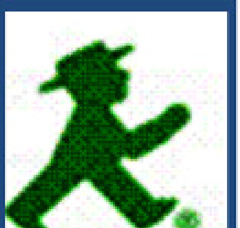
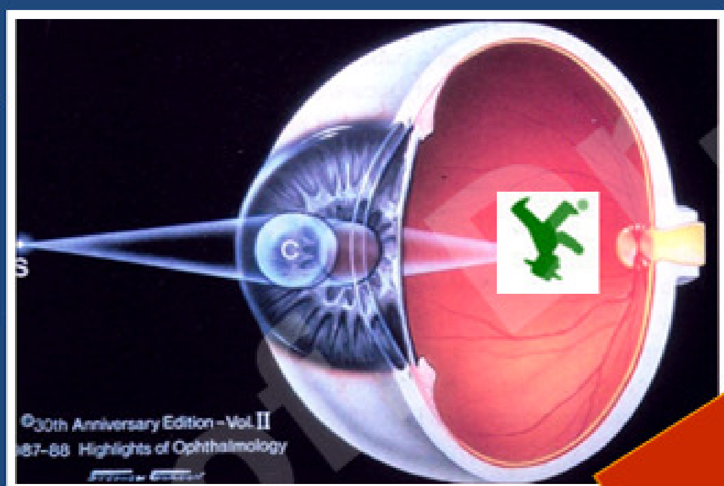
İzzet Can, MD, Prof.
Bozok University Medicine Faculty

CATARACT SURGERY IS A REFRACTIVE SURGERY ...?

Quality of Vision / Definition





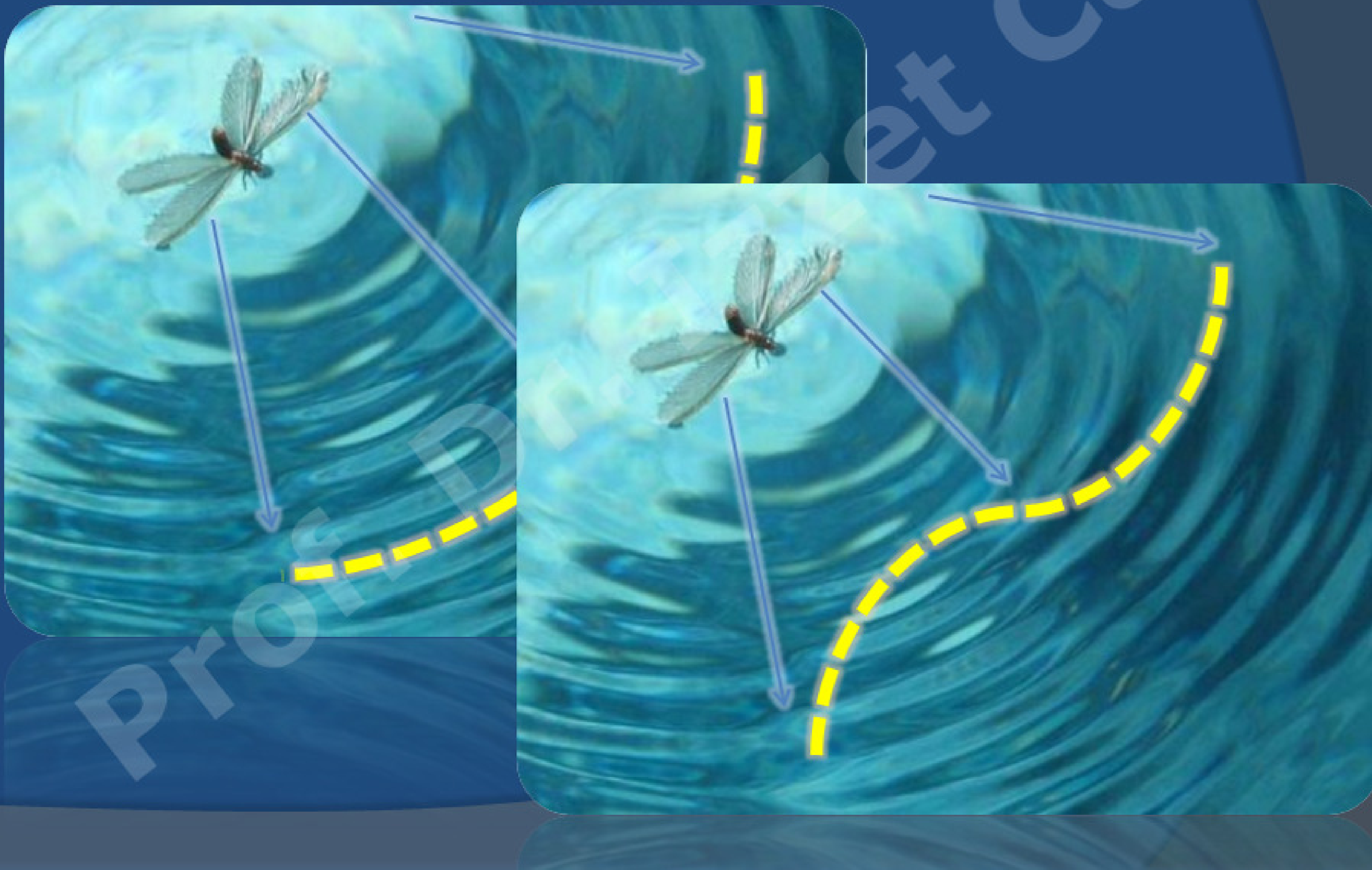
1. **Optical system**
2. **Photoreceptors**
3. **Neural system**

Quality of Vision / Negative Impacts

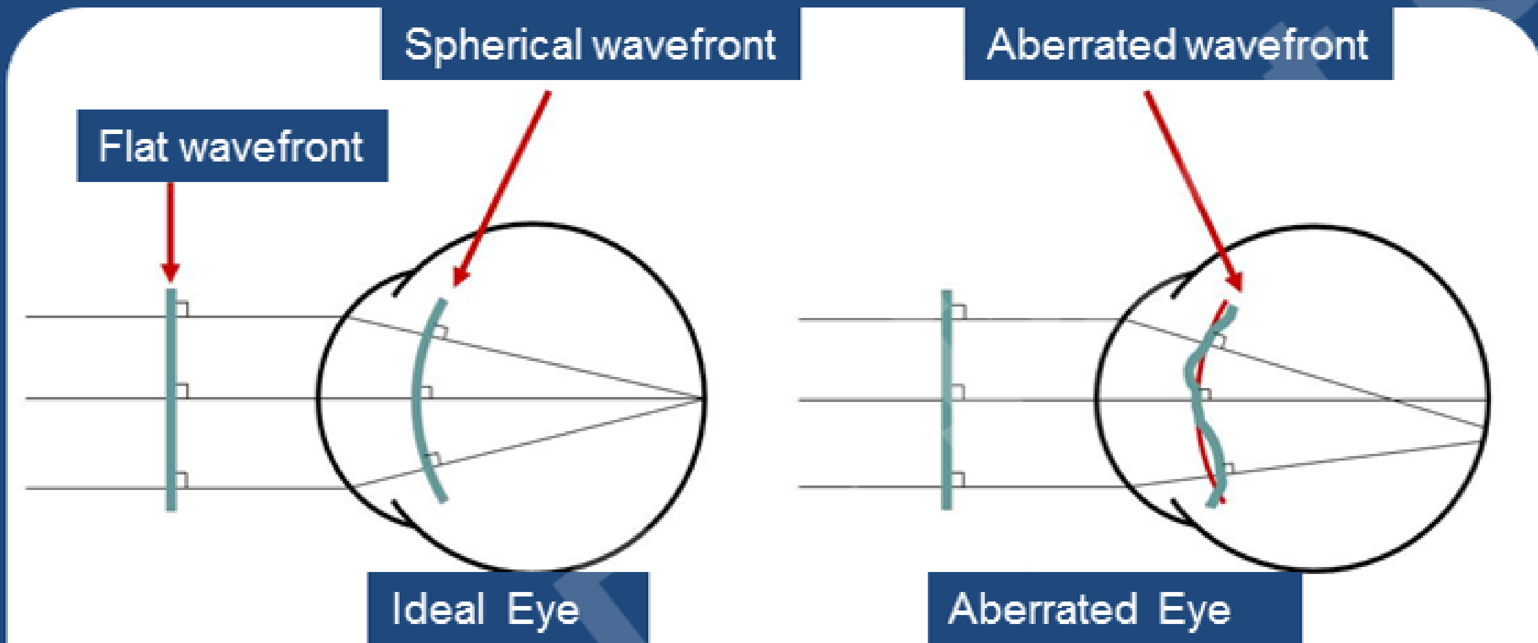
- Optical problems which may deteriorate the image quality

1. Scatter
2. Diffraction
3. Aberration

What is Aberration?



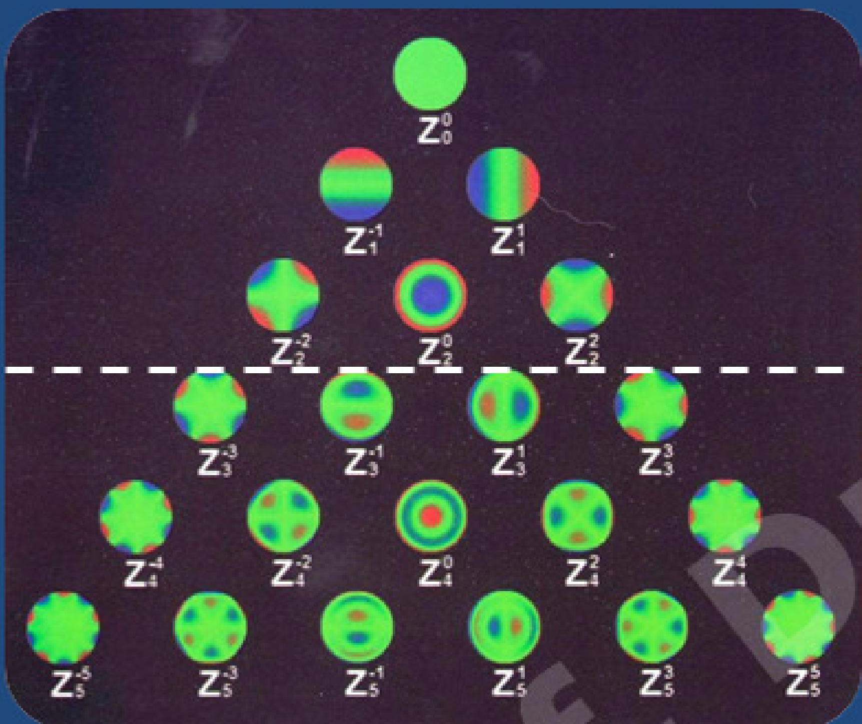
What is Aberration?

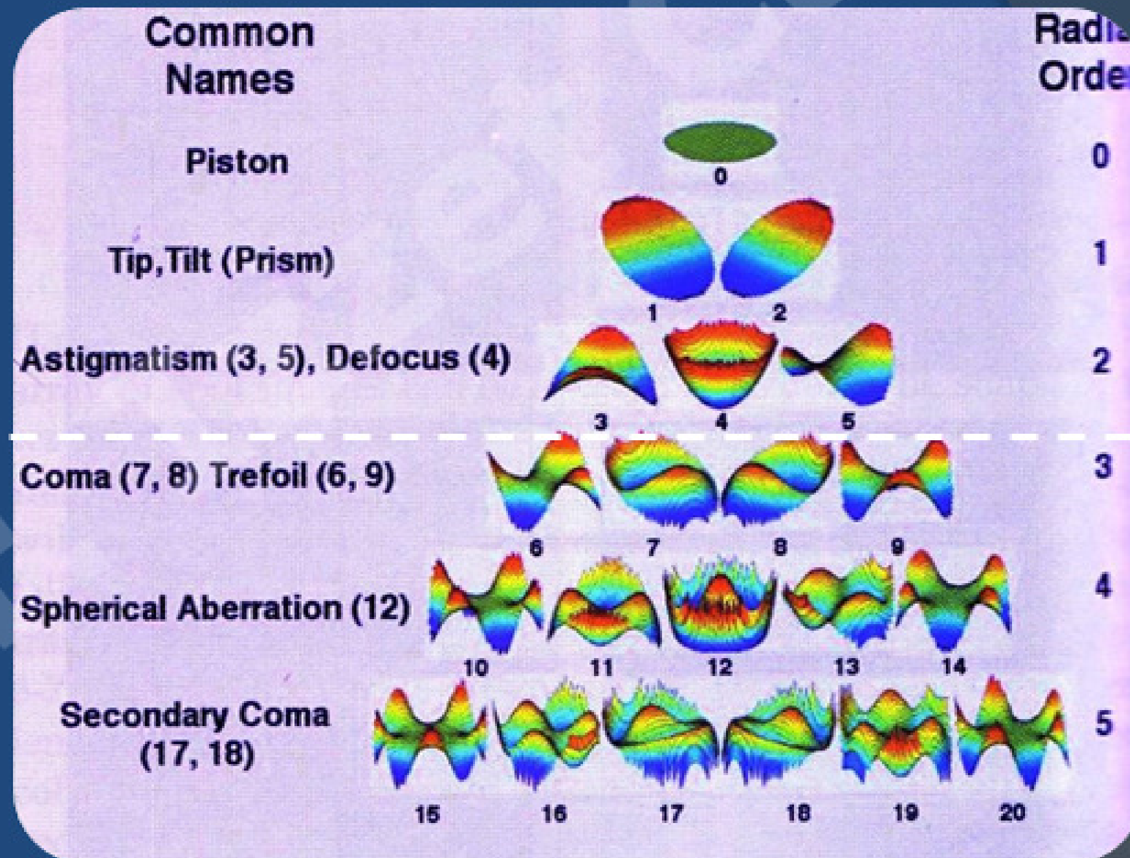


- The wave aberration is defined as the differece between the actual aberrated wavefront and the ideal or intended wavefont.

