المؤتمر السنوي الدولي للجمعية المصرية
INTERNATIONAL CONGRESS OF THE
EGYPTIAN OPHTHALMOLOGICAL SOCIETY
EOS 2023

Wavefront
A Chance for a Better Vison

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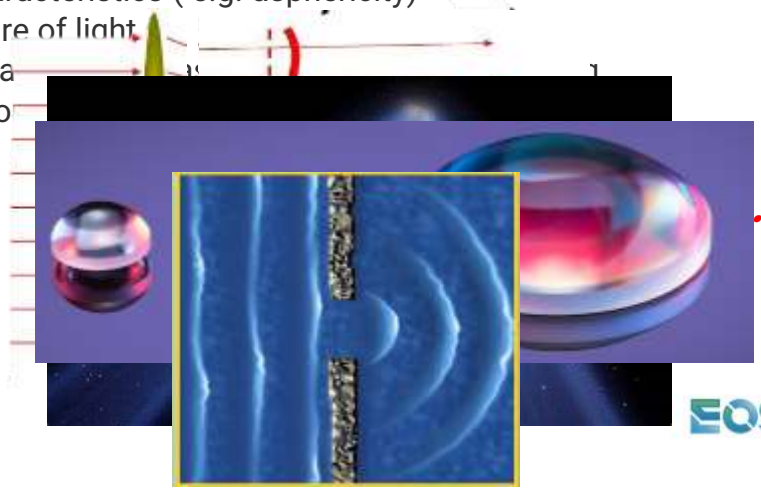
Optical aberrations

Deviations from a perfect, mathematical model of a light wave passage in an optical medium.

It can be caused by:

- Physical, optical, or mechanical flaws in the optical system.
- Shape and characteristics (e.g. asphericity)
- The wave nature of light
- Change of refra
- Decentration o



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Optical Aberrations

Monochromatic

(Can be corrected by refractive surgery)

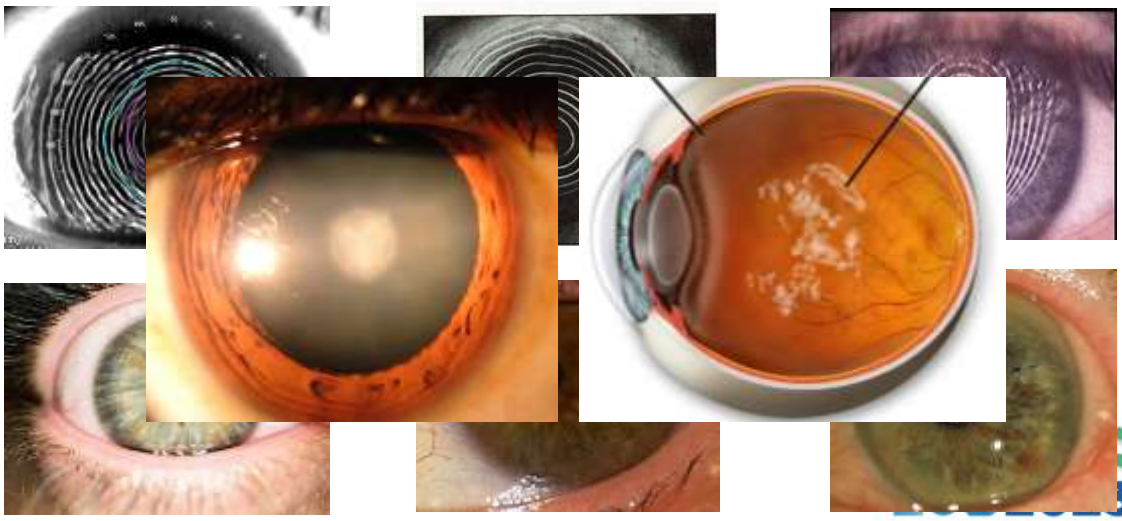
Chromatic

(Can't be corrected by refractive surgery)

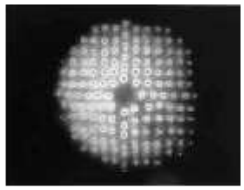
Low Order

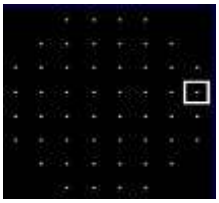
High Order

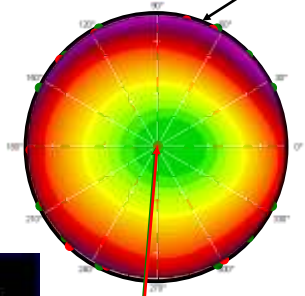
Sources of optical aberrations in the eye

