.845μ