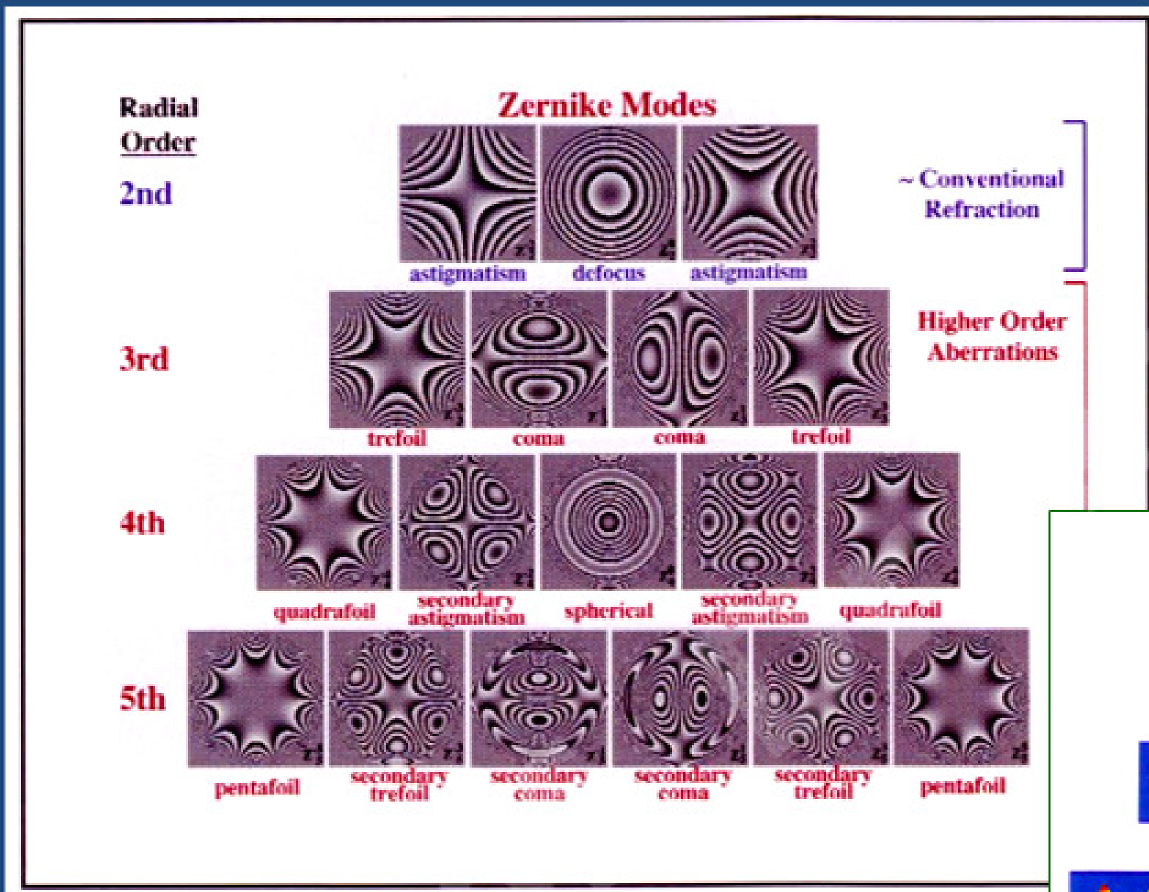
Born M, Wolf E. Principles of Optics 1985

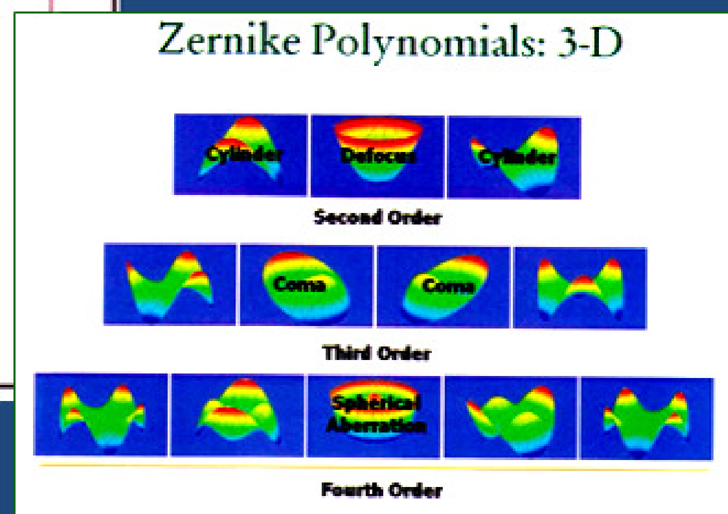
What is Aberration?





What is Aberration?





Traditional treatment

Customized treatment

What is Refractive Cataract Surgery?

- Recovering some functions which have been lost in time or innate by using cataract surgery.
- This not only corrects defocus aberrations called myopia or hyperopia but also corrects
  - **Astigmatism**
  - **Spherical aberration**
  - **Presbyopia**

Eye, How Flawed ?

- Helmholtz's Comment on Eye

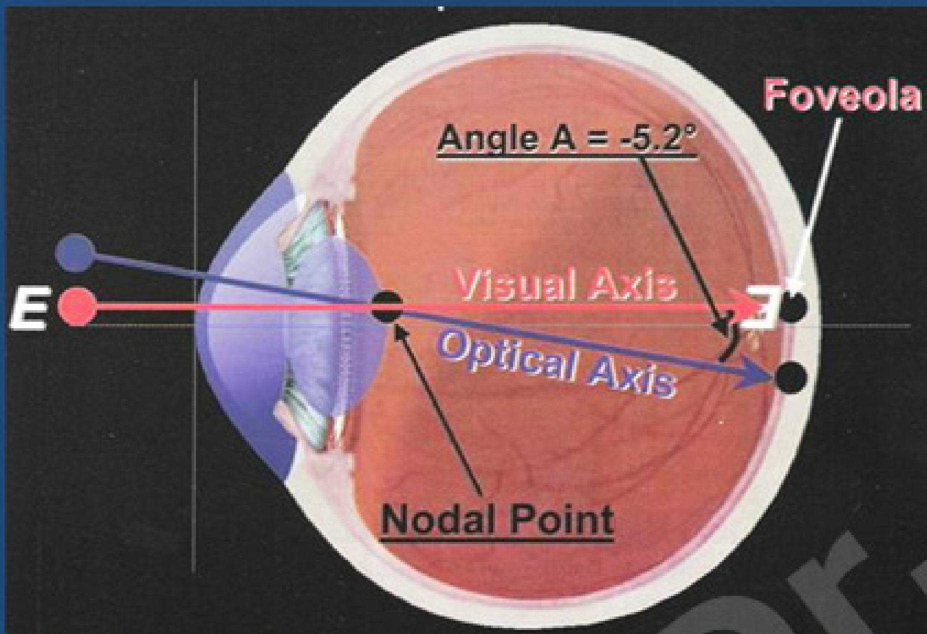
Now, it is not too much to say that if an optician wanted to sell me an instrument (the eye) which had all these defects, I should think myself quite justified in blaming his carelessness in the strongest terms and giving him back his instrument.

Hermann Ludwig Ferdinand von Helmholtz

(1821-1894)

Helmholtz,
Berlin, Humboldt University

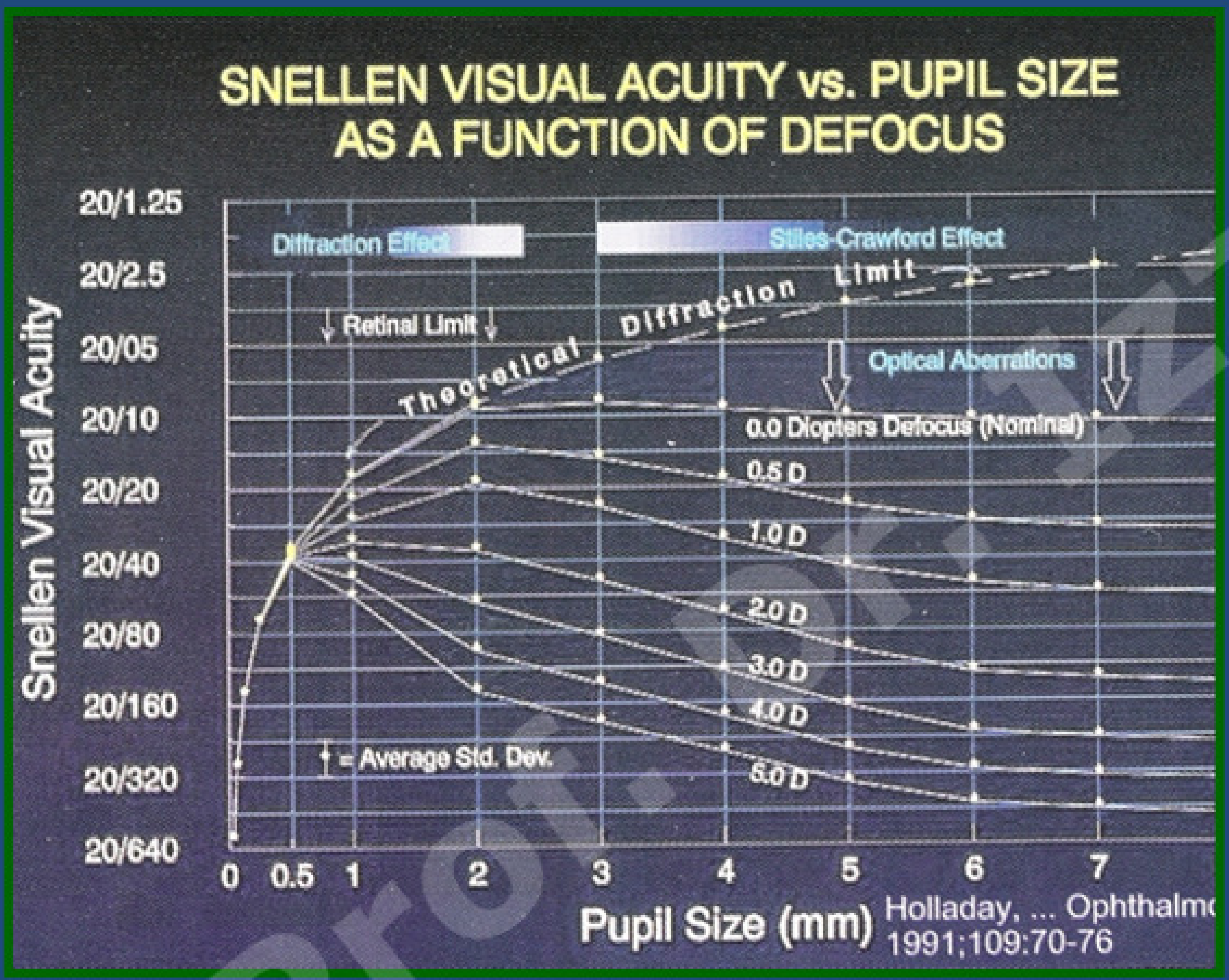
Limitations of Visual Function



The eye is often described as being like a camera. The aperture (the pupil) would be aligned on the optical axis with the lenses (the cornea and crystalline lens) and the film (the fovea). If the eye were a diffraction-limited camera with the same focal lenght and aperture size as the human eye, our quality of vision would be **2.5** times better than a human eye.

- Anatomical tilt of the eye relative to the optical axis : (Angle Alpha)
  - Horizontal: 5.2˚
  - Vertical: 1.4˚
- Distance between the pupillary center and visual axis (Angle Kappa)
  - Horizontal: 2.6°
  - Vertical: 0.6°