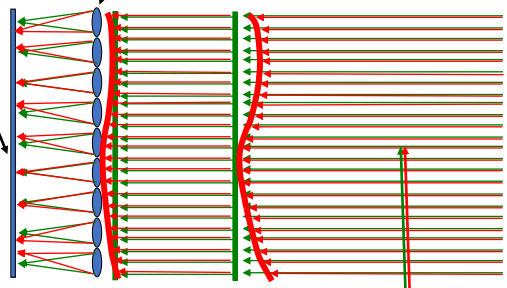


How Wan We Measure Aberration









CCD sensor

Lenslet array

Deformed wavefront as sensor image

Deformed wavefront

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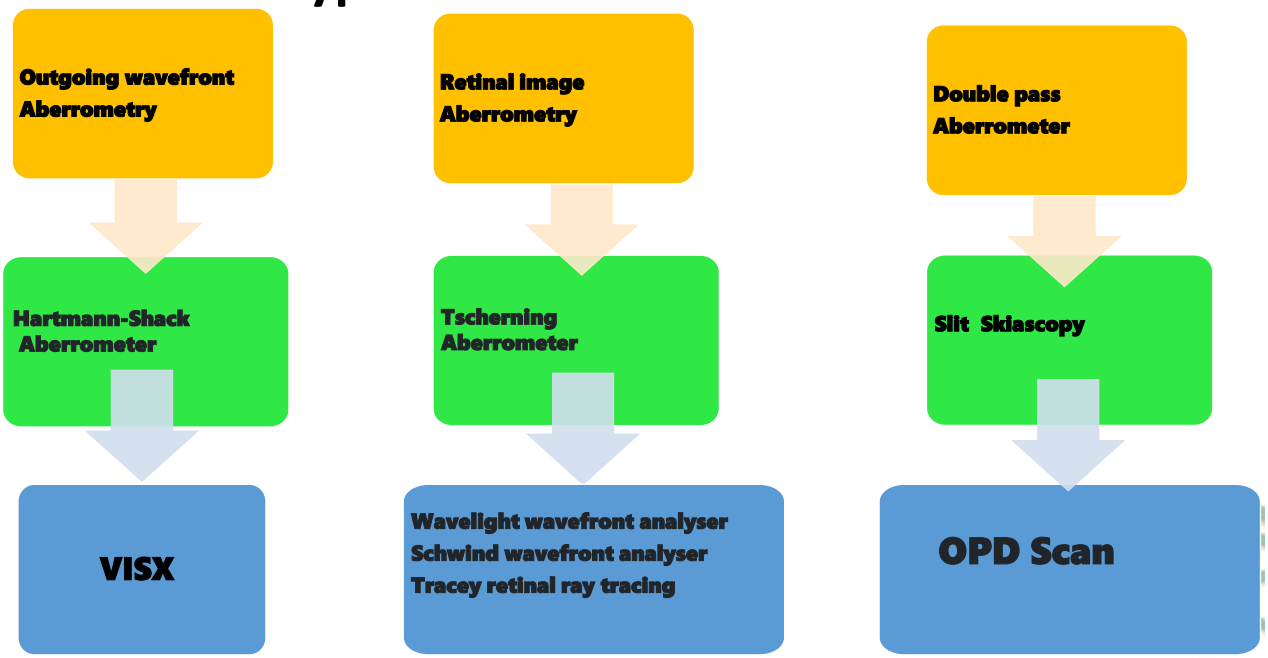
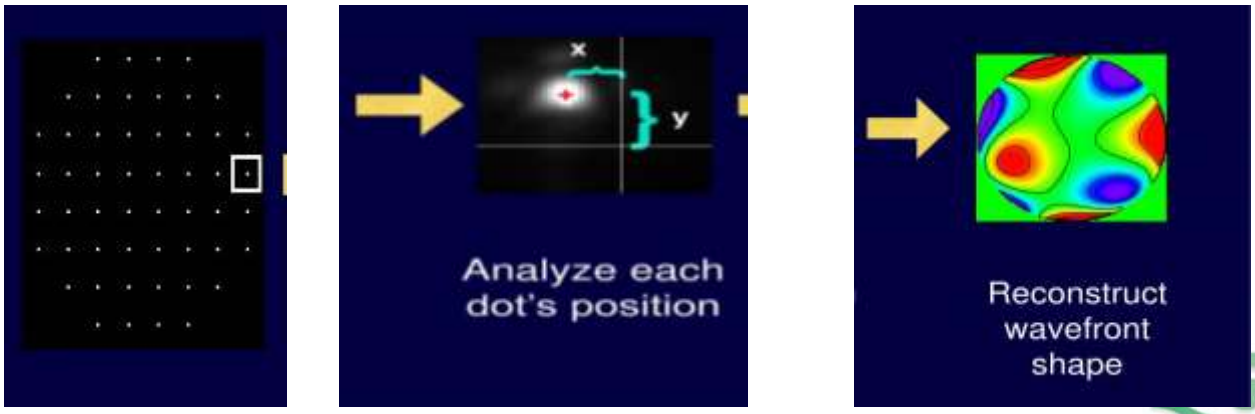
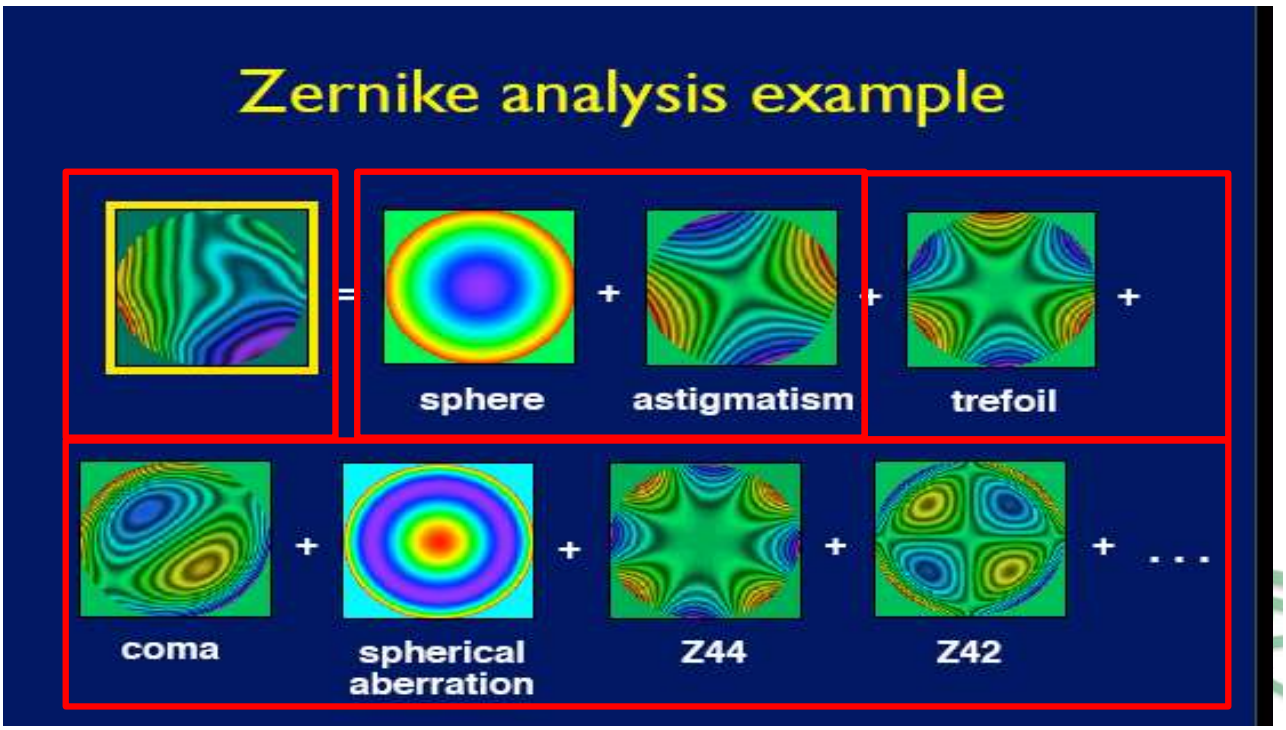
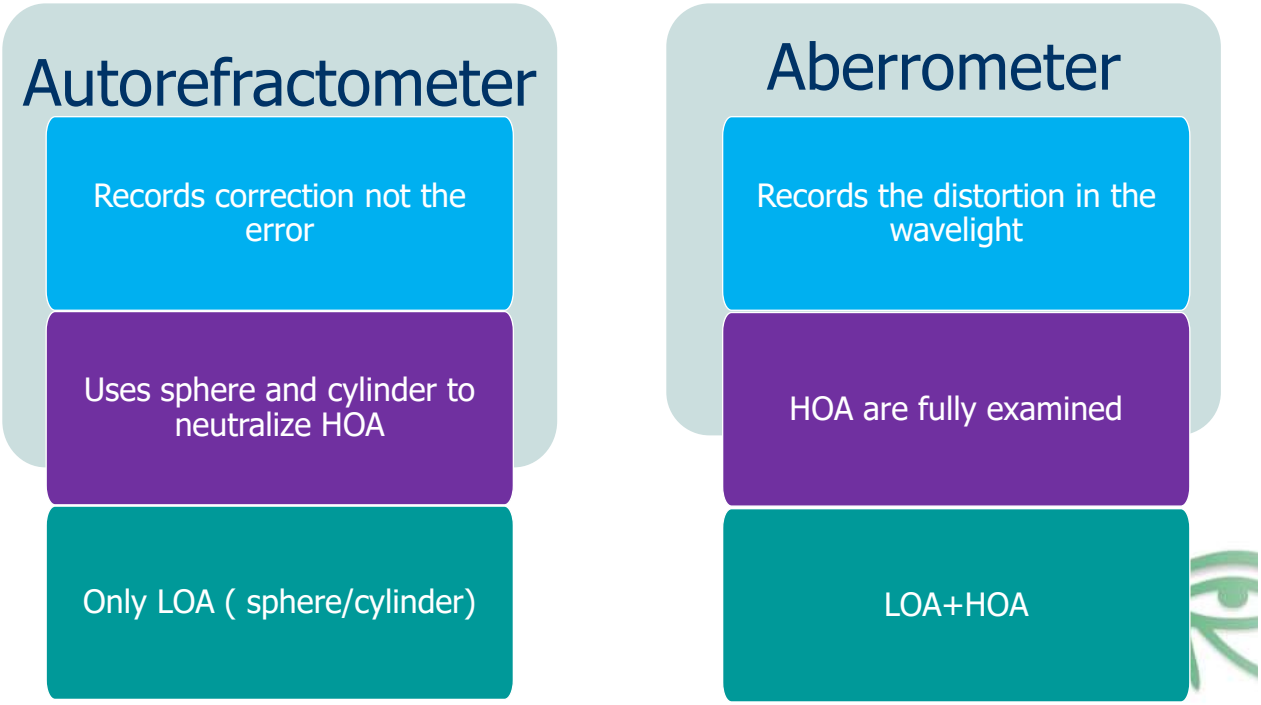
Types of Wavefront Aberrometers




x
y
Analyze each dot's position
Reconstruct wavefront shape


Zernike analysis example
=
+
+
+
sphere
astigmatism
trefoil
+
+
+
+
. . .
coma
spherical aberration
Z44
Z42



