

Aberrations caused by decentration in customized laser refractive surgery

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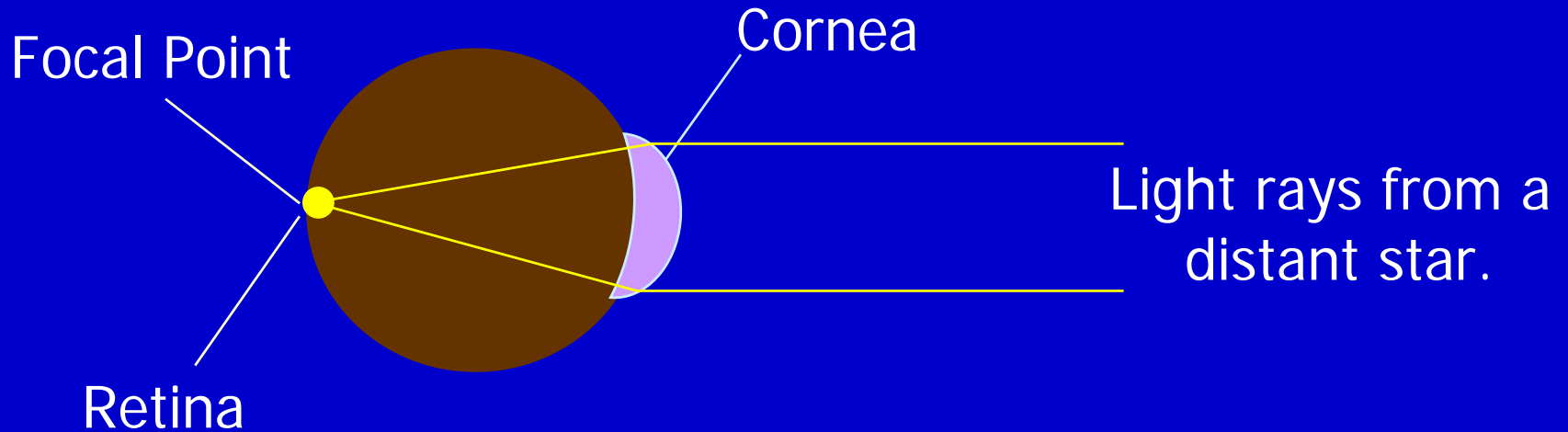
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Outline

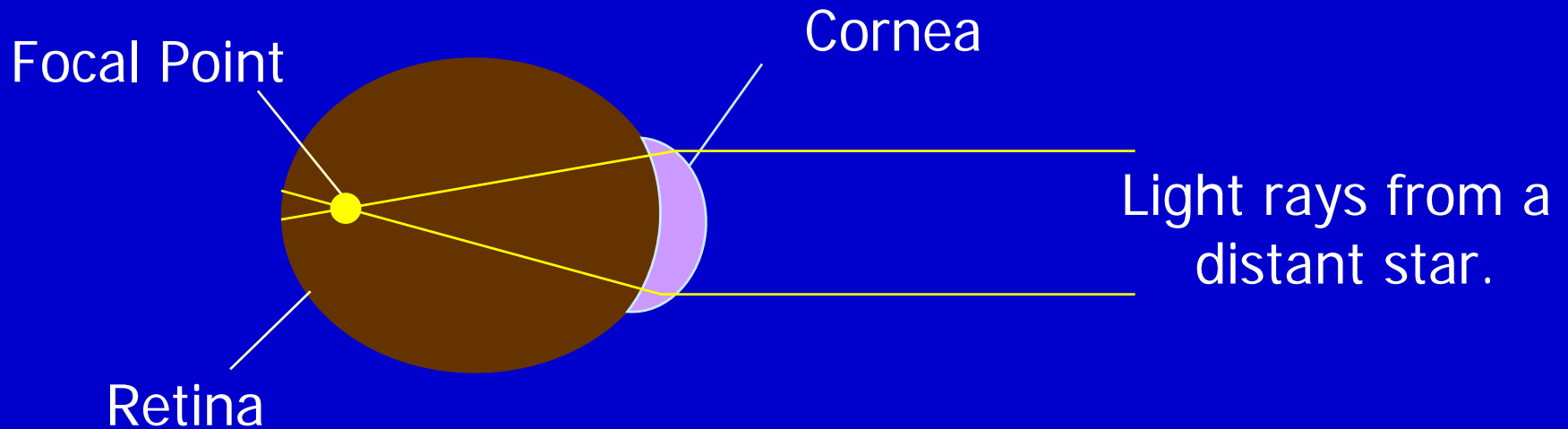
- What are refractive errors in the eye?
- What happens during refractive surgery?
- How does refractive surgery (LASIK) correct myopic errors?
- Effectiveness of LASIK treatments
- Sources of aberrations in LASIK: Decentration
- Decentration of the laser ablation treatment
- Project goals
- Methods
- Results
- Conclusion