Limitations of Visual Function



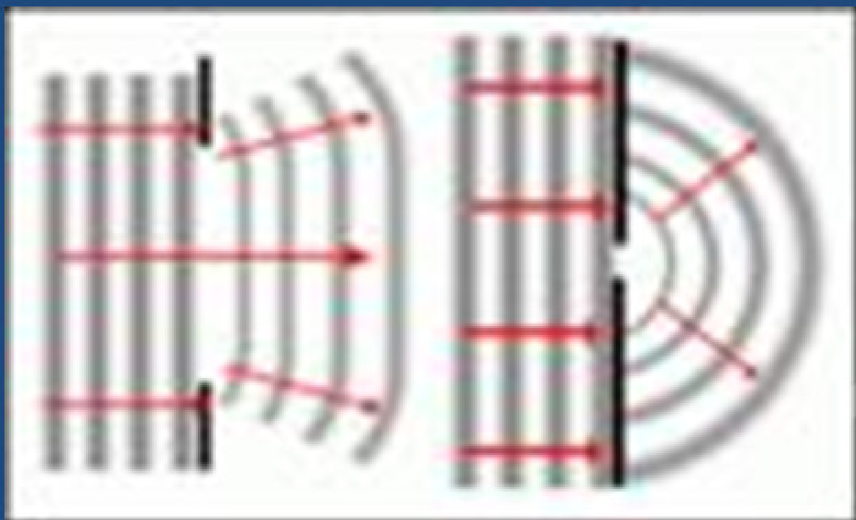
Aberrations

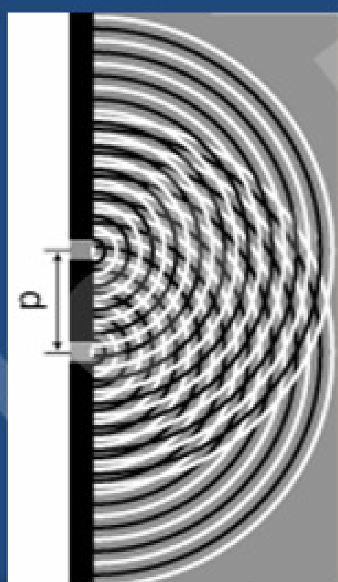
Pupil Size

Ideal: 3.0 - 3.2 mm

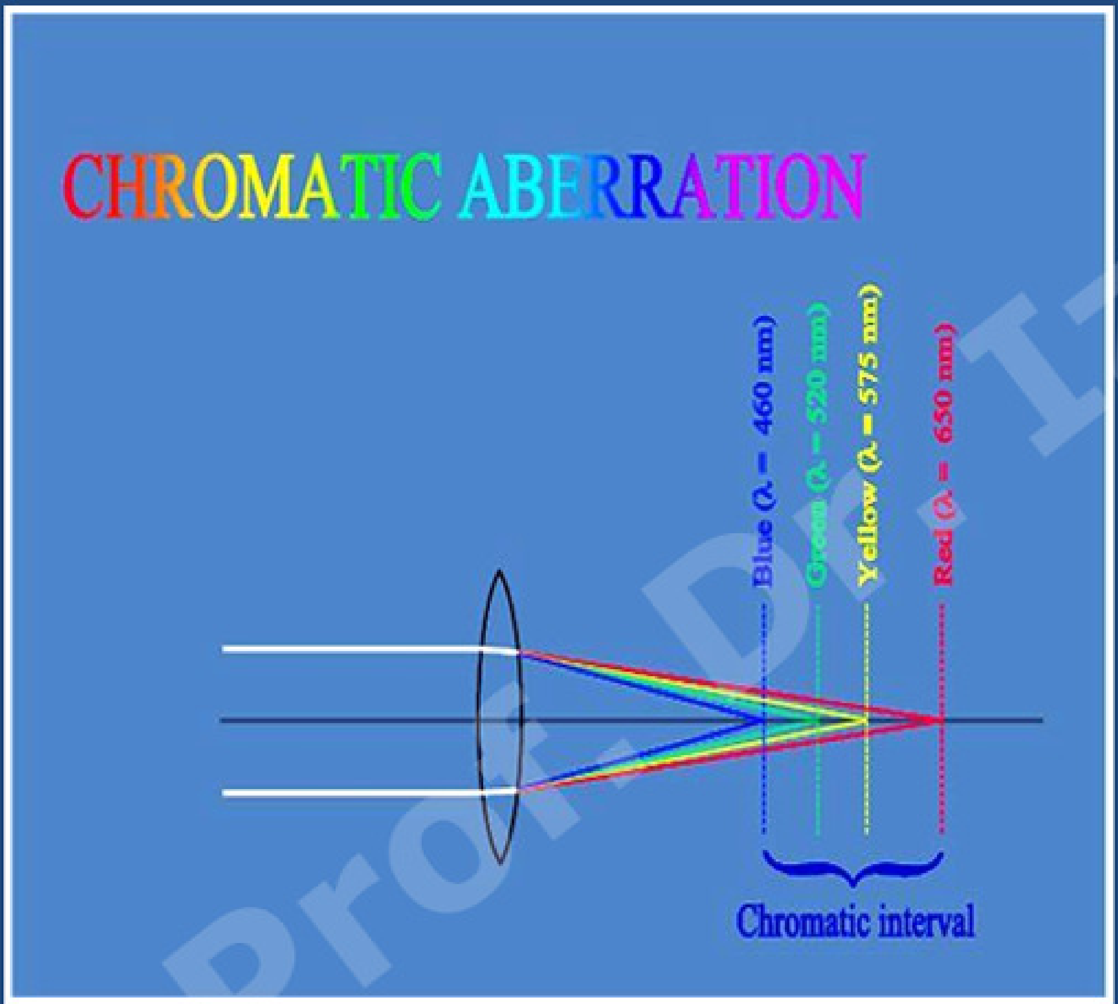
Diffraction

Limitations of Visual Function



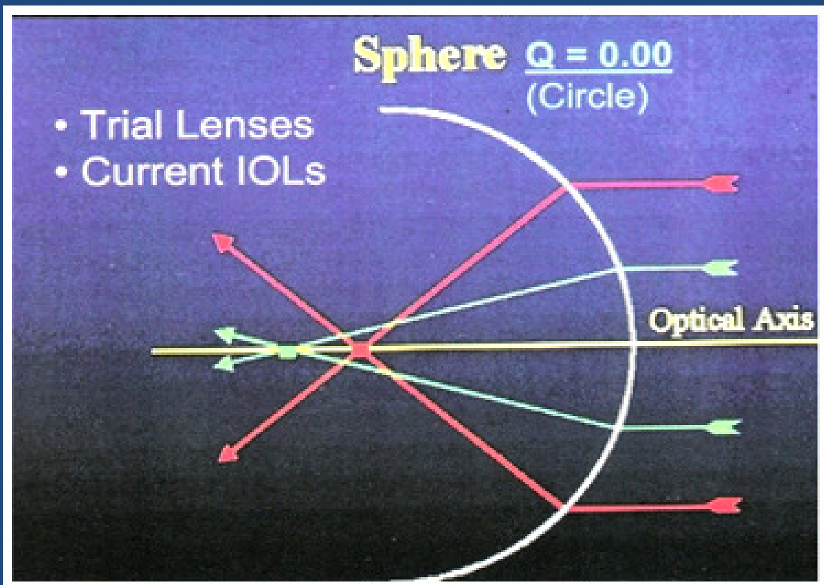


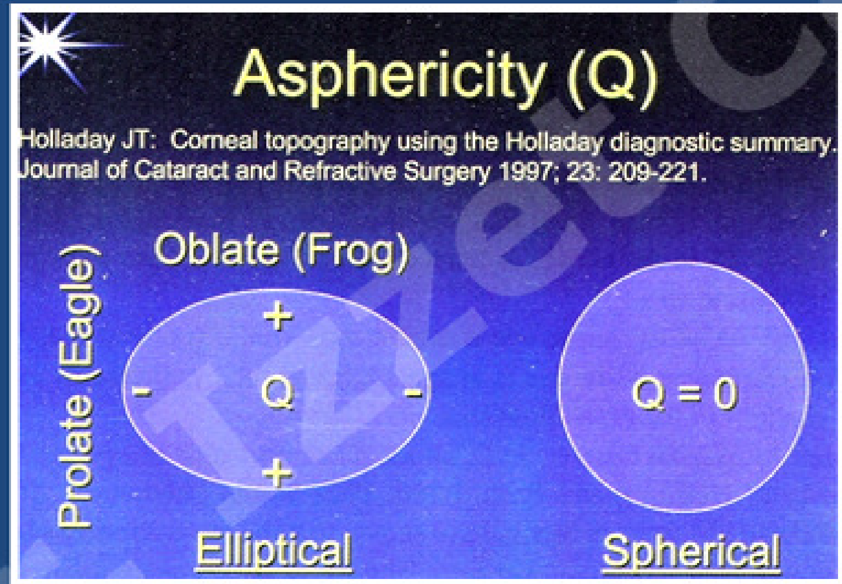
Limitations of Visual Function

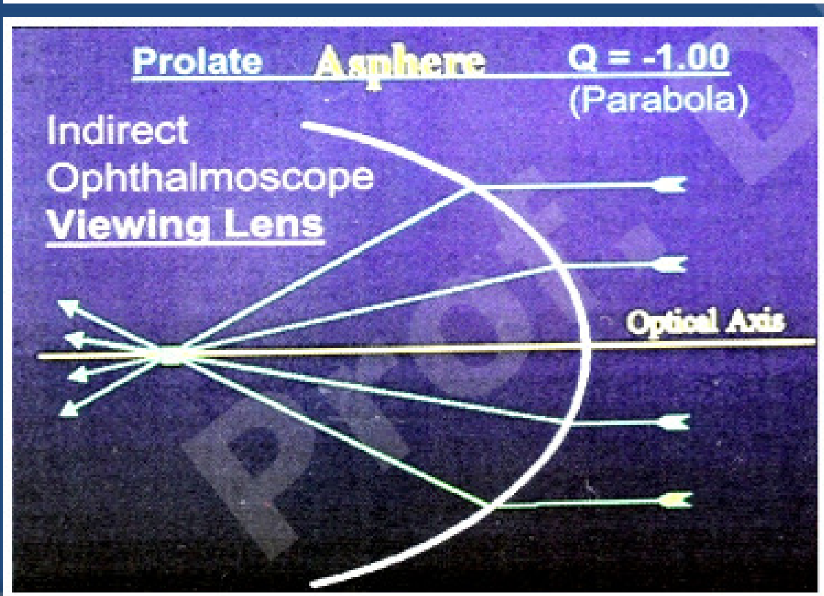


- The normal human eye has ~ 1.25 D. of clinical chromatic aberration, between red (+0.37) and blue (-0.87) .

Limitations of Visual Function

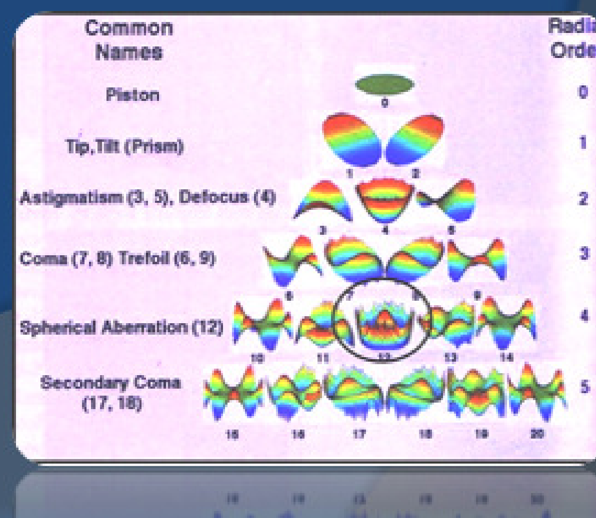




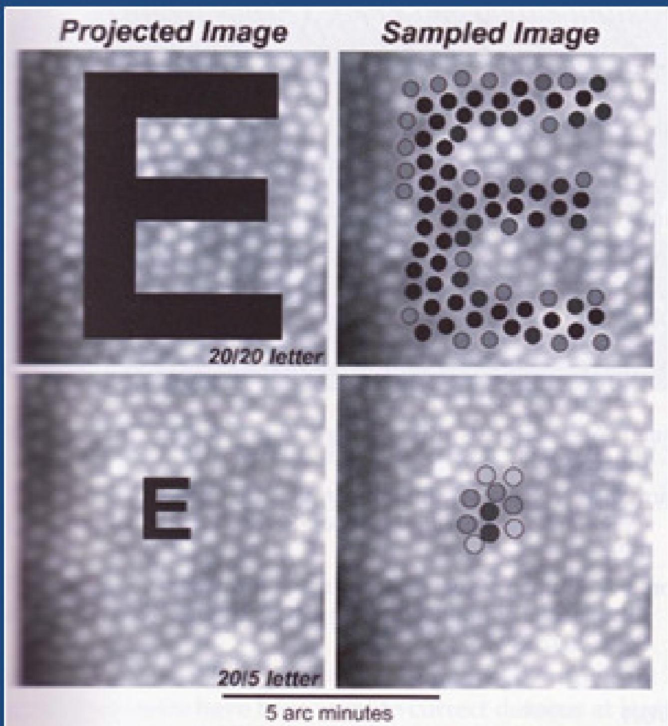


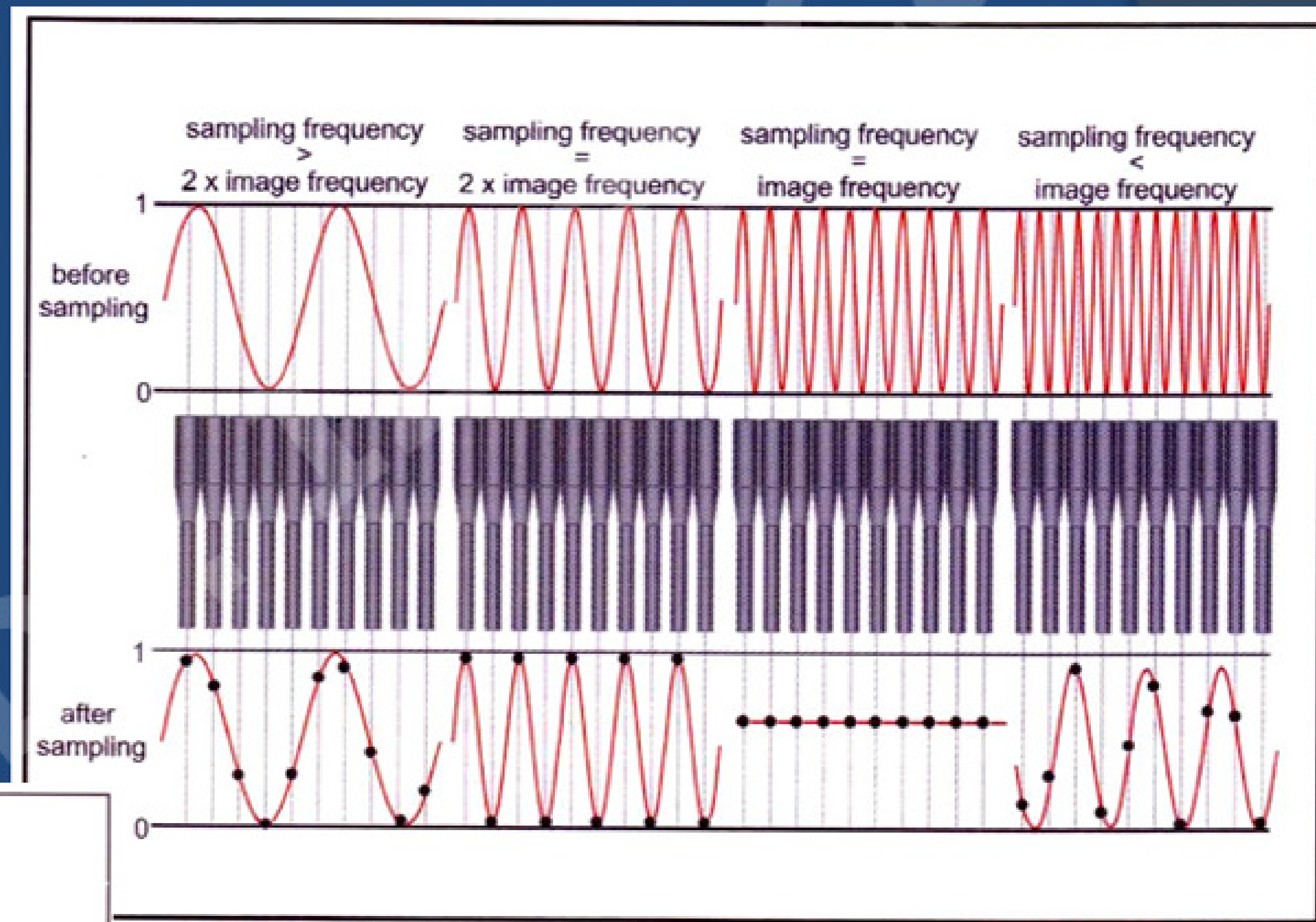
Ashericity Quotient

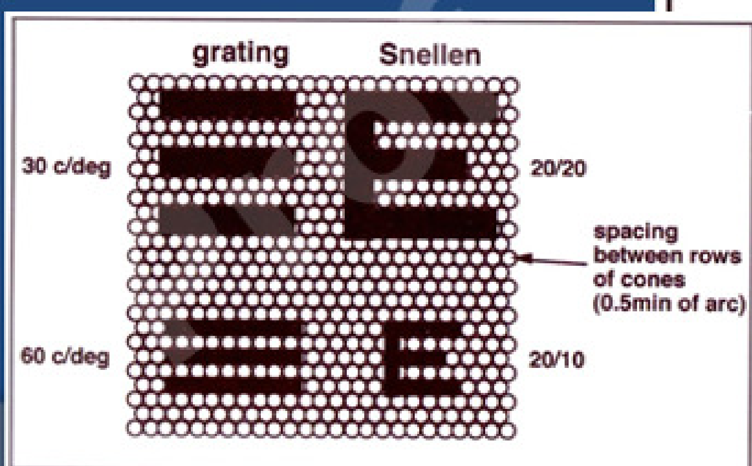
Q= -2.00 Severe Keratoconus,+5 D. PRK
Q= -1.00 Mild Keratoconus,+2 D. PRK
Q= -0.53 No Corneal SA
Q= -0.26 Normal
Q= 0 Spherical Cornea
Q= +1.00 -5 D. PRK
Q= +2.00 -12 D. PRK



