Is there a diagnostic role for Wavefront analysis?

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Why performing a wavefront analysis?

- Refractive patients are getting old (lens influence)
- Difficult correlation between patients symptoms and findings
- Is more and more difficult to determine the cause of loss of visual acuity
- Patients
  - are more demanding
  - expectations is growing
Nidek OPD scan features:
Perfect registration of 3 exams

- **Wavefront Aberrometer**
  - Wide measurement range: -20 D to +22 D Sph and ±12 D Cyl
  - High resolution: 1440 data points within 6 mm diameter
  - Measuring time only 0.4 sec.

- **Placido Disk Topographer**
  - 23 Rings (vertical 19 rings); measuring range 10 - 100 D

- **Autorefractometer/keratometer**
  - Minimal examination time; no dilation necessary
  - XYZ fully automatic alignment; auto measurement

- **Pupillometry**
  - Iris recognition --> torsion error detection
Case analysis with OPD
Normal
6mm pupil wavefront analysis up to 8 order
6mm pupil wavefront analysis up to 8 order
6mm pupil wavefront analysis up to 8 order
Myopia
6mm pupil wavefront analysis up to 8 order
6mm pupil wavefront analysis up to 8 order
6mm pupil wavefront analysis up to 8 order
Internal Aberration
6mm pupil wavefront analysis up to 8 order
6mm pupil wavefront analysis up to 8 order
6mm pupil wavefront analysis up to 8 order
thin IOL with 3 closed loop in a shrinked bag milded folded

-0.50@-4 cyl asse71
Corneal Aberration
6mm pupil wavefront analysis up to 8 order
Corneal and internal aberrations
Correction for hyperopia and presbiopia

Far +2 sf add +2.50 sf

Which wavefront?
Apodized Diffractive Optic

- Precise reduction in diffractive step heights from center to periphery of 3.6 mm diameter diffractive region
  - Steps reduce from 1.3 microns to 0.2 microns
  - larger steps direct more light to near at center
  - smaller steps direct more light to distance at edge
  - gradual energy blend between powers

- Unique to AcrySof® ReSTOR® IOL
Apodized Diffractive Optic

- Pseudoaccommodative central apodized diffractive optic blends into refractive distance periphery
- Gradually emphasizes energy going to distance vision with larger pupil sizes
- Nighttime visual disturbances minimized by directing more light to distance when pupils are larger
- Near vision image quality enhanced by ReSTOR apodized design
- Near add power = 4 D
Theory of Chromatic Aberration Cancellation Using the DO Lens

(1) Refractive optical element

(2) Multi-Layer Diffractive Optical Element

Combining (1) and (2)

Chromatic aberrations canceled out

Countering chromatic aberrations
Canon EF 400mm f4 USM riduzione pesi con miglioramento MTF

[Telephoto lens designed with only refractive optical elements]

[Telephoto lens utilizing a DO lens]

Difference in Size of Telephoto Lenses depending on the Use of DO Lens
### Zernike OPD No. 2 OD Zone: 4.0 Order: 8

<table>
<thead>
<tr>
<th>V.Sets</th>
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### Zernike Int No. 2 OD Zone: 4.0 Order: 8

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### VAIOPD/Tot

- CD
- OD

- VA: 0.25
- ZC: 0.50
- VA: 1.00
- VA: 1.00
- VA: 1.00
- VA: 1.00
- VA: 1.00
- VA: 1.00

### Exam

- SPH: +0.50
- CYL: -0.75
- Axis: 168
- SimK1: 44.12 (7.65) @ 98
- 3.01 5.29 MPdst 0.09 @ 07
- OPD-Station Version 1.00Ev12(CN 1.00)

### Analysis

- Cornea Index: n=1.3375 (Ax,Ins), n=1
- Diagnosis: Vinci overview 2
- Mapset: Vinci overview 2
- Pupil [mm]: 3.01 5.29 MPdst 0.09 @ 07
- OPD-Station Version 1.00Ev12(CN 1.00)
Restore
### 3. Zernike/OPD No. 1 OD Zone: 4.0 Order: 8

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### VA/OPD/Tot

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Cornea Index: n=1.3375 (Ax,Ins), n=1.3750 (Ref,Refr) Q=0.8446 A=1.5876mm
Diagnosis: , Mapset: Vinci overview 2  OPD-Station Version 1.00Ev12(CN 1.00)
PSF $\rightarrow$ FFT $\rightarrow$ MTF (OPD Station)

Diffraction Limited

Normal eye (Emmetropia)

