Wavefront Aberrometry and iTrace: Screening and Planning Surgeries

Dr Neelam Pawar

Ophthalmologist

Dr Agarwals Eye Hospitals
Ex - Aravind Eye Hospital, Tirunelveli, Tamilnadu, India

No Financial Interest
Poll Question 1

What is your current position?

1. Cataract Surgeon
2. Refractive Surgeon
3. Comprehensive Ophthalmologist
4. Fellow/Resident
5. Medical Student
6. Ophthalmic technician / Allied Health
• Basics of Wavefront aberrometry
• Screening of patients with
  ✓ Multifocal IOL candidates,
  ✓ Dysfunctional lens Syndrome
  ✓ Dissatisfied refractive and multifocal patients,
  ✓ Precision in Toric IOLs and
  ✓ other non surgical applications of iTrace.
Supranormal Vision

Better decision- better information-Better Technology & Design.
I Trace Ray Tracing Wavefront Aberrometer and Corneal Topography
Image Formation

Diffraction

Scattering

Optical Aberration

Sources of degradation
What is Wavefront? A Measure of “Aberropia”

Wavefront and Aberrations

**Optical aberrations** - impairment of the quality of the optical system. Optical aberration is a departure of the performance of an optical system from the predictions of paraxial optics.
What is a Wavefront Aberration?

parallel beam = plane wavefront

ideal wavefront
aberrated beam
= wavefront aberration error
ABERRATIONS

- Lower order aberrations
- Higher order aberrations

Blur and Double Vision

- Caused by COMA

Glare and Halo

- Caused by SPHERICAL ABERRATION

Starburst and Comet Tails

- Caused by TREFOIL
Poll Question 2

Do you have any abberometer in your hospital/clinic?

- Yes
- No
How do we Quantify Wavefront Aberrations?
How do we Quantify Wavefront Aberrations?

Coefficient value (microns)

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<tr>
<th>z</th>
<th>m</th>
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<tr>
<td>27</td>
<td>6</td>
<td>Hexafoil</td>
<td>0.045</td>
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</table>

2nd order, 3rd order, 4th order, 5th order, 6th order
Aberrometers

- Nidek OPD Scan
- WASCA (Carl Zeiss Meditec),
- Zywave, (Bausch & Lomb), and the.
- Multi-Spot Hartmann and Tscherning
- Allegretto Wave Analyzer

<table>
<thead>
<tr>
<th>Aberrometer</th>
<th>Vendor</th>
<th>Sensing Type</th>
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<tr>
<td>LADARWave</td>
<td>Alcon</td>
<td>Hartmann-Shack</td>
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<tr>
<td>WaveScan</td>
<td>AMO/Visx</td>
<td>Hartmann-Shack</td>
</tr>
<tr>
<td>COAS</td>
<td>AMO/Wavefront Sciences</td>
<td>Hartmann-Shack</td>
</tr>
<tr>
<td>Zywave</td>
<td>Bausch &amp; Lomb</td>
<td>Hartmann-Shack</td>
</tr>
<tr>
<td>WASCA Analyzer</td>
<td>Carl Zeiss Meditec</td>
<td>Hartmann-Shack</td>
</tr>
<tr>
<td>ORK Analyzer</td>
<td>Schwind</td>
<td>Hartmann-Shack</td>
</tr>
<tr>
<td>iTrace</td>
<td>Tracey</td>
<td>Hartmann-Shack</td>
</tr>
<tr>
<td>Allegro Analyzer</td>
<td>WaveLight</td>
<td>Tscherning</td>
</tr>
</tbody>
</table>
Clinical comparison of 6 aberrometers. Part 1: Technical specifications

Jos J. Rozema, MSc, Dirk E.M. Van Dyck, PhD, Marie-José Tassignon, MD, PhD

**Purpose:** To provide a detailed assessment of the techniques, technical features, and practical use of 6 aberrometers made available to our institution from September 2002 to January 2004.