Limitations of Visual Function



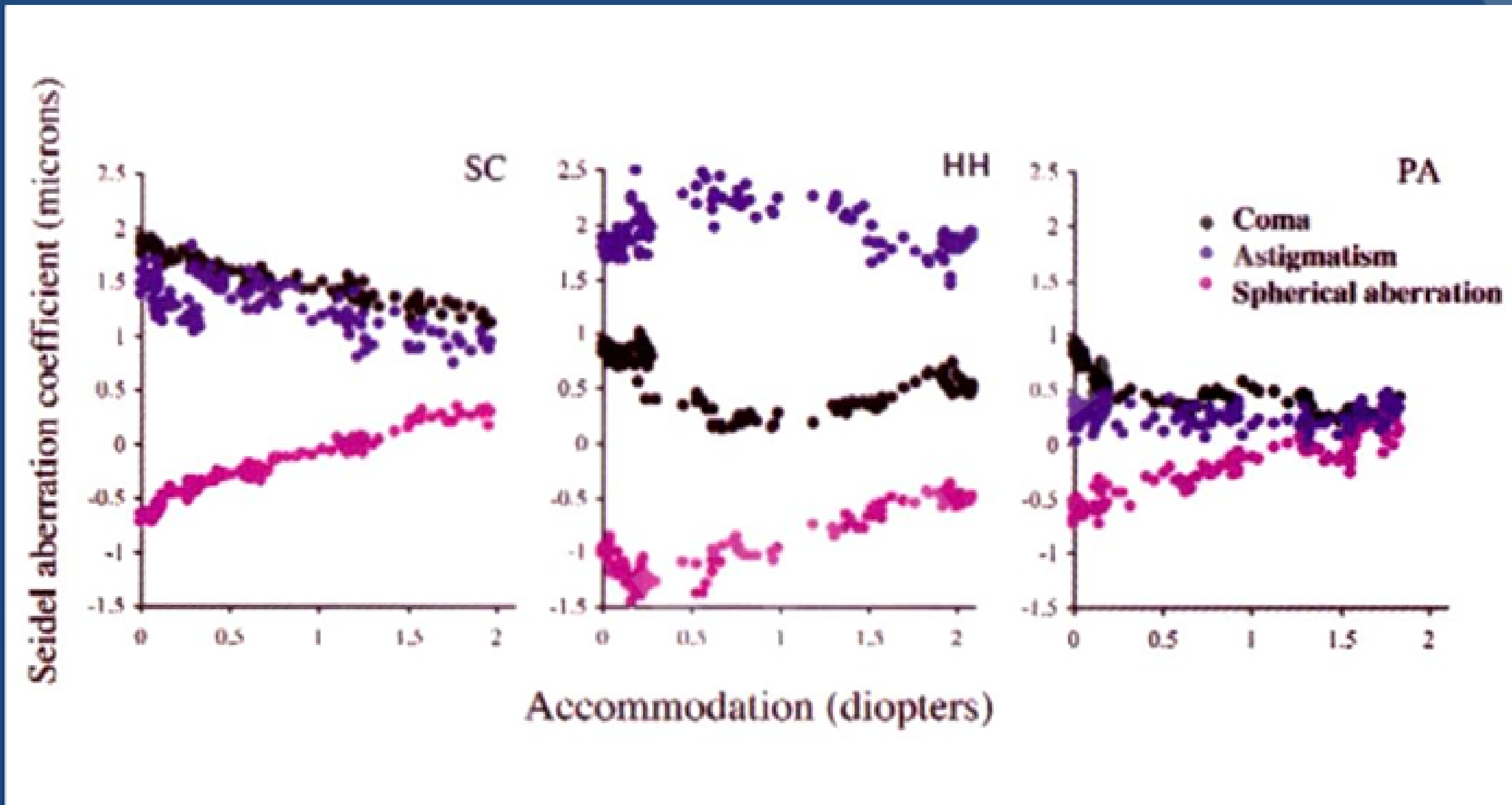




Nyquist sampling limit : Only the spatial frequencies lower than half of the cone frequency at the fovea can be adequately sampled.

- Photoreceptor intensity of Fovea→ ~ **120 c/deg.**
- Highest Spatial Frequency that can be adequately sampled → ~ **60 c/deg.**

Limitations of Visual Function



- Some of the higher order aberrations significantly change with accommodation. (Artal P, 1999)

Visual Optic/Compensation Mechanisms

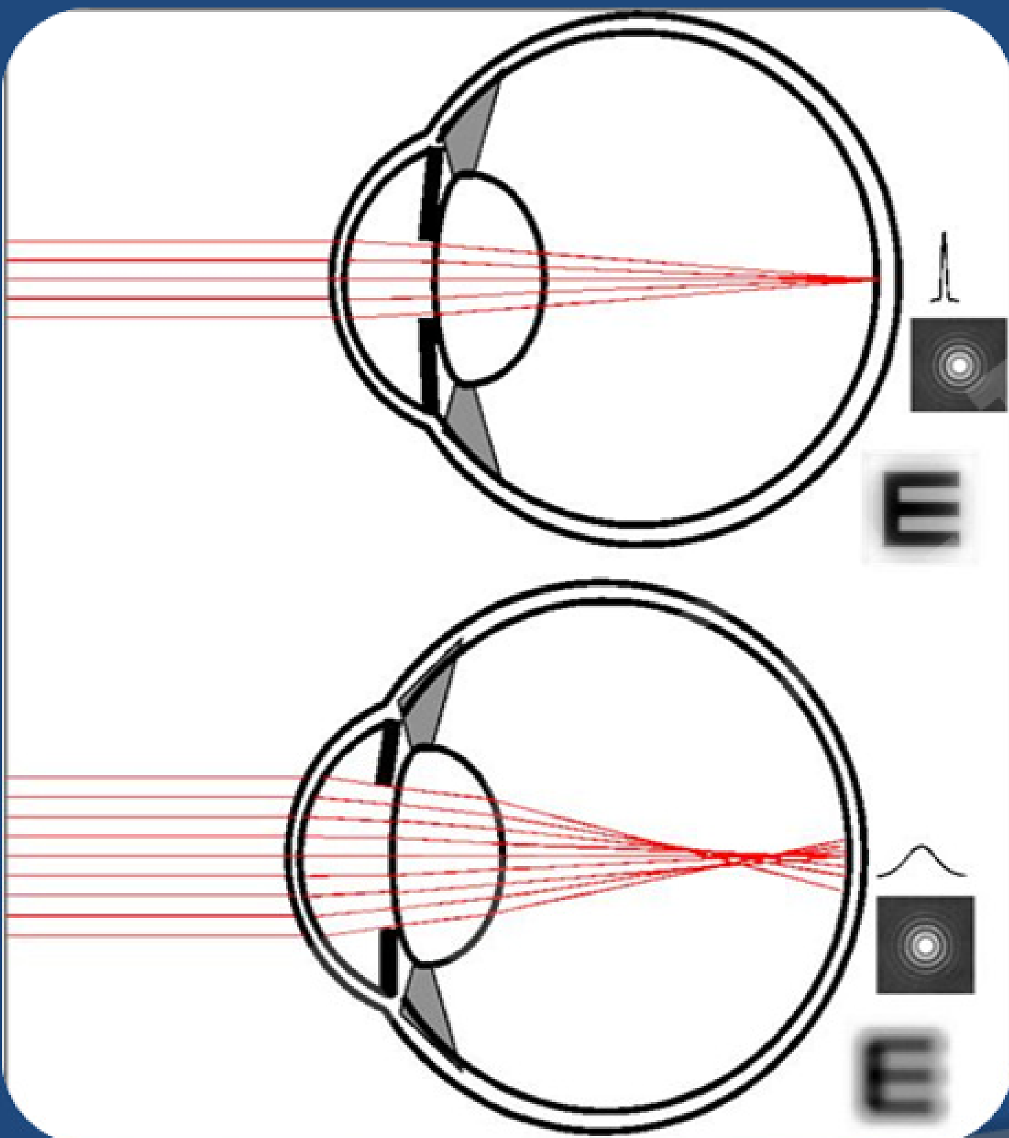
Charles Darwin
(1809 -1882)

Darwin's Comment on Eye

To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest degree.

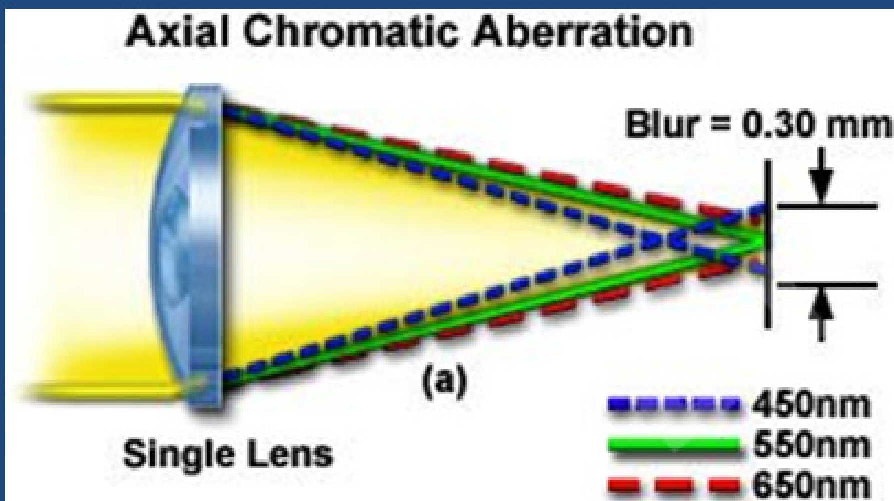
Charles Darwin, The Origin of Species, Chapter 6 "Organs of Extreme Perfection and Complication"

Visual Optic/Compensation Mechanisms



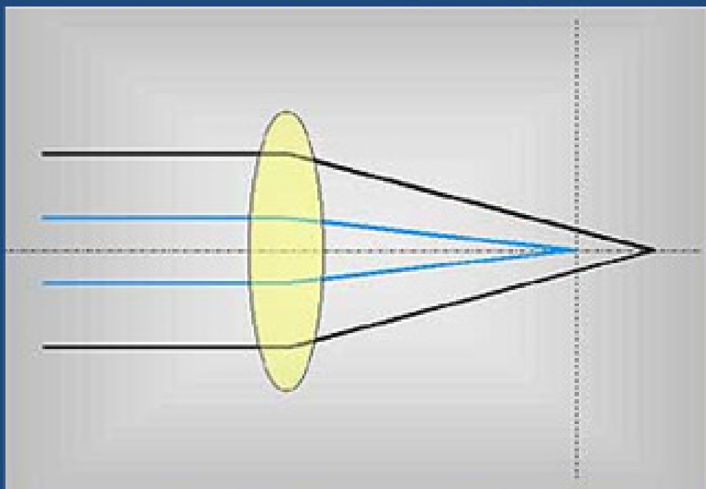
Although optical aberrations increase as the pupil gets larger, eye has a defense mechanism to decrease them. "Stiles-Crawford effect which weighs peripheral light rays as less important for vision than central rays, therefore the effect of these aberrations on the quality of vision reduces.