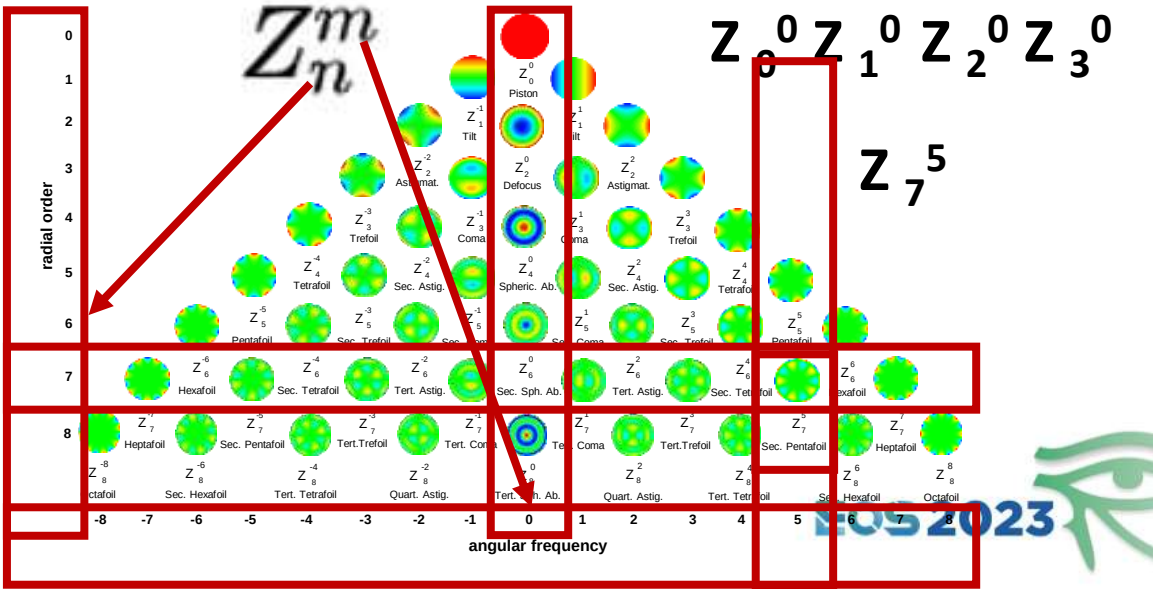
Zernike vs Fourier Terminology

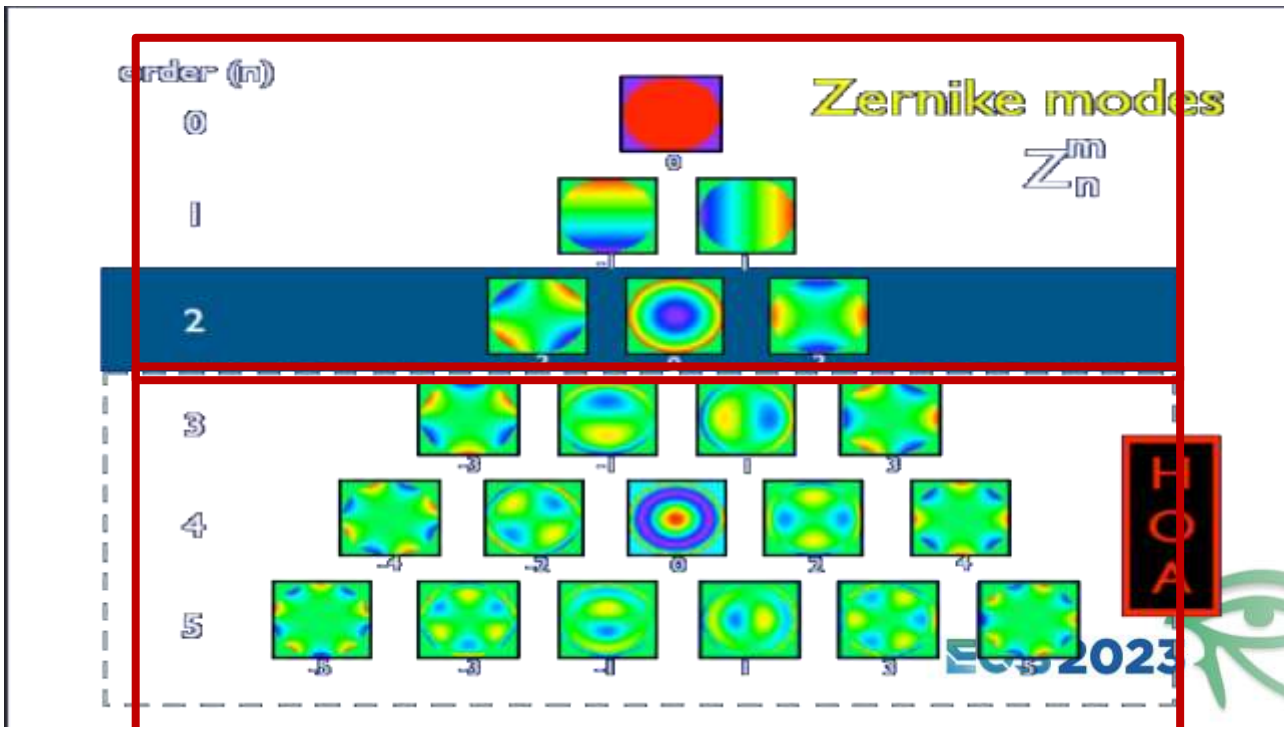
- These are mathematical formulas to convert the captured dots of an aberrated optical system into a reconstructed wavefront map.

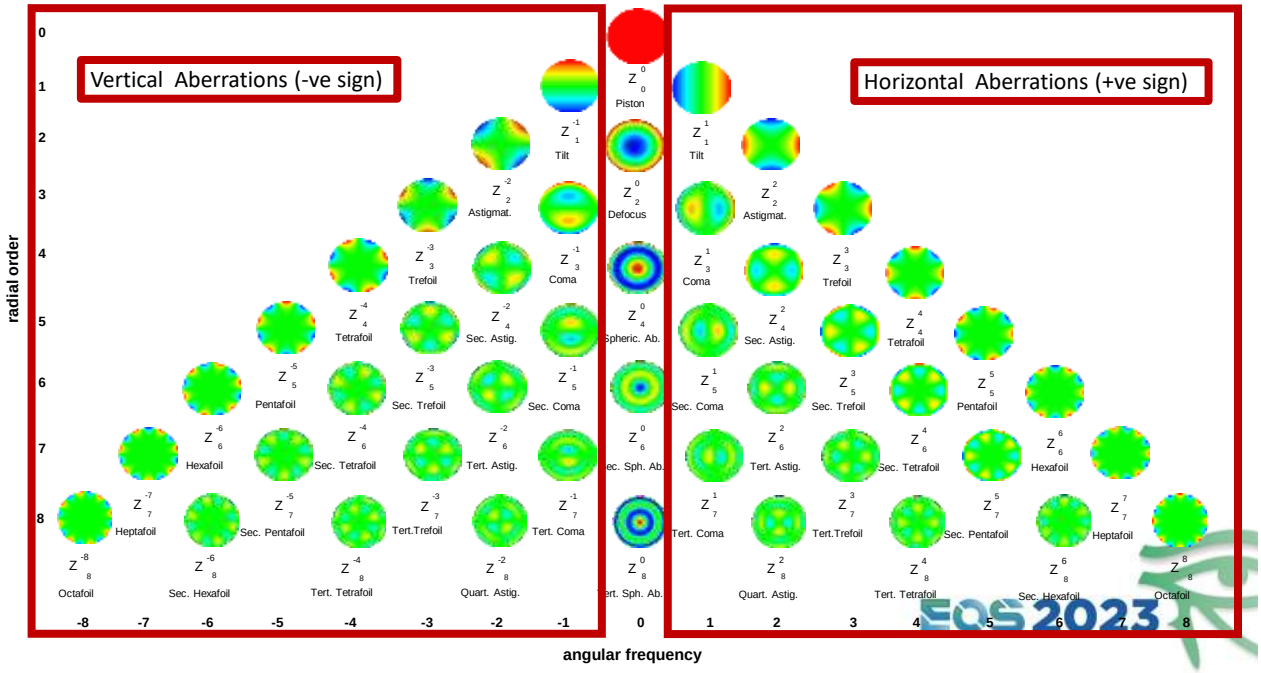
- **Zernike** has **12 orders** of aberration description. It is **simpler , faster but less accurate in the periphery** of the analyzed areas.