**Setting:** Department of Ophthalmology, University Hospital Antwerp, Antwerp, Belgium.

**Methods:** A number of technical and practical parameters are listed for the Visual Function Analyzer (Tracey), the OPD-Scan (ARK-10000; Nidek), the Zywave (Bausch & Lomb), the WASCA (Carl Zeiss Meditec), the MultiSpot Hartmann-Shack device, and the Allegretto Wave Analyzer including working principles, data acquisition, aberrometer alignment, wavefront calculation, and data analysis. Operator and patient comfort as well as practical advantages and disadvantages are discussed.

**Conclusion:** All devices met at least half the following parameters: alignment, correction for source wavelength, data averaging, measurement quality check, and inhibition of accommodation.

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Clinical comparison of 6 aberrometers. Part 2: Statistical comparison in a test group

Jos J. Rozema, MSc, Dirk E.M. Van Dyck, PhD, Marie-José Tassignon, MD, PhD

**Purpose:** To compare and mutually validate the measurements of 6 aberrometers: the Visual Function Analyzer (Tracey), the OPD-Scan (ARK-10000, Nidek), the Zywave (Bausch & Lomb), the WASCA (Carl Zeiss Meditec), the MultiSpot Hartmann-Shack device, and the Allegretto Wave Analyzer.

**Setting:** University Hospital Antwerp, Antwerp, Belgium.

**Methods:** This prospective study was conducted on a group of 44 healthy eyes with refractions ranging from −5.25 diopters (D) to +5.25 D (cylinder 0 to −2 D). For each aberrometer and each eye, the averaged Zernike data were used to calculate various kinds of root-mean-square (RMS). These parameters, together with the refractive parameters, were then analyzed with a repeated-measures analysis of variance (ANOVA) test complemented by paired t tests. A similar analysis was done for the comparison of the variances of these parameters.

**Results:** The aberrometers gave comparable values for all studied parameters with the following exceptions: The OPD-Scan underestimated the polynomials describing 4- and 5-fold symmetries, and the Visual Function Analyzer slightly overestimated the astigmatism terms. The 3rd-order radial RMS value was different for each device, as well as the RMS in the central 20 mm zone. The WASCA presented the lowest variance.

**Conclusion:** These results suggest that in healthy eyes, all aberrometers produced globally similar results but they may vary in some details.

*J Cataract Refract Surg 2005; 31:1114-1127 © 2005 ASCRS and ESCRs*

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*J Cataract Refract Surg 2006; 32:33-44 © 2006 ASCRS and ESCRs*
Rozema’s et al the HOA measurements obtained with iTrace tended to be larger than those obtained with Shack–Hartmann aberrometers including Zywave (Bausch & Lomb), WASCA (Zeiss/Meditec) and MultiSpot 250-AD, and significant differences between the devices were found in the coma measurements.

Aberrometers based on the ray tracing principle and aberrometers based on the Hartmann–Shack principle should not be interchanged in clinical applications.

Precision and agreement of higher order aberrations measured with ray tracing and Hartmann-Shack aberrometers Zequan Xu. BMC Ophthalmol. 2018; 18: 18
POLL QUESTION 3

What is your preferred choice of aberrometry in your clinic?

1. Zywave
2. WASCA
3. I Trace
4. Nidek OPD Scan
5. Others
6. Not having any experience
5 IN ONE SYSTEM

This 5-in-1 system provides Auto-refraction, Corneal topography, Ray tracing aberrometry, Pupillometry and Auto-keratometry
Pitfalls

- **Age**
- **Pupil**
  - Wavefront aberrations pupil size-dependent
  - Increase with increasing pupil diameter.
  - Location of the pupil center is also an important factor
  - Pharmacologic pupil dilation erroneously induce a shift in the location of the pupil center, whereas natural pupil dilation resulted in minor changes in the location of the pupil center compared with the pupil center's location in photopic conditions.

*Wavefront analysis with natural pupil dilation in mesopic light conditions.*


- **Head movements**
- **Observer variations**
Principles of iTrace

How Does the iTrace Measure Wavefront

Using **Ray Tracing technology**, the iTrace measures where 256 individual and consecutive light rays enter the pupil and land on the retina.
Why do I need it?