Visual Optic/Compensation Mechanisms

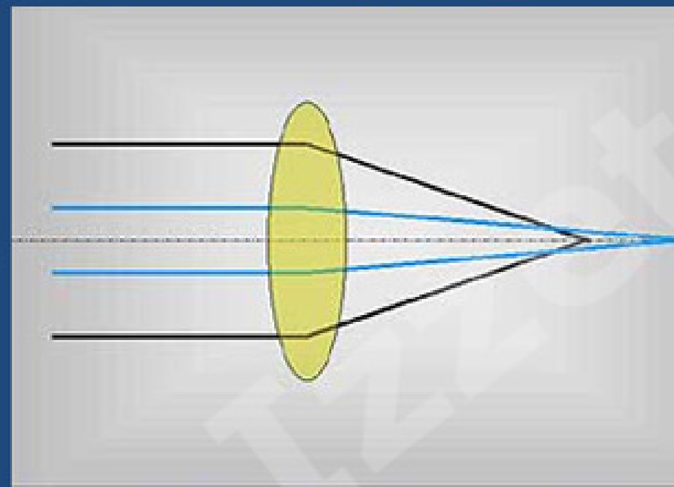


- Forming by prismatically fragmentation of white light, chroma is an important visual blurring factor.
- In spite of that we do not see chromatic rainbows around objects or light sources. Because some higher order aberrations in our visual system balance out them. (McLellan PS,et al. 2002)

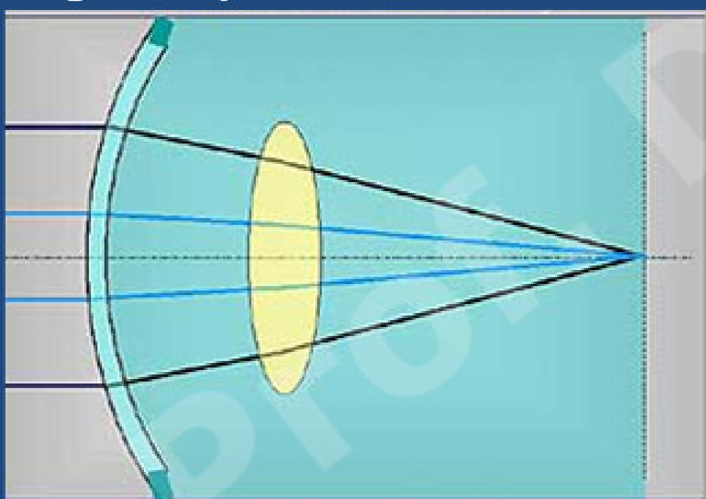
Visual Optic/Compensation Mechanisms



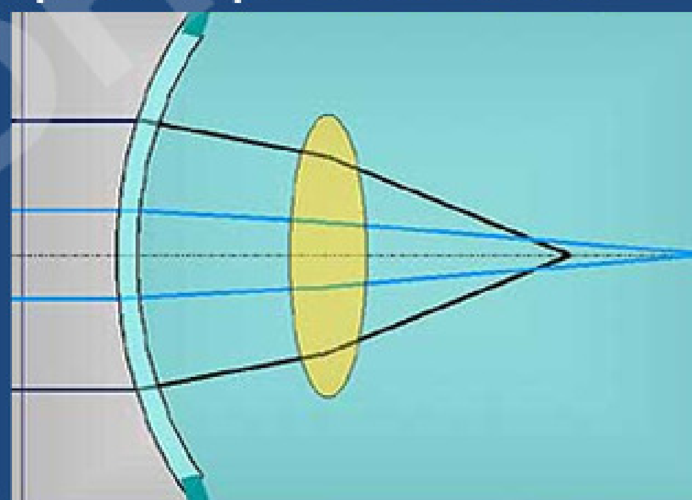
Young crystalline lens has negative spherical aberration



Old crystalline lens has positive spherical aberration

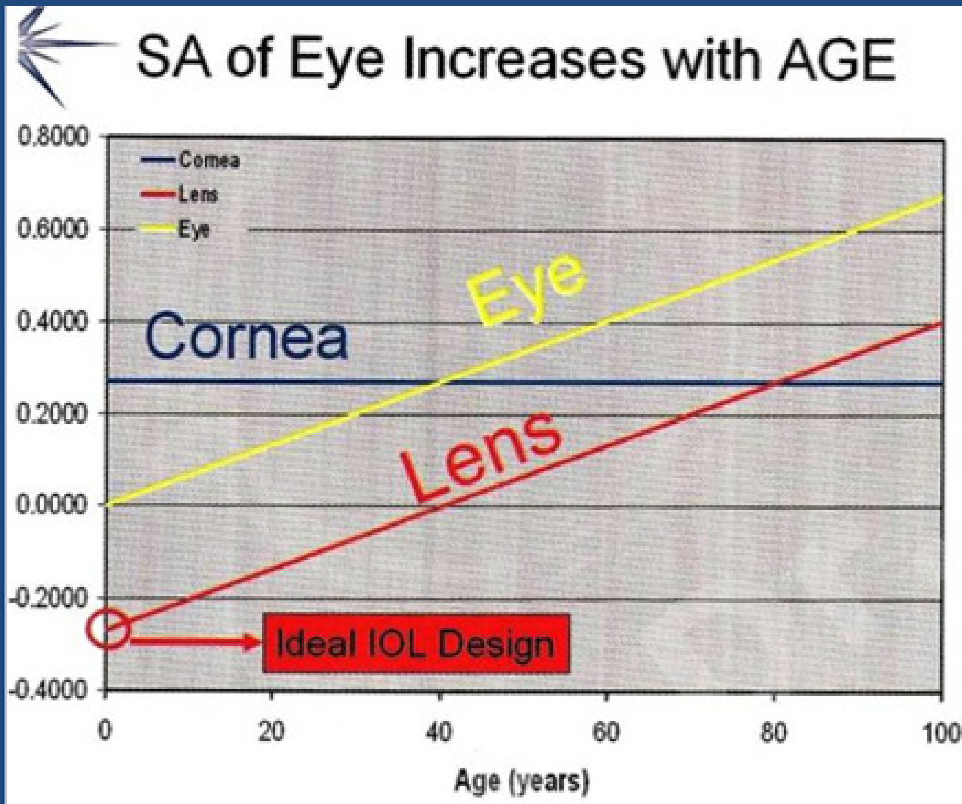


Young crystalline lens compensates for spherical aberration of cornea

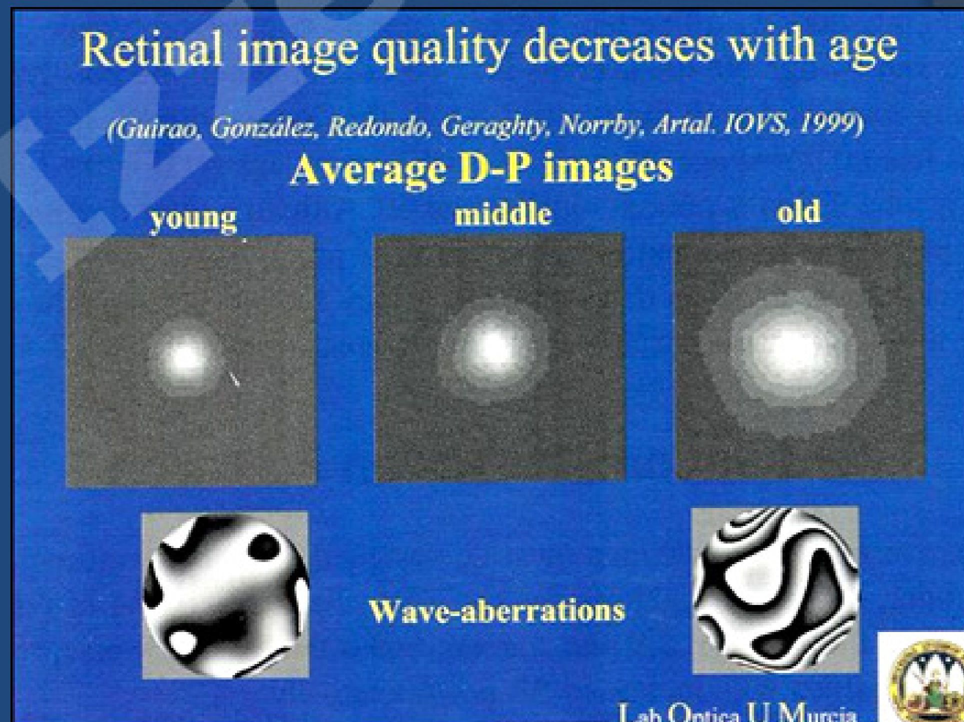


Old crystalline lens increases spherical aberration of the eye

Visual Optic/Compensation Mechanisms



	Cornea SA (Q=-0,26)	Lens SA	Total SA
20 y.	+0,27 µm	-0,27 µm	0
40 y.	+0,27 µm	0	+0,27 µm
60 y.	+0,27 µm	+0,13 µm	+0,40 µm



Visual Optic/Compensation Mechanisms

- The angle kappa, the 5,2° tilt of the eye, induces coma, a distortion that causes a point of light to appear as a comet-shaped image. Because coma exists in both eyes, the distortion is duplicated as a mirror image in each eye. Our brains have learned over time that a coma image with its tail in opposite directions in two eyes should be a point. The brain can eliminate the tail and still achieve depth perception, using Panum's area to achieve binocular fusion.

- That reminds us the importance of maintaining the binocular vision during various surgical or clinical approaches.

Visual Optic/Compensation Mechanisms


Compensation of corneal aberrations by the internal optics in the human eye

Pablo Artal

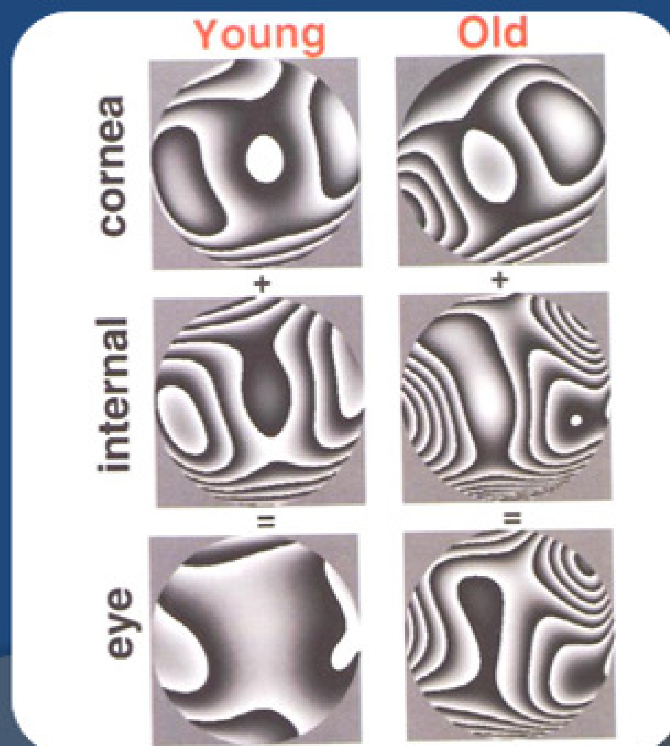
Antonio Guirao

Esther Berrio

David R. Williams

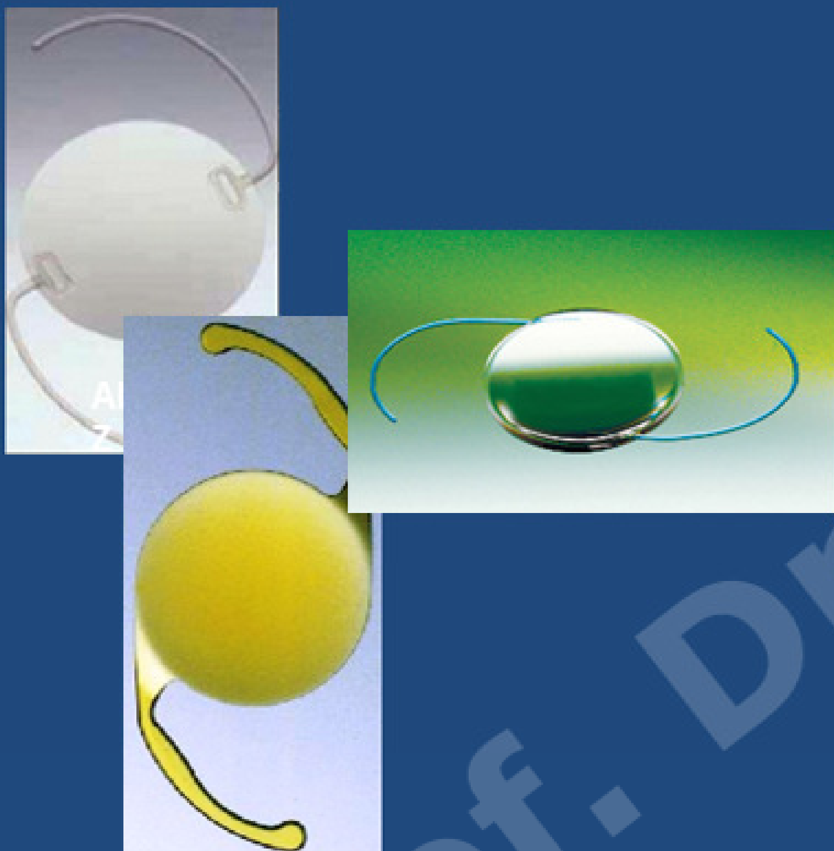
Introduction

- Artal P. et al. J Vis 2001; 1: 1-8.
- Both wave aberrations of cornea and internal optics and complete eye aberrations were measured one by one in the study.



- Corneal + Internal optics aberrations > Total eye aberrations
- Result: The aberrations of internal optics compensate in part of the corneal aberrations.

Correction of Spherical Aberrations



Aspherical IOLs	
AMO-Tecnis	- 0.27 µm
Alcon -Acrysof IQ	- 0.20 µm
VSY –AcrivaUD	- 0.165 µm
PhysIOL-FineVision Micro F	- 0.11 µm
Alcon -Restor	- 0.10 µm
B&L –Akreos and Sofport	0 µm
AnadoluTıp-Focus Force	0 µm

Correction of Spherical Aberrations

- Belluci et al. *J Refract Surg* 2004; 20: 297-306

Optical Zone	4 mm	6 mm
	Spherical Aberration	
AMO Tecnis Z 9000	0	0,6 µm
AMO 911 Edge	0,2 µm	0,8 µm
AcrySof SA60AT	0,4 µm	0,6 µm
AcrySof MA60BM	0,5 µm	0,8 µm
Sensar AR40	0,3 µm	0,6 µm

Correction of Spherical Aberrations

- Padmanabhan et al. *J Refract Surg* 2006; 22: 172-177

Optical Zone;	6 mm
	Spherical Aberration
AMO Tecnis Z 9000	0,07 ± 0,12 µm
AcrySof MA60BM	0,29 ± 0,21 µm
Sensar AR40	0,20 ± 0,09 µm

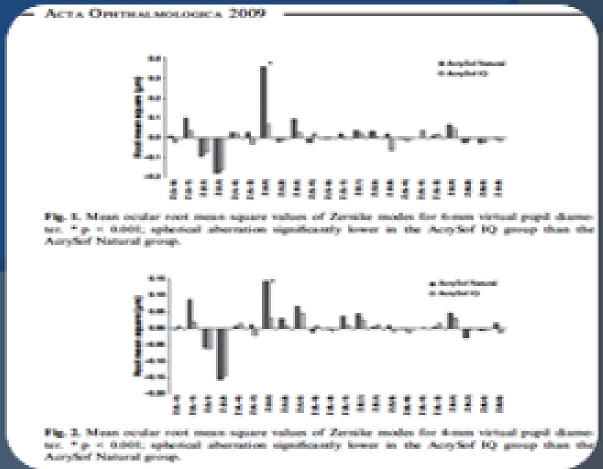
Correction of Spherical Aberrations

- Takmaz T, Genç İ, Yıldız Y, Can İ. Ocular wavefront analysis and contrast sensitivity in eyes implanted with AcrySof IQ or AcrySof Natural intraocular lenses. *Acta Ophthalmol* 2009; 87: 759-763.