- **Fourier** has **64 terms** of aberration description. It is **more complex , slower and more accurate in the periphery** of the analyzed area

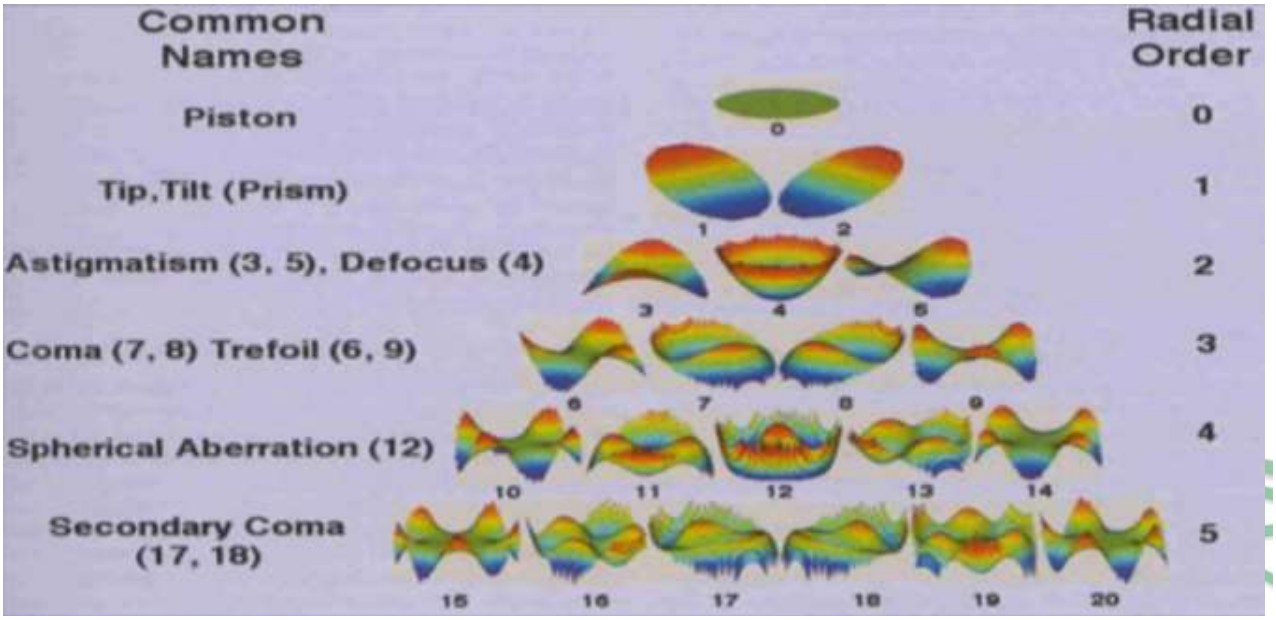
Zernike Polynomials







Another nomenclature for Zernike wavefront aberrations



Low Order Aberrations

Zero Order = Piston

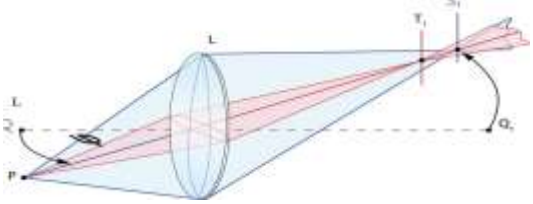
- Piston of an engine .
- Closer objects look bigger than farther objects
- Only t
  Qualit
- It is nc

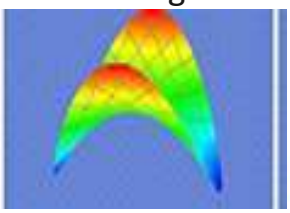
1st order =Tilt Aberration

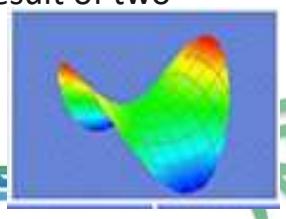
- It is a change in the image shape by changing the angle of view.
- It can be a vertical or a hor
- This is ***not a true aberratic*** es aberration free with a change in position of the observer.
- It is ***not a Qualitative aber***
- This aberration is ***of little c***

2nd Order Aberrations =Defocus (Myopia/Hypermetropia/ Astigmatism)

- This order of aberration is clinically significant. Can be used to correct other aberrations
- Myopia and hypermetropia focus images on an incorrect plane because of its focusing power.
- Astigmatism has two main principal planes of images as a result of two refractive meridal powers



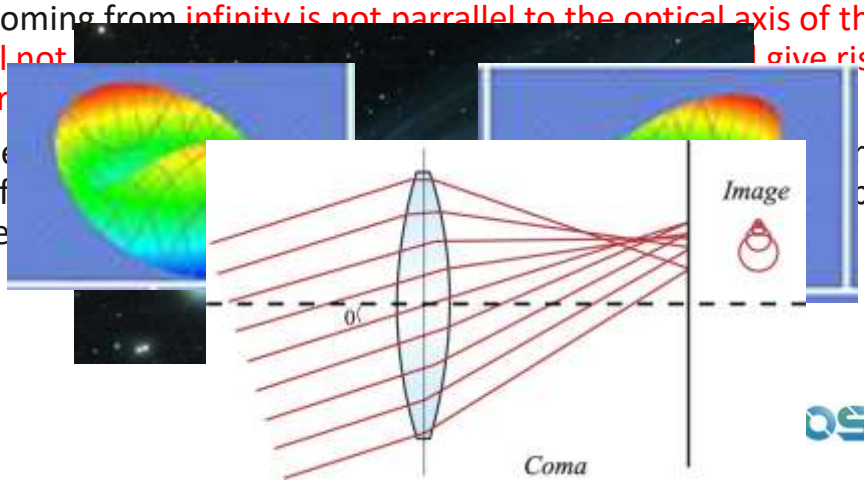




High Order Aberrations

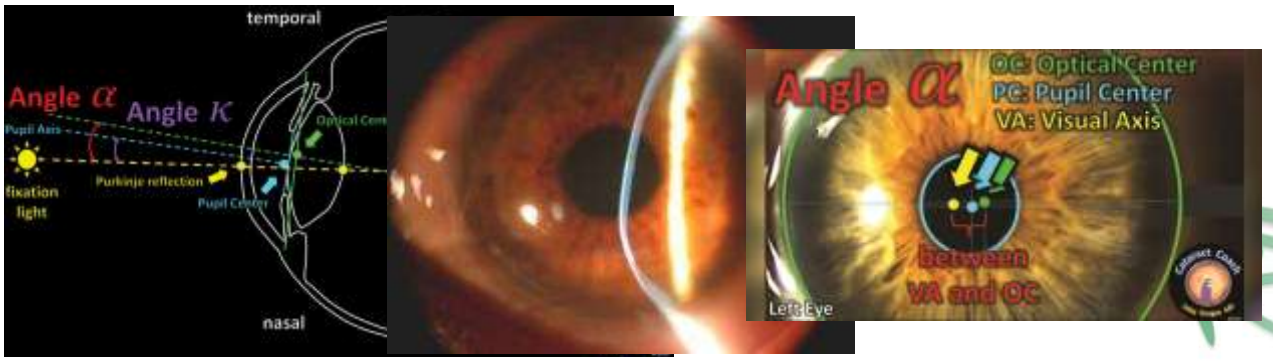
3rd Order Aberrations= Coma

- Comes from the word comet, (Having a head and a tail).
- The Coma can be vertical and horizontal
- If light coming from infinity is not parrallel to the optical axis of the lens, all the light will not give rise to a comet like aber
- This is be relatively sharply f phery of the lens, the