✓ Integrating wavefront aberrometry with corneal topography,

✓ Subtract Corneal from total aberrations in order to isolate the internal aberrations

✓ Refractive lensectomies, dysfunctional lens syndrome

✓ Aspheric, Accommodative and Multifocal IOL's and for post-op evaluation

► Better information about the patient's optical system's alignment so that you can decide which IOL is best for the patient.
What data we get from I trace

- **Total aberrations of an eye** - Root mean square (RMS) wavefront error - the magnitude of combined aberrations for any combination
- **Optical quality metrics** - function Modulation Transfer Function (MTF) and point spread function (PSF)
- **Simulated vision of patient**
Overview screen
Overview screen of the WF Verification Display

[Image of the WF Verification Display]

- **Point 1**
  - **Horizontal Point Profile**
  - **Vertical Point Profile**
  - **Retinal Spot Diagram**

**Specifications**
- **Date**: 05-24-2017 08:44:57
- **Group**: Cataract
- **Operator**: J.J. Menadez
- **ID**: 1422032

**Tracey Refraction**
- +1.25 D -0.37 D x 40°
- +1.87 D -1.27 D x 49° @ D <= 2.00 mm
- +1.22 D -0.40 D x 40° @ D <= 3.00 mm
- +1.22 D -0.40 D x 40° @ D <= 3.00 mm
- VD = 12.00 mm
- VD = 12.00 mm
- VD = 12.00 mm

**Root Mean Square @ D <= 3.00 mm**
- Total: 0.38 µ
- LO Total: 0.34 µ
- Defocus: -0.335 µ
- Astigmatism: 0.095 µ x 130°
- HI Total: 0.162 µ
- Coma: 0.035 µ x 285°
- Spherical: +0.035 µ
- Secondary Astigmatism: 0.077 µ x 32°
- Trefoil: 0.117 µ x 90°

- **Angle kappa Distance**: 0.396 mm @ 316°
- **Angle Alpha Distance**: 0.465 mm @ 341°
Normal Eye – “Perfection”

Irregular Eye: Lenticular Aberrations
Chang Analysis
Aberration of internal optics analysis..
Wavefront analysis
a) Visual Function Analysis (VFASummary Display)
PSF Total and HOA PSF.
(Point Spread Function)
Doctor “Sees” Patient Problem:
Example: Night/Day Vision Changes

- Patient has Double Vision/Blur at Night as seen on the left.
- The iTrace demonstrates actual vision problem to patient and doctor.
Evaluation in case of cataract

- Advisable to perform a scan in a dark room, so as to simulate mesopic conditions
- Photopic well as mesopic pupil size is very important in multifocal IOLs.

- Evaluating spherical aberrations of the eye
- Evaluating angle alpha and angle kappa
- Evaluating ocular astigmatism
- Postoperative evaluation following cataract surgery
How Can the iTrace Help You When Selecting Aspheric IOLs?

Aspheric Intraocular Lens Selection Based on Corneal Wavefront

Mark Packer, MD, FACS; I. Howard Fine, MD; Richard S. Hoffman, MD


TABLE 3
Comparison Among Published Reports Shows Relative Superiority of the Customized IOL Selection Approach

<table>
<thead>
<tr>
<th>Study</th>
<th>Mean Postoperative Spherical Aberration (±SD) (µm)</th>
<th>IOL Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packer (Current study)</td>
<td>-0.013±0.07</td>
<td>Custom</td>
</tr>
<tr>
<td>Kasper et al[23]</td>
<td>+0.017*</td>
<td>Tecnis</td>
</tr>
<tr>
<td>Awad et al[14]</td>
<td>+0.09±0.04</td>
<td>AcrySof IQ</td>
</tr>
<tr>
<td>Padmanabhan et al[21]</td>
<td>+0.07±0.12</td>
<td>Tecnis</td>
</tr>
<tr>
<td>Denoyer et al[20]</td>
<td>+0.03±0.06</td>
<td>Tecnis</td>
</tr>
<tr>
<td>Caporossi et al[12]</td>
<td>+0.05±0.06</td>
<td>Tecnis</td>
</tr>
<tr>
<td></td>
<td>+0.11±0.10</td>
<td>AcrySof IQ</td>
</tr>
<tr>
<td></td>
<td>+0.19±0.08</td>
<td>SofPort AO</td>
</tr>
<tr>
<td>Bellucci et al[31]</td>
<td>+0.0054±0.017</td>
<td>Tecnis</td>
</tr>
<tr>
<td>Rocha et al[16]</td>
<td>+0.03±0.05</td>
<td>AcrySof IQ</td>
</tr>
</tbody>
</table>

IOL = Intraocular lens

*Standard deviation not reported.