- 60 eyes of the 60 patients; AcrySof Naturale (n:30), AcrySof IQ (n:30)

	AcrySof Naturale	AcrySof IQ
Corneal Spherical Aberration	0,273±0,074 μm	0,294±0,086 μm
Total Spherical Aberration	0,362±0,141 μm	0,069±0,043 μm*

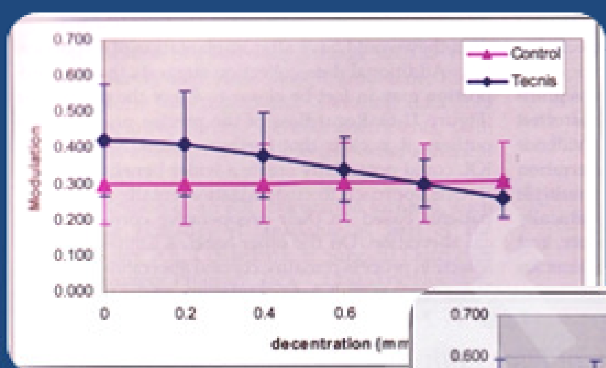
- Significant contrast sensitivity difference in favor of AcrySof IQ
  - **Photopic conditions; 6 cpd**
  - **Mesopic; 6 ve 18 cpd**
  - **Mezopic + glare; 6,12,18 cpd**

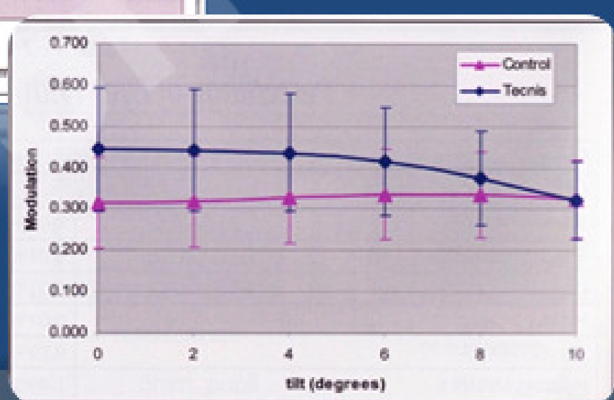


Correction of Spherical Aberrations

- Negative effects of decentralization and tilt have known even with conventional IOLs.

Akkın C et al. Doc Ophthalmol , 1994; 87: 199-209.
Mutlu FM et al. Ophthalmologica, 1998; 212; 359-63.
Hayashi et al. Ophthalmology, 1997; 104; 793-8.





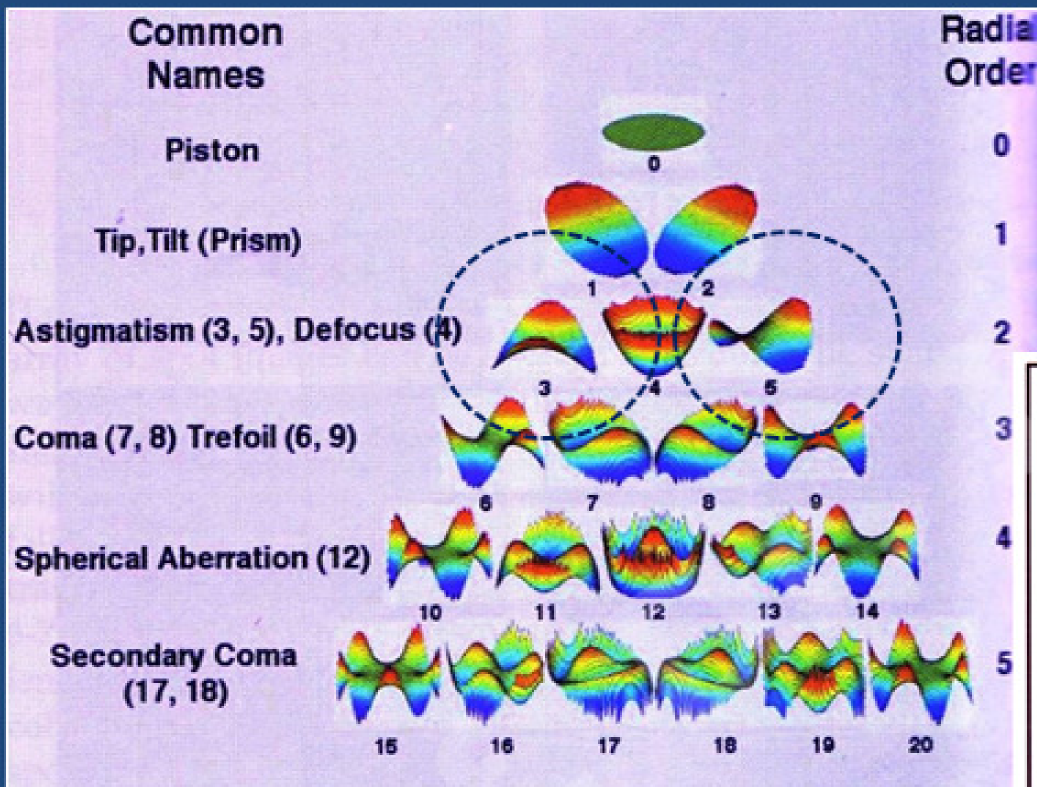
- Aspheric IOLs should be centralized in 0.4 mm and shouldn't show tilt over 7°. If not they may produce much more higher order aberrations.

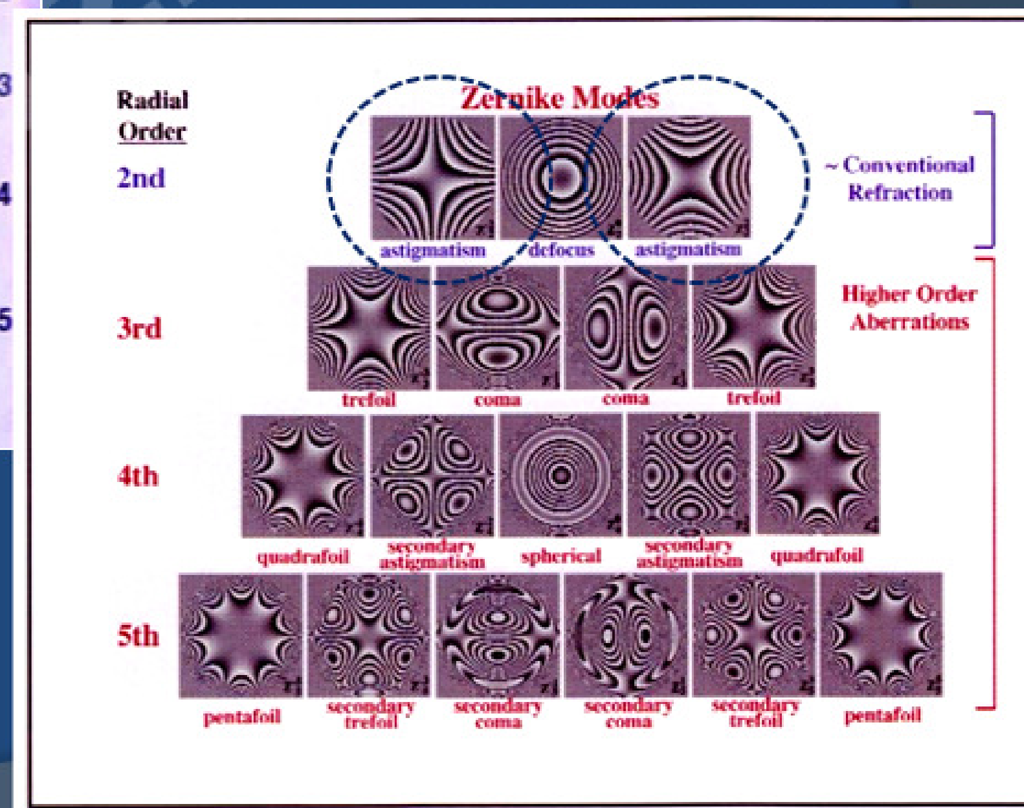
Holladay JT et al. J Refract Surg 2002; 18: 683-9.
Wang et al. Arch Ophthalmol, 2005; 123; 1226-30.

- One of the drawbacks of SA decreasing is focal length loss. This may affect near vision.

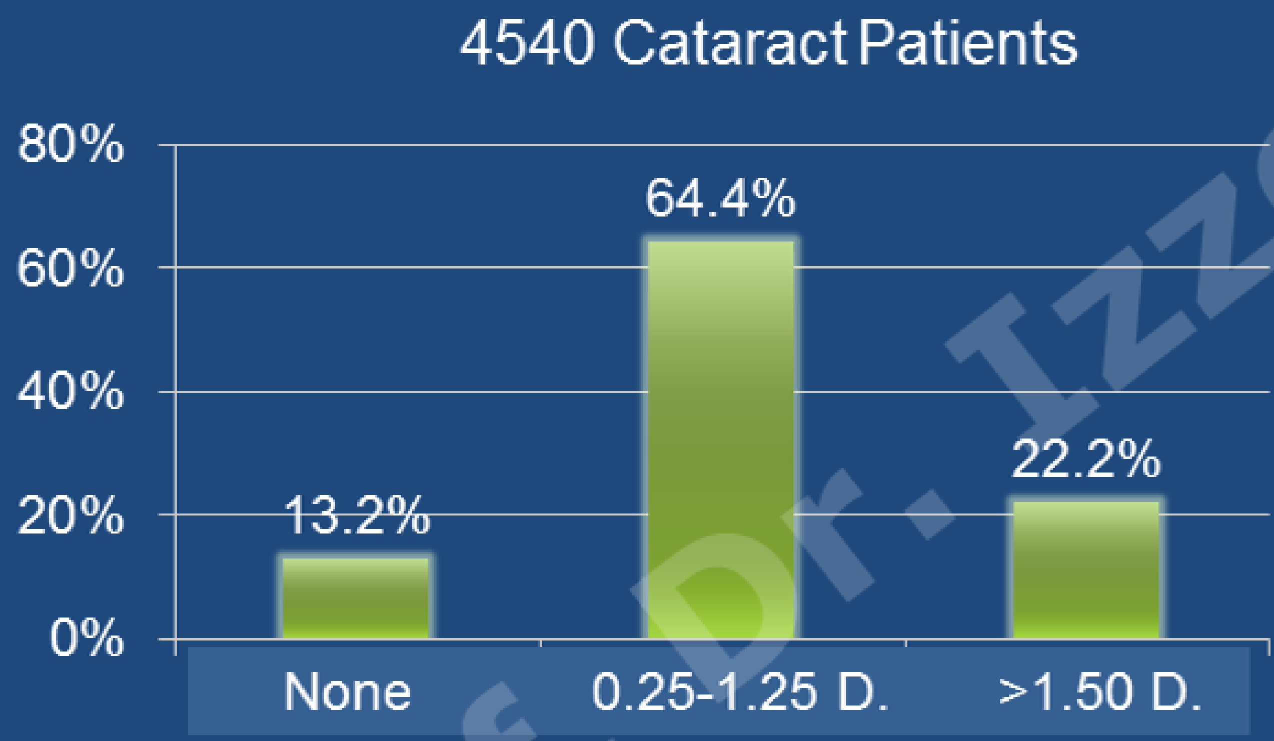
Markos et al. J Cataract Refract Surg. 2005; 21: 223-35
Nio et al. Ophthalmic Physiol 2002; 22: 103-12.

Correction of Astigmatism





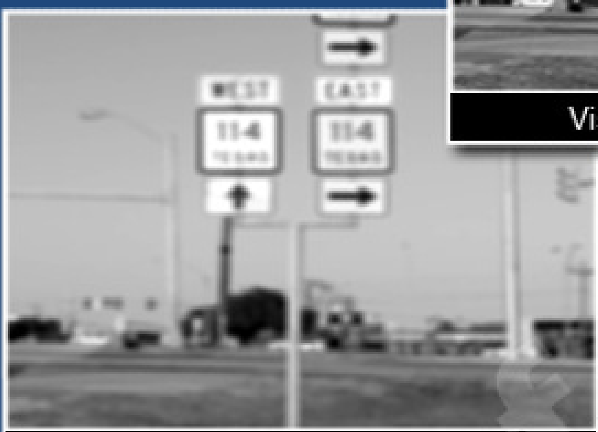
Correction of Astigmatism



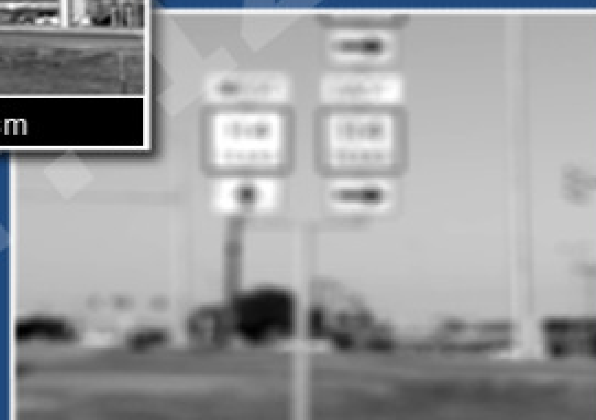
Ferrer-Blasco T et al. Prevalence of corneal astigmatism before cataract surgery. J Cataract Refract Surg 2009; 35:70–75.