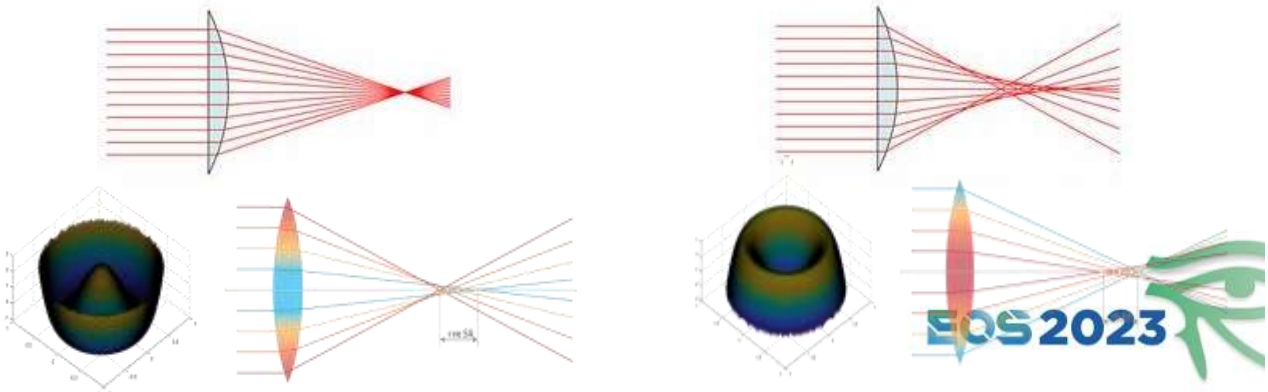
3rd Order Aberrations= Coma (cont.)

- Coma is typically less apparent than spherical aberration.
- Coma is more with larger angle alpha.
- Keratoconus has more pronounced and more displaced corneal apex leading to higher amounts of coma.

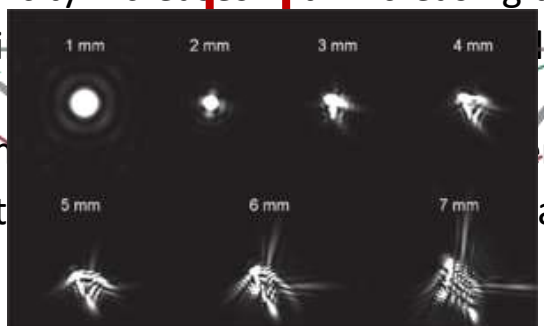


4th Order Aberration=Spherical Aberration

- Image Appears Blurred, Rays from Edge Focus at Different Point than Rays from Center



- In normal human eyes ***SA is the greatest represented ocular aberration.***
- The sources of asphericity in the human eye are the cornea and the lens.
- In the normal eye, the cornea has positive spherical aberrations and the lens has negative spherical aberrations.
- The ocular asphericity increases with increasing the pupil size.
- Accommodation i aberration of the eye.
- Myopic correctio rration.
- Hyperopic correct aberration.



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Optical Quality Metrics

- Refractive errors
- Point spread function (PSF)
- Line spread function
- Strehl ratio
- Modulation transfer function (MTF)
- Contrast Sensitivity
- Wavefront measurements
- Simulate the patients vision!

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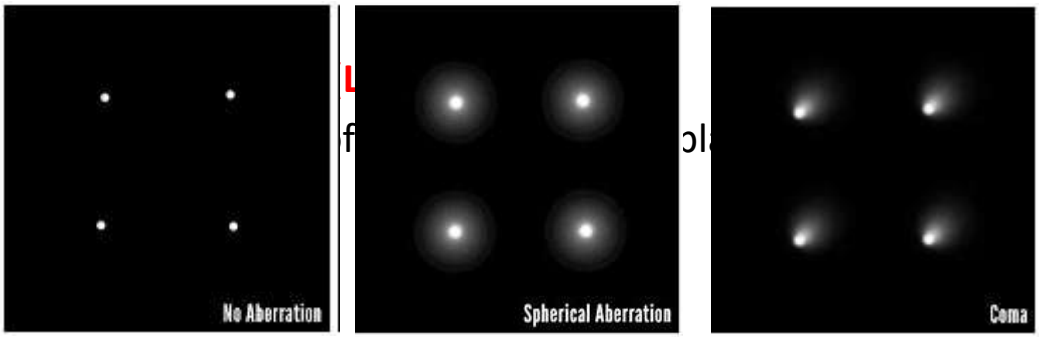
1-Point Spread Function(PSF):

- Is the distribution of light in the image plane for a point

2-Lir **L**

- f ol



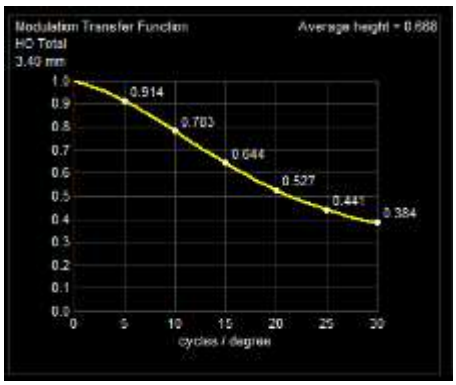
3-Th

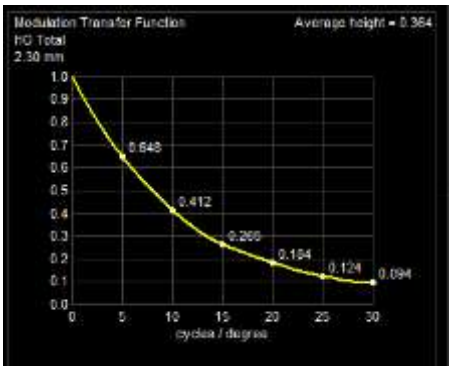
- A measure of the quality of optical image formation,
- Strehl ratio has a value between 0 and 1, with a hypothetical, perfectly unaberrated optical system having a Strehl ratio of 1.

Modulation Transfer Function (MTF)

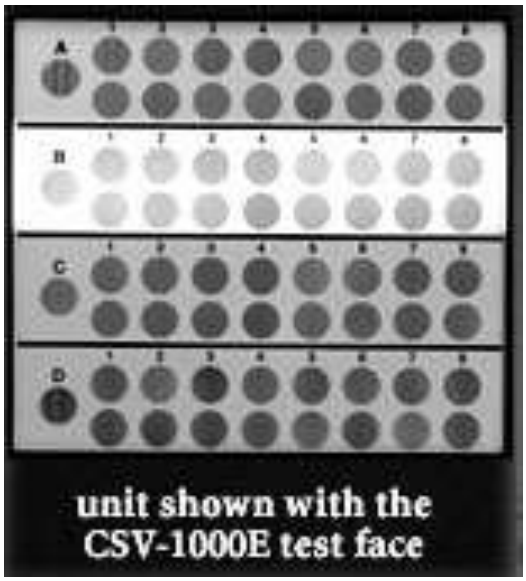
➢It is a ratio of image contrast to object contrast.