Note: Bellucci used a 4-mm pupil; Caporossi used a 5-mm pupil.
• Measured corneal spherical aberration Z4,0 at the 6mm optical zone, and chose one of three aspheric IOLs — corneal spherical aberration + pseudophakic spherical aberration = zero

• "Customized selection of aspheric IOLs based on corneal wavefront is feasible and produces favorable results compared with studies of unselected patient populations implanted with aspheric IOLs."

### Residual Aberration Comparison

<table>
<thead>
<tr>
<th>AcrySof®-IQ</th>
<th>Tecnis™</th>
<th>SofPort AO®</th>
<th>Akreos®</th>
<th>Softec HD®</th>
<th>enVista®</th>
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<tbody>
<tr>
<td>Aberration correction of the lens³</td>
<td>-0.20 μm²³</td>
<td>-0.27 μm²³</td>
<td>0 μm³</td>
<td>0 μm³⁰</td>
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<tr>
<td>Residual aberration of the eye³</td>
<td>0.07 μm</td>
<td>0 μm</td>
<td>0.27 μm</td>
<td>0.27 μm</td>
<td>0.27 μm</td>
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Ocular wavefront analysis of aspheric compared with spherical monofocal intraocular lenses in cataract surgery: Systematic review with metaanalysis

Alexander K. Schuster, MD, MSc; Jonas Tesarz, MD; Urs Vossmerbaeumer, MD, MSc.
IOL Selection Checklist:

- Is Tracey Refraction normal? Yes
- Are Corneal HOAs present? No
- Are Internal HOAs present? No

Angle Alpha (μ) 0.65mm:
- Angle Alpha <= 0.50mm: 0.280mm
- Total Corneal HOA <= 0.200μ: 0.35μ
- Total Astigm. <= 1.00D: 0.17D

Lenses to Consider:
1. MonoFocal Non-Toric IOL
2. Advanced Balance Curve IOL
The patient had a previous myopic LASIK and presented with interest in cataract surgery. The iTrace revealed high (+) Spherical Aberrations. Because of the Q value, the IOL of choice for this surgeon is generally the Alcon ACRYSOF® IQ offering -0.177 of negative lenticular aberration correction. The AMO TECNIS® offers -0.27 which is currently the maximum in (-) lenticular aberration correction. Therefore, because of the patients high (+) corneal S.A. at 5mm, the surgeon determined that the Tecnis will be the planned IOL for this patient's upcoming cataract surgery to offset the (+)-spherical aberration as much as currently possible.

This patient had a previous hyperopic LASIK procedure some years back. He presented for possible cataract surgery and expressed interest in IOL options. The iTrace revealed high (-) Spherical Aberrations as a result of the hyperopic LASIK and its resulting highly prolate cornea (Q=-1.03) which is a markedly negative aspheric corneal shape. If the surgeon selected to use his IOL of choice, the ACRYSOF® IQ, it would actually induce more (-)-spherical aberration. The surgeon instead opted to use a traditional spherical IOL which offers a (+)-spherical aberration to offset the (-)-spherical aberration of the cornea.
Using Angle Alpha in premium IOL Screening

- Why is Optical Alignment critical for Multi-focal IOLs?

**The Angle Alpha** - considered a confidence metric because knowing this number helps the surgeon predict how well the MIOL will align optically with the patient's visual axis.
Figure 1. The iTrace measures the distance between the visual axis, as estimated by the center of the first Purkinje reflex (red cross hair), and the center of the pupil (green cross hair), which is useful for LASIK. The angle alpha is the distance from the visual axis to the center of the limbus (blue cross hair), which is useful for IOL implantation.