Correction of Astigmatism

Vision without astigmatism

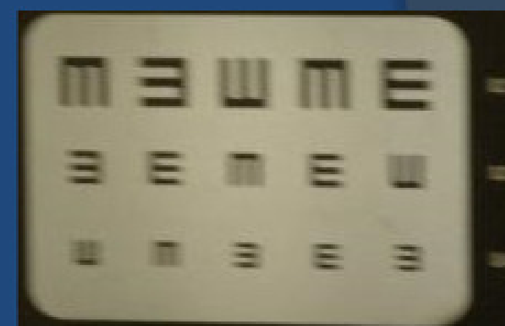


Vision with astigmatism 1.5D cyl @ 90



Vision with astigmatism 3.0D cyl @ 90

No astigmatism



1.0 D astigmatism

2.0 D astigmatism

Correction of Astigmatism

- Spectacles
- Contact Lenses

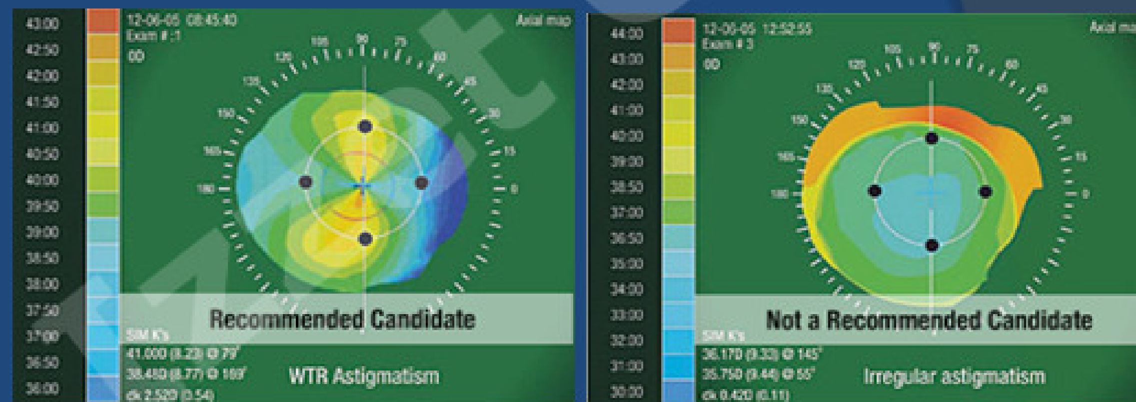
- Astigmatic Keratotomy
  - Corneal Relaxing Incisions
  - Limbal Relaxing Incisions (LRI)
- Toric IOLs
  - Phacic / Pseudophacic
  - Anterior / Posterior Chamber lenses
- Excimer Laser
  - PRK
  - Lasik
  - Lasek
- Bioptics

- What you might do to correct astigmatism during cataract surgery.
  - Surgery with steep axis (on-K) entrance
  - Corneal Incisions
    - Relaxing limbal incisions
    - Astigmatic keratotomy
  - Torik IOL ☺

Correction of Astigmatism

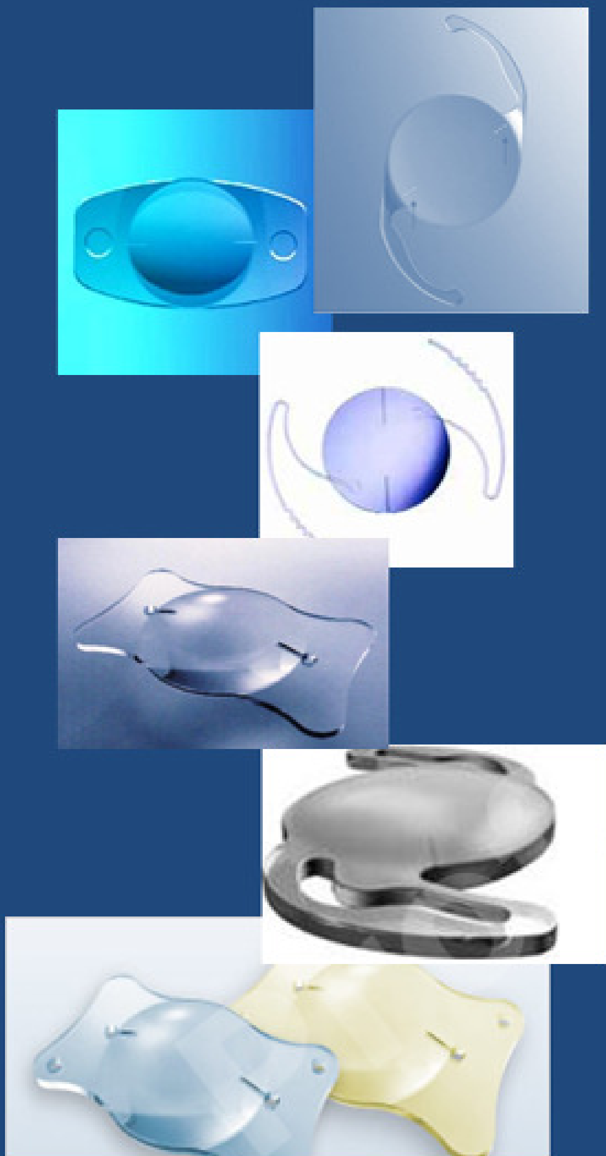
Indications for Toric IOL Surgery

- Patients with 0.75 D. and higher corneal astigmatism
- Regular astigmatism patients with flat and steep meridians are 90˚ with each other in manual keratometry.
- Patients with bowtie or wedge type regular astigmatism in corneal topography.
- Patients had uneventful surgery.
  - Flawless centralized CCC
  - Intact posterior capsule
  - In the bag IOL placement



- **Toric IOL firstly designed by Shimizu in 1994 and has been used since then increasingly.**
  - Shimizu K, Misawa A, Suzuki Y. Toric intraocular lenses: correcting astigmatism while controlling axis shift. J Cataract Refract Surg 1994; 20:523–6.

Correction of Astigmatism



Toric IOLs	
STAAR Surgical (Monrovia, CA)	AA4203 TF AA4203 TL
Dr. Schmidt, Humanoptics (Erl, Ger)	Microsil MS6116TU / T-Y Torica s/s
Rayner Surgical (Hove, UK)	T-Flex 573T T-Flex 623T
Alcon (Fort Worth, Tx,USA)	Acrysof Toric SN60T3-9 Acrysof IQ Toric SN6AT2-9
Carl Zeiss Meditec (Ber, Ger)	AT Torbi 709 M
VSY Biotechnologies (Ist, Tur)	Acriva UD Toric T UDM611

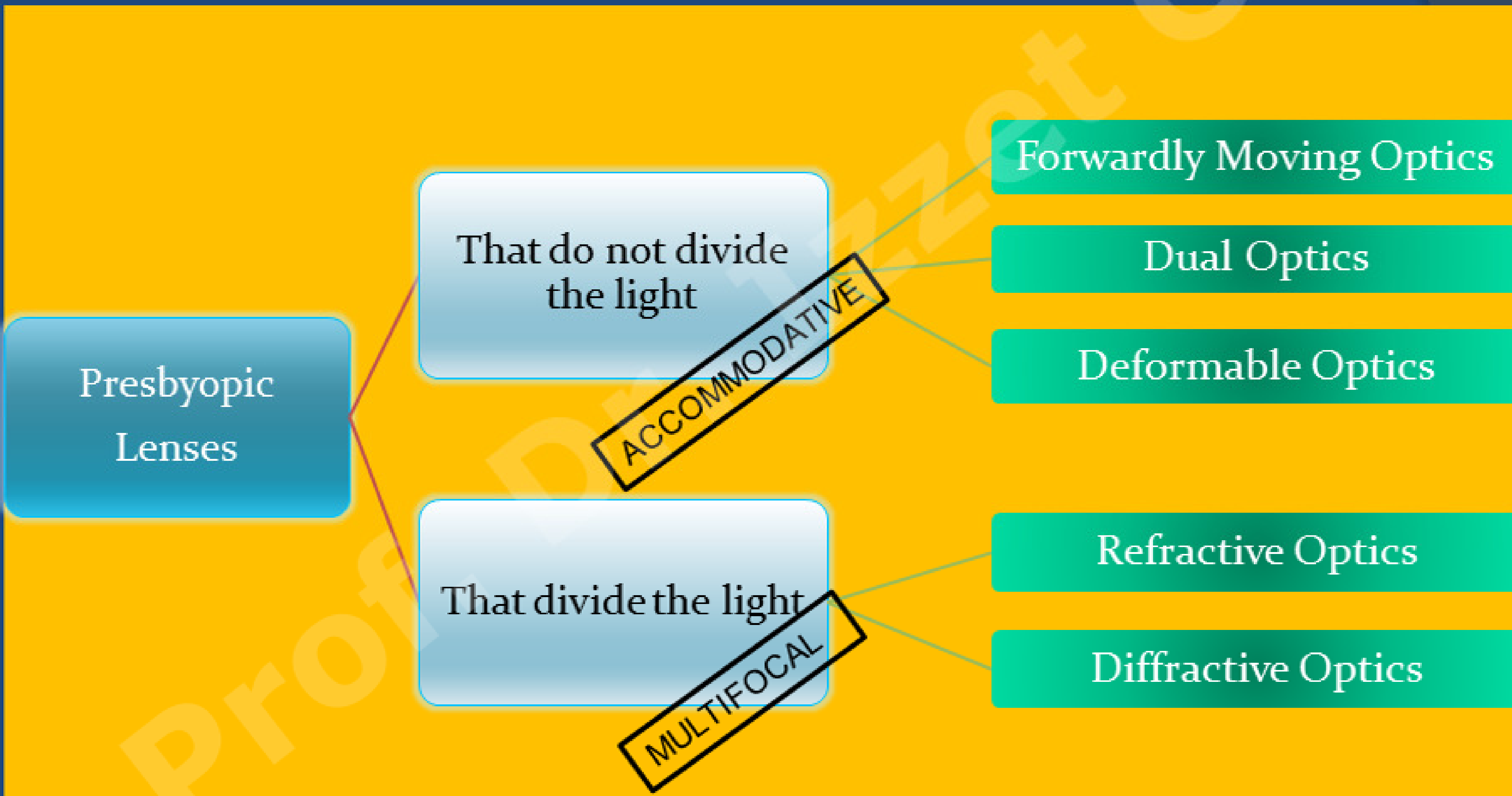
Correction of Astigmatism

Toric IOL	Author Year	Eye (n:)	Follow-up (max.)	Rotational Stability	Surgical Reop. (%)	Residual Astigmatism (D.)	Uncorrected VA	Corrected VA
Staar Toric	Schimuzu (1994)	47	3 mo.	44.6% “ 30° 55.3% > 30°	-	-	-	100% > 20/40 77% > 20/25
	Ruhswurm (1999)	37	20.3 mo.	18.9% “ 25° 100% “ 30°	18.9	0.84 ± 0.63	18.9 % >20/20 67.5% >20/40	54% >20/20 91.8% >20/40
	Sun (2000)	130	3 mo.	75% “ 20° 18 % 20-40°	11.3	1.03 ± 0.79	84% >20/40 69% >20/30	-
	Till (2002)	100	23 wk.	62% “ 5° 27% “ 5-15°	5	-	66% >20/40 45% >20/30	96 % >20/40 85% >20/30
	Chang (2003)	50 (TL)	1 mo.	72% “ 5° 90% “ 10° 98% “ 15° 2% = 20°	0	0.92 ± 0.87	7% >20/20 -	32% >20/20 92% >20/40
Alcon Acrysof SN60TT	Mendicute (2008)	30	3mo.	96% “ 10° 3.3% “ 12°	0	-0.72 ± 0.34	93.3% >20/40 66.6% >20/25	100% >20/25
	Zuberbuhler (2008)	44	3 mo.	95 % “ 5° 68% “ 2°	0	-	-	0.01 ± 0.11 logMAR
Dr Schmidt Microsil / Humanoptics / Torica	Dick (2006)	68	3 mo.	85% “ 5° 15% >5°	8	1.12 ± 0.9	68 % >20/40 12% >20/20	85% >20/40 31% >20/20
	De Silva (2006)	21	6 mo.	100% “ 15° 90% “10°	4.76	1.23 ± 0.9	0.23 ± 0.24 logMAR	0.23 ± 0.22 logMAR
Acri.comfort 646 TLC	Alio (2010)	21	3 mo.	95% 5°	0	0.45 ± 0.63	0.65 ± 0.22 Decimal	0.85 ± 0.15 Decimal

Correction of Astigmatism

Visser N. et al. J Cataract Refract Surg 2011; 37: 1403-1410.		Alio JL et al. J Cataract Refract Surg 2010; 36:44–52	Entabi M et al. J Cataract Refract Surg 2011; 37:235-240.
SN60T 6-9, 67 eyes/45 patients Follow: ~ 6.3 mo., **~ 3.43 D. ±0.95**		AcriComfort 646 TLC , 21 eyes, ~ Follow: 3 mo, **~3.73 D ±1.79**	T-Flex 623T, 23 eyes/ 25 patients, Follow: 4 mo., **~3.35 D ± 1.20**
UDVA	0.61 ± 0.26 20/ 40 ↑ 83% 20/ 30 ↑ 50%	0.65 ± 0.22 20/ 40 ↑ 76%	0.52 20/ 40 ↑ 70%
CDVA	0.81 ± 0.21	0.85± 0.15	0.65
Residual refractive cylinder	<0.75 D. 62% <1.00 D. 81%	-0.45 ± 0.63	-0.95 ±0.66
~ IOL rotation	3.2 ± 2.8 degree	1.75 ± 2.93 degree	3.4 degree

Correction of Presbyopia



Correction of Presbyopia

Advantages

- ✓ Higher vision quality (No Contrast Sensitivity Loss)
- ✓ No night symptoms
- ✓ Continuous accommodation range

Accommodative IOL Group

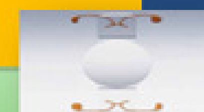
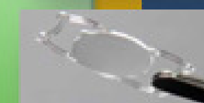
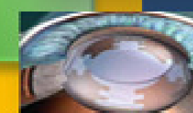
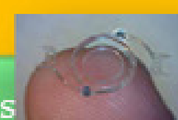
Lenses with Deformable Optics