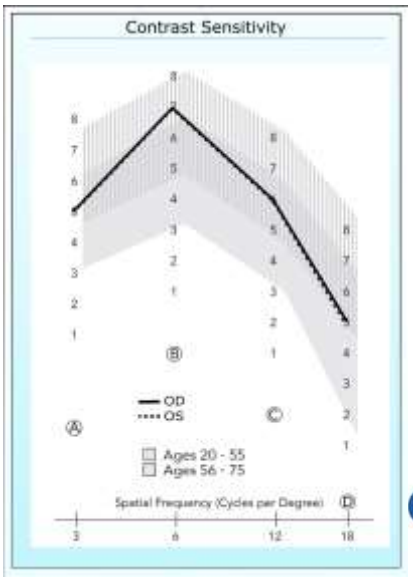
➢Ideally MTF of a lens should be 100 % or the value of the MTF ratio should be 1.



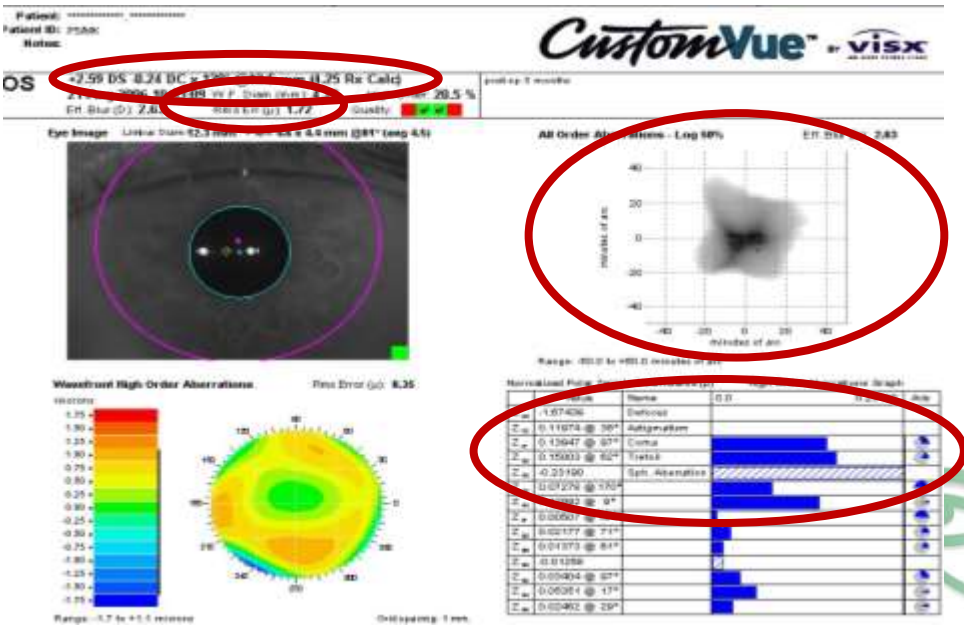


The Contrast Sensitivity

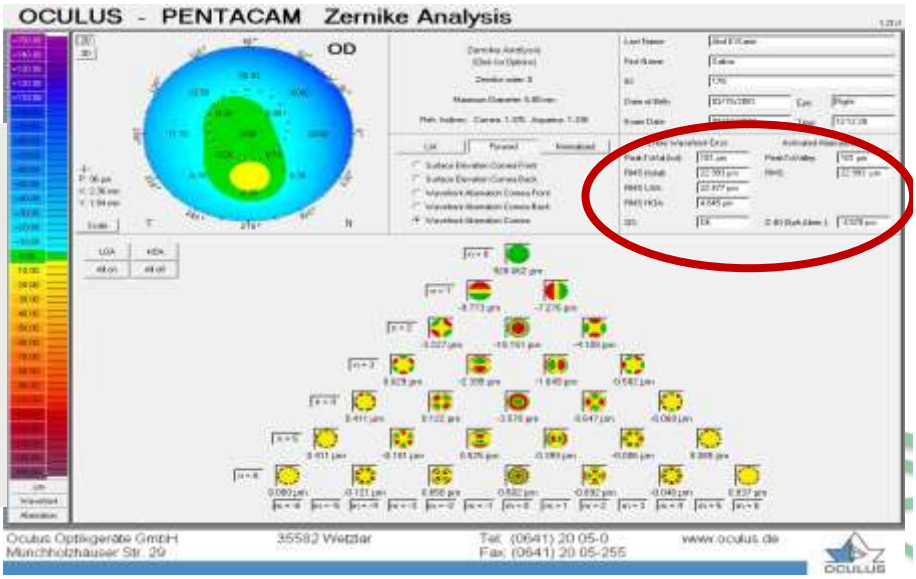




Ocular Wavefront Measurement



Corneal Wavefront



Root Mean Square (RMS)

- RMS wavefront error is a way to measure wavefront aberration.

$$x_{rms} = \sqrt{\frac{(x_1^2 + x_2^2 \ldots x_n^2)}{N}}$$

- 6.0mm pupil HOA RMS is about 0.33 µm
- 5.0mm pupil HOA RMS is about 0.19 µm
- 4.0 mm pupil HOA RMS is about 0.12 µm
- 90% of Normal eyes have less than twice these values

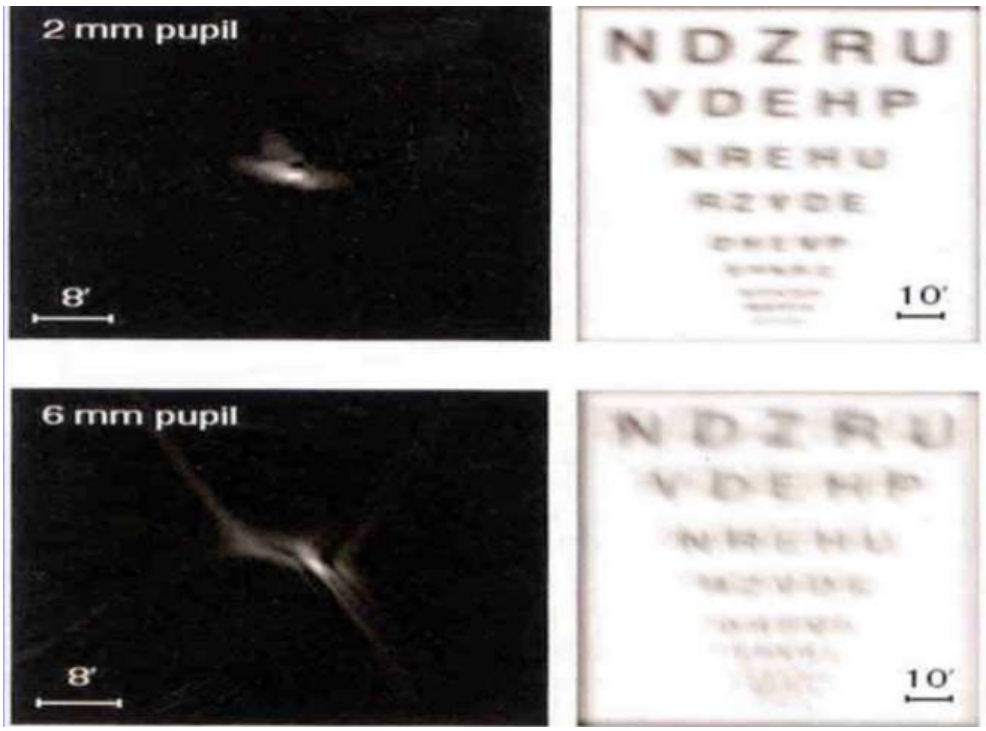
- Every 3 microns distortion on the cornea creates about one micron of Wavefront error