Patient's HO MTF

Patient’s MTF

Courtesy of Stephen Pieger
Reading MTF Graphs

Emmetropia
A/B: 86%
H/B: 102%

Myopia
-2 D
A/B: 15%
H/B: 83%

Irregular Cornea
A/B: 30%
H/B: 34%

Courtesy of Stephen Pieger
Custom Ablation, no Torsion Error Detector
Materials & Methods

Custom Ablation, no Torsion Error Detector

125 eyes

• Mean age: 34 years (range: 20 to 53 yrs)

• Mean ± SD sph.: -5.12 D ± 2.54 D ( -12.75 to 2.00)
• Mean ± SD cyl: -0.94 D ± 0.81 D ( -4.50 to 0.00)
• Mean ± SD SE: -5.59 D ± 2.54 D ( -13.63 to 2.00)
Double Angle Average Cyl

month

0 1 2 3 6 10 14 17
Custom Ablation, Torsion Error Detector
Axis Rotation

- 24% negative axis rotation (i.e 10° to 5°)
- 76% positive axis rotation (i.e 10° to 15°)
- Mean: 3°
- S.D.: 2.64°
- Min.: 0°, Max.: 10°
- Mode: 3°, Median: 3°
What is the Affect of Axis Misalignment

- Uncorrected Astigmatism: 30%
- Uncorrected Trefoil: 50%
- Uncorrected Tetrafoil: 65%

Torsional Alignment Error: 10°
Per favore visitate: www.refractiveonline.it

Arrivederci
September 17
2005
Conclusions

- Wavefront analysis is an extremely powerful diagnostic tool
- Identification of wavefront error source is becoming important
- Combined registered maps:
  - Wavefront anterior and internal
  - Topography
  - Refractometry
  - Pupilometry
Per favore visitate: www.refractiveonline.it

Arrivederci
September 17
2005
What is the problem? Unmasking genuine astigmatism!

- Even the most sophisticated custom ablation may result in residual wavefront errors
- That is because custom ablation (the correction of high order errors) unmasks the genuine cylinder power and axis
Preop refraction: -6.25 D, -0.25 D @ 1

After high order treatment. Note the unmasking of the genuine astigmatism -1.9 D @ 40°
One can be fooled!
No astigmatism

- Sometimes what looks like astigmatism is actually a combination of high order aberrations. After those are treated it may turn out that there is actually no astigmatism.
Axis change

- Treating high order errors changes the axis of the unmasked astigmatism
22° of axis change
What if we ignore these facts?

- Pseudo decentration
- Residual astigmatism
- Inducing new high order errors
- Residual refractive error
- Poor vision
What a difference $3^0$ make!

- Small axis errors would appear to be insignificant
- Errors in determining axis are usually coupled to power errors
- But high order aberrations are more sensitive to axis errors
Inducing new High order aberrations

3° error!
# Number of Eyes Pre OP: 309

**Age**: Average 34 years (from 20 to 64)

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<th>Eye</th>
<th>Percentage</th>
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<tr>
<td>Right</td>
<td>48.5%</td>
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**Pre Sph. Eq**: Mean -5.31 D ± 2.87 D (from -14.13 to 3.50)

**Pre Sph**: Mean -4.87 D ± 2.86 D (from -13.50 to 4.00)

**Pre Cyl**: Mean -0.89 D ± 0.81 D (from -5.00 to 1.00)

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Paolo Vinciguerra, MD
REFRACTIVE OUTCOME: % within Attempted

- 2.0
- 1.01 to -2
- 0.51 to -1
+ 0.5
+ 1.01 to +2
> +2.0

1 y (119)
3 m (244)
6 m (135)
Paolo Vinciguerra, MD

EFFICACY: UCVA - Percent

- 3 m (138)
- 6 m (85)
- 1 y (69)
1 year

Achieved [D] vs Attempted delta SR equiv. [D]

- **Overcorrected**
- **Undercorrected**

PREDICTABILITY: Attempted vs Achieved (Scatter) 119 eyes

y = 0.99x + 0.52
R² = 0.91
preOP BSCVA vs. postOP UCVA - Percent

- '20/10' vs. postOP UCVA
- 20/12 or better vs. postOP UCVA
- 20/15 or better vs. postOP UCVA
- 20/20 or better vs. postOP UCVA
- 20/25 or better vs. postOP UCVA

- month (eyes)
  - 1 y (69)
  - 3 m (138)
  - 6 m (85)
  - preSCVA (303)