Dual Optics

NuLens

FluidVision

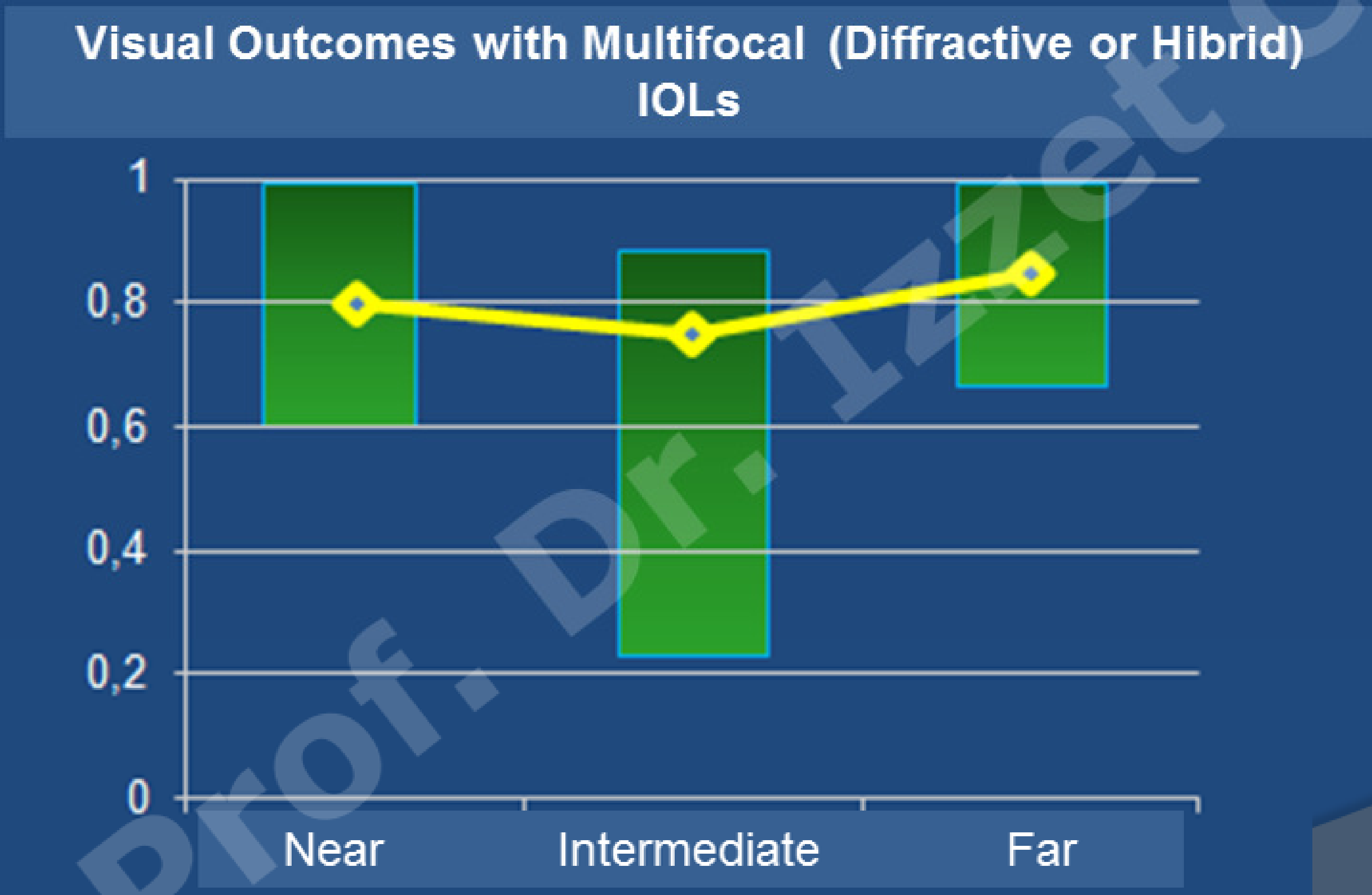
Synchrony

Correction of Presbyopia

Diffractive Multifocal IOLs	
Alcon (Fort Worth, Tx,USA)	Restor +4 Restor IQ Restor IQ +3
Abbott Medical Optics Inc. (AMO) (Santa Ana, CA, USA)	Tecnis Multifocal 1Piece
Anadolu Tıp (Sivas, Tur)	FocusForce ReVision
Carl Zeiss Meditec (Ber, Ger)	AT Lisa
VSY Biotechnologies (Ist, Tur)	Acriva Reviol
PhysIOL (Liege, Bel)	FineVision Micro F

Correction of Presbyopia



Correction of Presbyopia

Table 4. Postoperative visual acuity, refraction, and spectacle independence at 3 months.

Parameter	Group 1	Group 2	*P* Value
Mean monocular UDVA ± SD			
Decimal	0.80 ± 0.14	0.86 ± 0.17	.158[†]
LogMAR	0.10 ± 0.07	0.07 ± 0.08	.113[†]
Mean binocular UDVA ± SD			
Decimal	0.98 ± 0.06	0.96 ± 0.09	.647[†]
LogMAR	0.01 ± 0.02	0.007 ± 0.01	.647[†]
Mean monocular CDVA ± SD			
Decimal	0.98 ± 0.05	0.96 ± 0.09	.219[†]
LogMAR	0.01 ± 0.02	0.02 ± 0.05	.219[†]
Mean monocular UNVA ± SD			
Jaeger	1.46 ± 0.73	1.23 ± 0.50	.155[†]
LogMAR	0.08 ± 0.20	0.02 ± 0.05	.104[†]
Mean binocular UNVA ± SD			
Jaeger	1.06 ± 0.25	1.00 ± 0.00	.155[†]
LogMAR	0.007 ± 0.03	0.00 ± 0.00	.155[†]
Mean monocular DCNVA ± SD			
Jaeger	1.20 ± 0.55	1.13 ± 0.34	.577[†]
LogMAR	0.06 ± 0.20	0.01 ± 0.03	.219[†]
Mean monocular UIVA ± SD			
Jaeger	3.06 ± 0.90	2.23 ± 0.73	0.000[†,§]
LogMAR	0.16 ± 0.055	0.11 ± 0.064	0.002[†,§]
Mean binocular UIVA ± SD			
Jaeger	2.36 ± 1.32	1.73 ± 0.78	.028[†,§]
LogMAR	0.11 ± 0.10	0.07 ± 0.07	.041[†,§]
Mean monocular DCIVA ± SD			
Jaeger	2.76 ± 0.81	2.16 ± 0.74	.004[†,§]
LogMAR	0.14 ± 0.051	0.11 ± 0.066	.013[†,§]
Mean SE refraction (D)	−0.30 ± 0.30	−0.26 ± 0.28	.584[†]
Mean corneal toricity* (D)	0.53 ± 0.26	0.66 ± 0.22	.057[†]
Subjective complaints, n (%)			
Halo	7 (23.3)	8 (26.6)	.766[‡]
Glare	6 (20.0)	6 (20.0)	1.000[‡]
Spectacle Independence (%)			
Far	100.0	100.0	—
Near	100.0	100.0	—
Intermediate	96.6	100.0	.313[‡]

Means ± SD

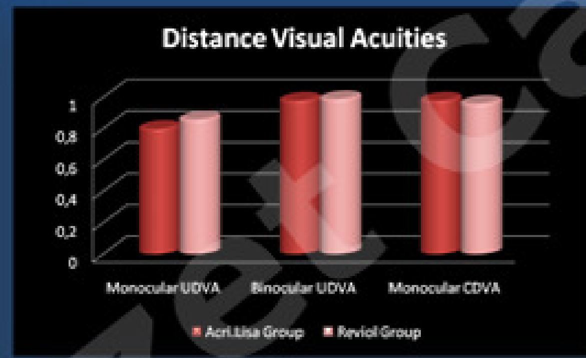
CCT = central corneal thickness; CDVA = corrected distance visual acuity; DCIVA = distance-corrected intermediate visual acuity; DCNVA = distance-corrected near visual acuity; SE = spherical equivalent; UDVA = uncorrected distance visual acuity; UIVA = uncorrected intermediate visual acuity; UNVA = uncorrected near visual acuity

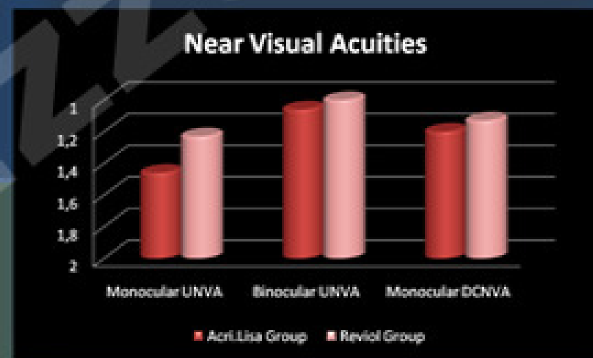
*Simulated keratometry

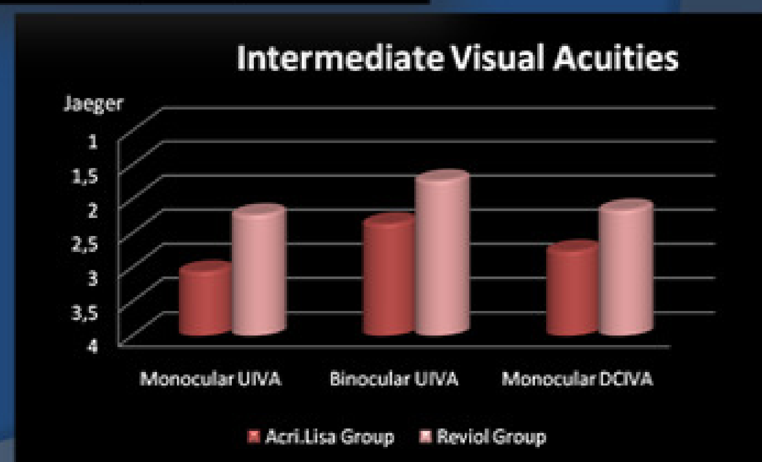
†Student *t* test

‡Chi-square test

§Statistically significant

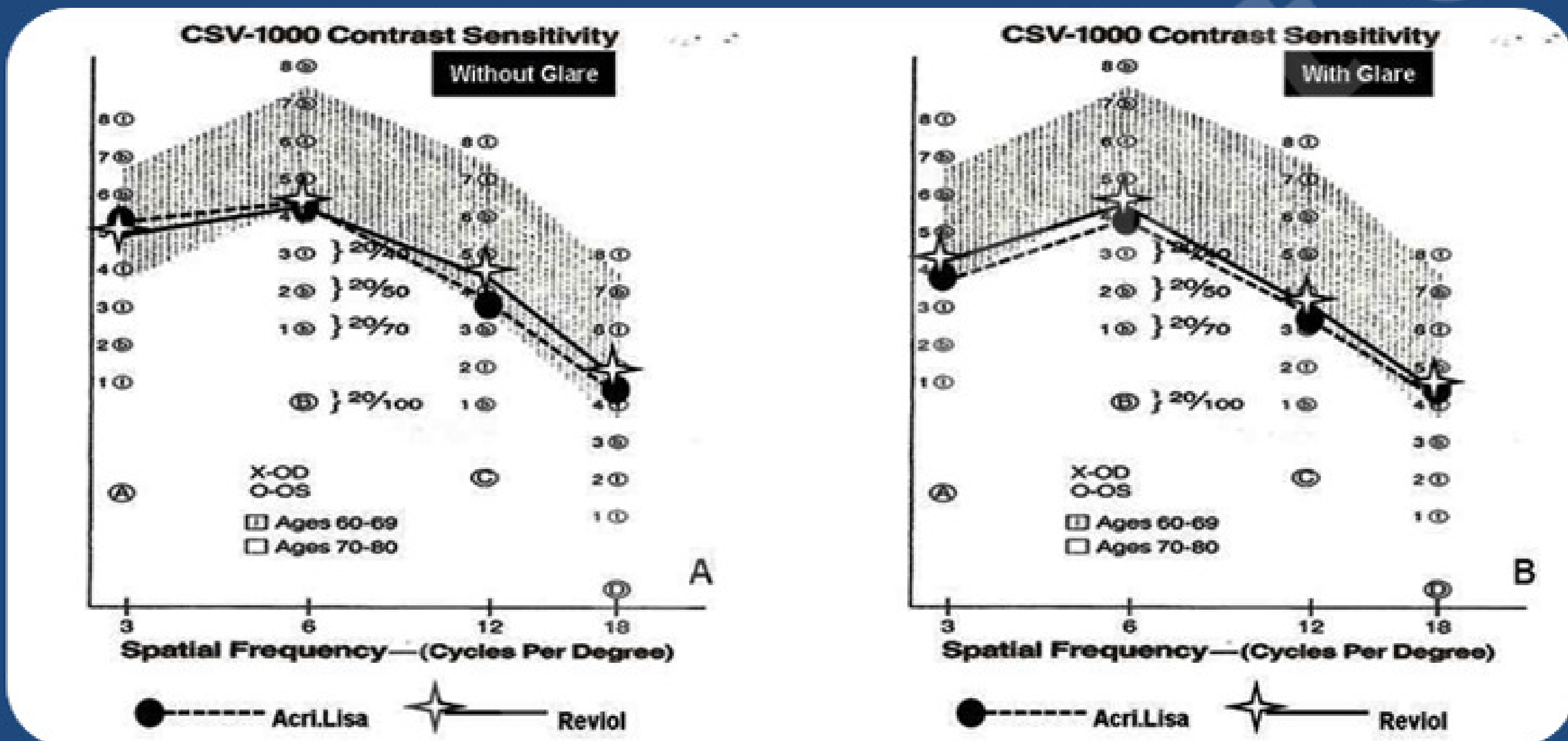






Can İ, Bostancı Ceran B., Soyugelen G, Takmaz T. Comparison of clinical outcomes with 2 small incision diffractive multifocal intraocular lenses. *J Cataract Refract Surg*. 2012 Jan; 38: 60-67.

Correction of Presbyopia



Can İ, Bostancı Ceran B, Soyugelen G, Takmaz T. Comparison of clinical outcomes with 2 small incision diffractive multifocal intraocular lenses. *J Cataract Refract Surg.* 2012 Jan; 38: 60-67.

Conclusion

- Today
  - Defocus (Refractive Errors)
  - Spherical Aberration
  - Astigmatism
  - Presbyopia
- Future
  - Customized IOL

Thanks