Figure 2. When there is a large (> 0.5 mm) angle alpha, the optical axis/center of the capsular bag may not match the patient’s visual axis, leading to a potentially unpleasant refractive surprise if a multifocal IOL is implanted.

The iTrace color codes the angles Kappa and Alpha to indicate when they reach cautionary thresholds.
Process for iTrace Decision Support in a Premium IOL Evaluation

1. Cataract Patient, Premium Lens Eval
   - Perform iTrace exam and diagnose cataract with DLI
2. Evaluate optical alignment with Angle Alpha
   - High Angle Alpha?
     - Yes: Consider a monofocal option.
     - No: Analyze corneal quality of vision with Chang Analysis & DLI
3. Low Corneal HOAs?
   - Yes: Use the iTrace Toric Planner to calculate and locate the placement axis.
   - No: Is this a Toric Candidate?
     - Yes: Continue with multi-focal or other premium option.
     - No: Continue with monofocal or other premium option.
Anterior corneal coma values greater than 0.32 mm may result in intolerable dysphotopsia in the presence of a diffractive optics multifocal IOL

Extended Depth of Focus IOLs

Clinical outcome and higher order aberrations after bilateral implantation of an extended depth of focus intraocular lens

Pilger, Daniel; Homburg, David; European Journal of Ophthalmology, Volume 28 (4): 8, 2018

Refractive Surgery RP30053446 — 2017 RSS
Analysis of Pseudoaccommodation in Aspheric and Extended Depth of Focus IOLs Using Ray Tracing Aberrometry

Presented in 2017
Author(s): Karolinne M Rocha MD; Jorge Haddad, MD; Eliza Longstreet Barnwell BA; George O Waring IV MD;
VSOT
Postop Unhappy patient
Example1  MFIOL  20/20,
Example 2, Unhappy MFIOL - ReSTOR
Example 3: Good alignment with low Angle Alpha
Good Candidate for MIOL
Example 4  Mid-level Angle Alpha
Borderline candidacy
Depends on the IOL
POLL QUESTION 4

Whether you use term Dysfunctional lens syndrome in your clinical practice
1. Yes
2. No
3. Cannot comment
Dysfunctional Lens Syndrome

- As described by George O. Waring IV, M.D.*:
- Characterized by difficulty seeing at distance (due to congenital ametropia) and at near (due to aging and progressive presbyopia)
- The clinical findings typically include
  - (1) lens opacities, whether they are cortical lens changes or nuclear lens changes or both;
  - (2) the inability to accommodate due to presbyopia; and
  - (3) an aberration profile that has changed

What is the Dysfunctional Lens Index™?

- DLI™ - first objective measure of the performance of the lens
- Using the Dysfunctional Lens Analysis display, a surgeon can quickly determine if a patient is experiencing Dysfunctional Lens Syndrome.

“A 10 is a perfectly clear lens, and a zero is a dense cataract.
Anything below 5.0 is significant for Cataract and if the patient is at a 6.0 or 7.0, he’s getting close.
Opacity is less, DLI High - patient claims good vision
Observable opacity and low DLI score
Cornea will support a Premium lens.

DLI is low and patient claims less vision OS
Opacity Map Correlates to Slit Lamp
The DLI was correlated with the LOCS III nuclear opalescence score and the Scheimpflug-based lens density. The DLI had a stronger correlation with CDVA compared to the LOCS III classification or the Scheimpflug-based lens density. The DLI may improve the preoperative evaluation of nuclear cataract and the monitoring of its progression.
“Did my LASIK wear-off?”
The iTrace can locate the cylinder axis of the Toric IOL?