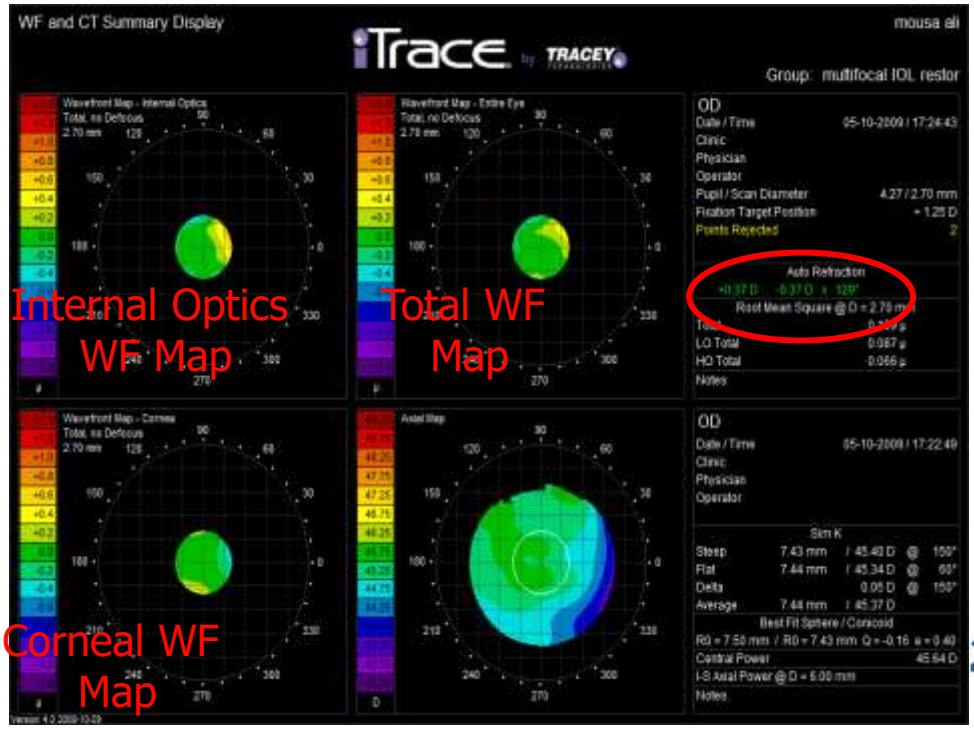
Total aberrations
(Corneal+ Lenticular Aberrations)

- Total aberrations is simply achieved by summing the absolute values (any negative signs removed) of the individual Zernike polynomial weights

- Higher number indicating greater complexity in the overall shape of the wavefront.

- **Larger pupil diameters usually exhibit higher amounts of aberration.**





Simulation of Vision

Normal Vision

Vision Due To Astigmatism

Coma

Spherical Aberration

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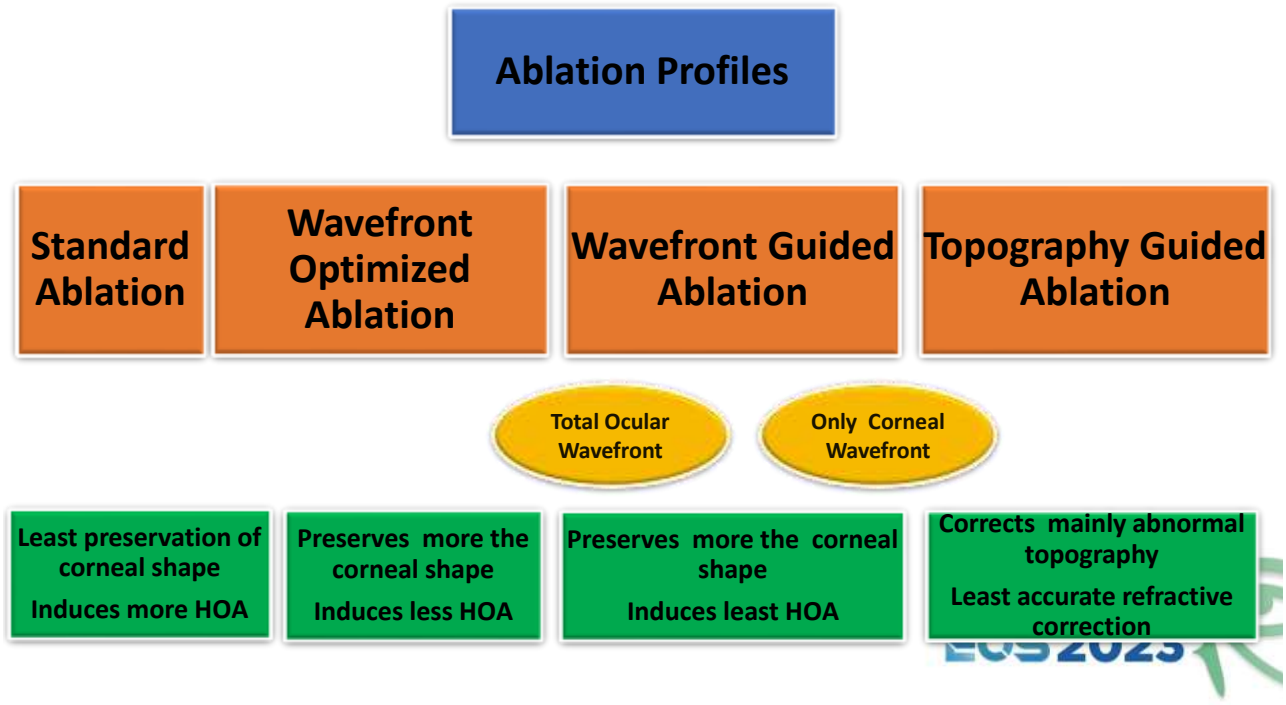
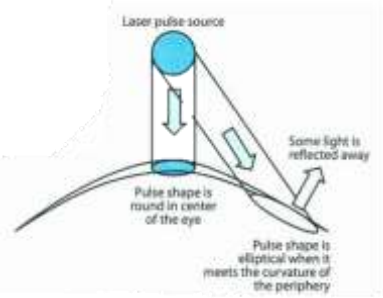
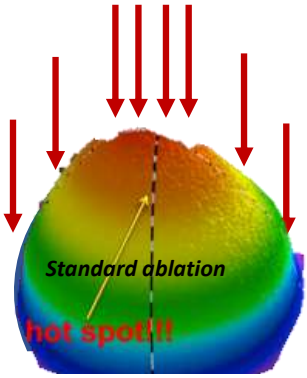
Post Refractive surgery

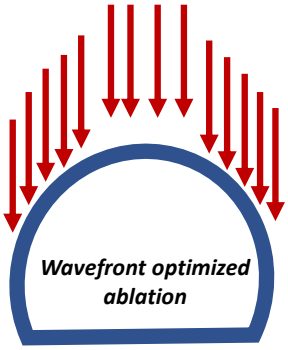
Practical Implications

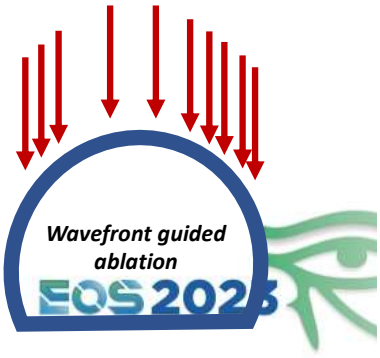




Ablation Profiles







1-Advantages of Ocular Wavefront Guided Refractive Surgery

- Better Quality of vision
- Greater chance of achieving 20/20 vision
- Reduced chance of losing best-corrected vision
- Reduced chance of losing visual quality or contrast sensitivity
- Reduced chance of night-vision disturbances, halos and glare
- Better for large pupil