- iTrace Toric Check Display guides the cataract surgeon to monitor post-op torics and determine rotation necessity
- Know if a toric IOL is off-axis or off-power and understand the change to the BCVA that is likely with a lens rotation.
Improve Toric Precision with WF Ks

**Sim Ks**

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<th>°</th>
<th>SimK</th>
<th>WF</th>
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<tbody>
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<td>4.80</td>
<td>141</td>
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<tr>
<td>Pre-op internal optics astigmatism</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-op entire eye astigmatism</td>
<td>25.76</td>
<td>113</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Surgical incision location (0-359°)</td>
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<td>180</td>
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<tr>
<td>Surgery induced corneal astigmatism (0-2D)</td>
<td>0.50</td>
<td>90</td>
<td></td>
<td></td>
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</table>

Calculated based based on 4 orthogonal points at a 1.5mm radius.

**Or Wavefront Ks?**

<table>
<thead>
<tr>
<th></th>
<th>D</th>
<th>°</th>
<th>SimK</th>
<th>WF</th>
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<tbody>
<tr>
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<td>5.81</td>
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<tr>
<td>Pre-op internal optics astigmatism</td>
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<td>0.50</td>
<td>90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculated based on the best Zernike fit on the cornea.
Toric - Unhappy

51° rotation
1.13 D change in cylinder power.

Toric - pre enhancement
Estimated Rx prior to rotation
+0.20 +0.35 x 90

Measured Rx after rotation
+0.00 +0.37 x 99

51° rotation
1.13 D change in cylinder power.

3° rotation
0.01 D change in cylinder power.
Improve Toric Precision with Post-op Axis Analysis

- **Case 1:** Rotation wouldn’t provide much improvement

  - Toric IOL Check and Enhancement
  - Post-op corneal astigmatism 3.09 D 90
  - Post-op internal optics astigmatism 2.11 D 0
  - Post-op entire eye astigmatism 0.98 D 90
  - 8° rotation clockwise = 0.21 D change in cylinder

- **Case 2:** Rotation improves results dramatically

  - Toric IOL Check and Enhancement
  - Post-op corneal astigmatism 4.63 D 85
  - Post-op internal optics astigmatism 4.53 D 175
  - Post-op entire eye astigmatism 0.10 D 85
  - 25° rotation clockwise = 3.72 D change in cylinder

- **Case 3:** Lens is off-powered, not off-axis

  - Toric IOL Check and Enhancement
  - Post-op corneal astigmatism 2.53 D 71
  - Post-op internal optics astigmatism 4.32 D 161
  - Post-op entire eye astigmatism 1.79 D 161
  - 6° rotation clockwise = 0.11 D change in cylinder
Decentered Rhexis causes Trefoil

Tilted MF IOL with Scotopic Pupil
Internal Aberrations, Strehl ratio, Modulation transfer function, and Corneal Aspheric Function after Femtosecond Laser Assisted Cataract Surgery

Purpose: To compare high-order aberrations, Strehl ratio, modulation transfer function (MTF), and corneal aspheric function after femtosecond laser-assisted cataract surgery and traditional phacoemulsification.

Methods: In a prospective study, 32 eyes of femtosecond laser-assisted cataract surgery (FLACS) and 40 eyes of traditional phacoemulsification were studied. Wavefront aberrometry and visual quality were measured using the iTrace (Hoya Ltd.). Main outcomes included total internal aberrations, Strehl ratio, MTF, and corneal aspheric function. Results: No statistically significant differences were found between corneal aspheric function measurements. The FLACS group had significantly lower values of spherical aberration and higher MTF performance compared to traditional.
SA60AT - Pre and Post Yag Capsulotomy 20/20 OS

Influence of neodymium:YAG laser capsulotomy on ocular wavefront aberrations in pseudophakic eyes with hydrophilic and hydrophobic intraocular lenses

Jos J. Rozema, MSc, PhD, Carina Koppen, MD, Veva de Groot, MD, PhD, Marie-José Tassignon, MD, PhD
Other applications

- Corneal inlay planning
- Importance of the scan centration
- Over-refraction through spectacles or contact lenses
- Vitreolysis (Laser Floater Removal)
- Dry eye management
- Dysfunctional Lens Syndrome diagnosis

Accommodation studies
Future

Diagnostic tool

- Machine – Research Tool
- Educating Patients

More implications
Better understanding – better technology
Thank you
Minutes before leaving........

- WELCOME TO QUESTIONS ????????