Fingerprint of your eye

Disadvantages of Ocular Wavefront-Guided Refractive Surgery

- More corneal tissue ablation so Not recommended for thin corneas.
- More expensive
- Also Ocular Wavefront is :
  - ➢Pupil dependent
  - ➢Accommodation dependent
  - ➢Affected by aging changes
  - ➢Not suitable in corneal pathologies(irregular astigmatism and KC , scars and dry eye)

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Advantages of Corneal Wavefront Ablations

- Not accommodation dependent
- Not Pupil dependent
- Larger area can be treated by wavefront
- Most HOA are mainly corneal so it is wiser to treat these HOA at the corneal plane

Disadvantages of Corneal Wavefront

- Sphere cannot be measured.
- The measured cylinder represents the anterior surface corneal component. The true refractive cylinder may differ because of other components (posterior corneal surface, lens, etc.)
- Internal aberrations are not measured.
- Measurements should be taken within 3 seconds to get a regular, stable tear film and to avoid the break-up of the tear film
- Medications influencing the tear film should not be used prior to the measurement
- Pupil should not be dilated and should be detected properly.
- Correct patient fixation and conus positioning is necessary

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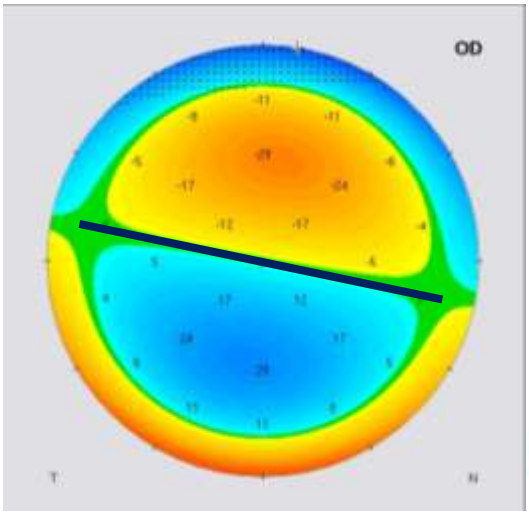
2-Comatic Meridian in ICRs planning



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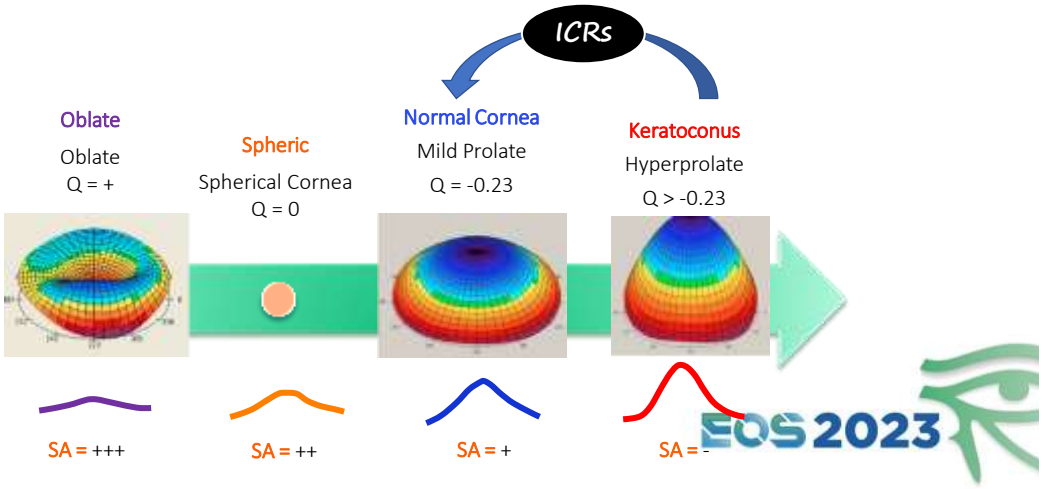
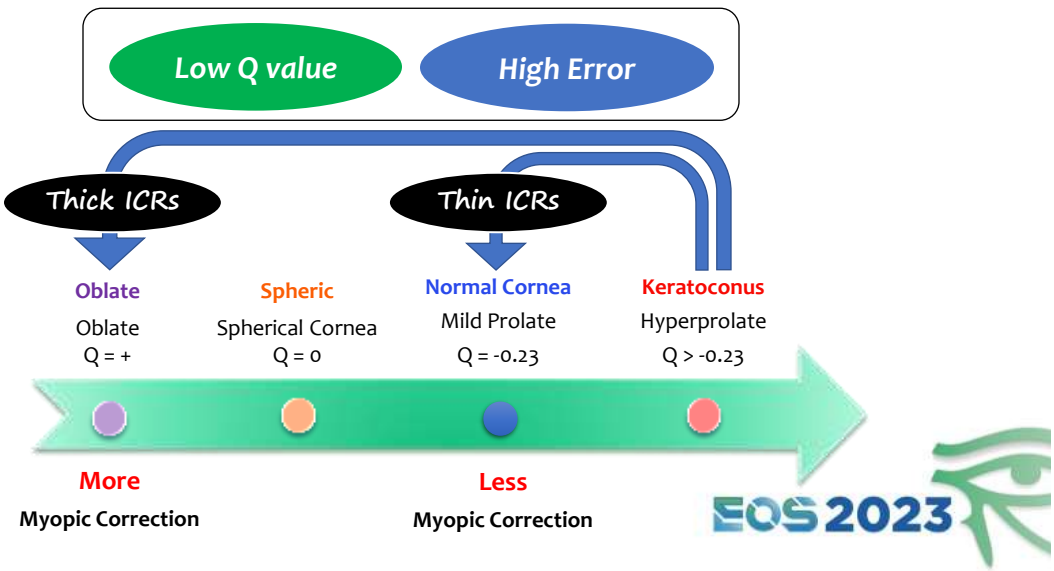
Q value Based Nomograms

Effect on Spherical aberration

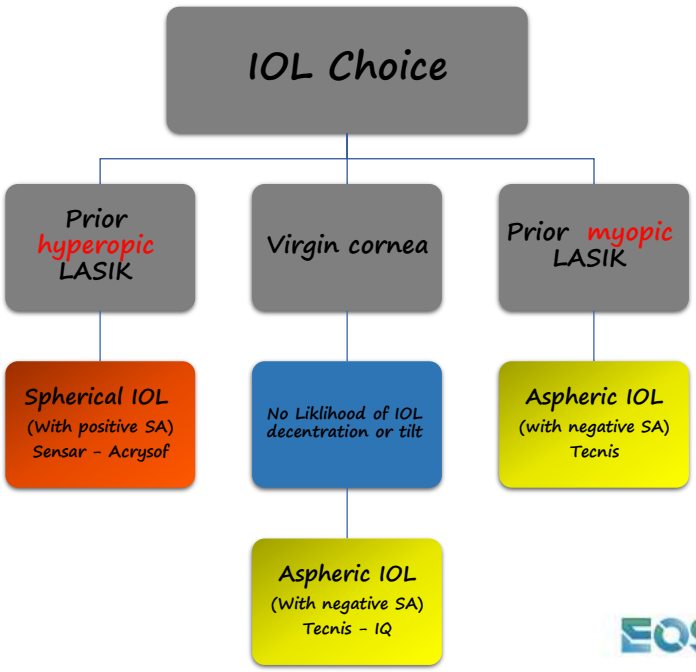


Conflicts



3- IOL Choice

Lens	TECNIS IOL	Acrysof IQ IOL	B&L IOL	Spherical IOL
Point spread function				
20/20				
Corneal SA	+0.27	+0.27	+0.27	+0.27
IOL SA	-0.27	-0.17	0.0	+0.15
Total Residual SA	0.0	+0.10	+0.27	+0.42



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Thank You