Refractive errors in the human eye

Normal Eye

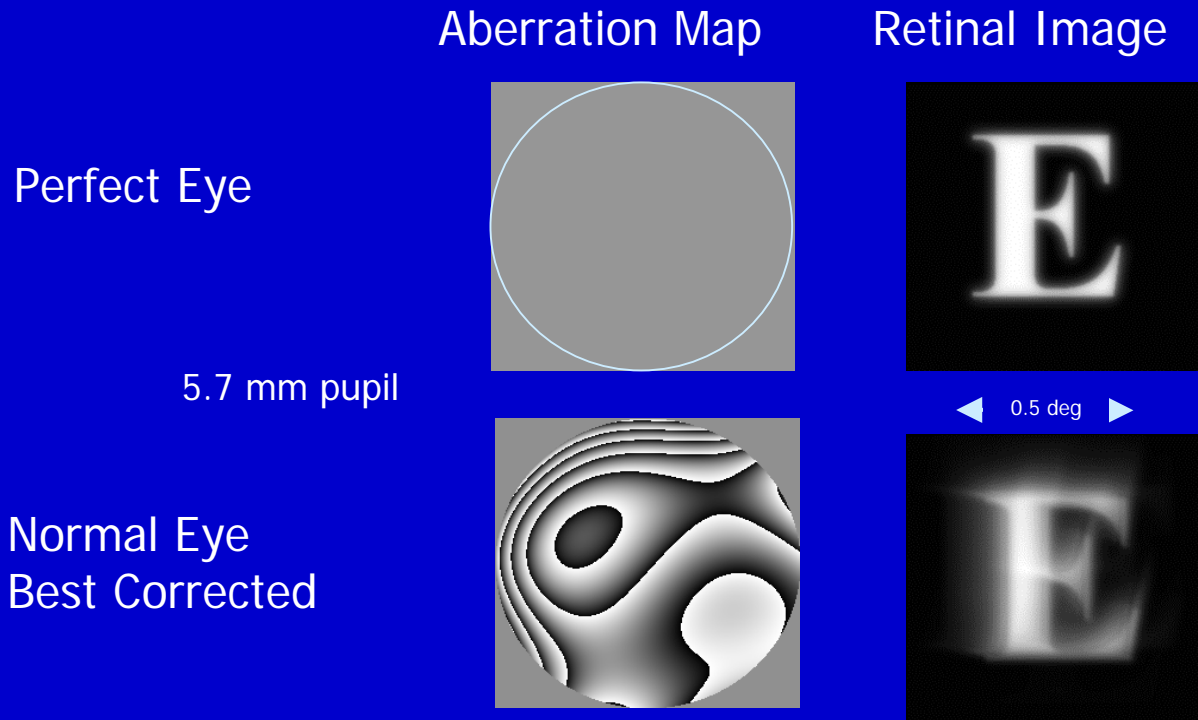


Myopic Eye



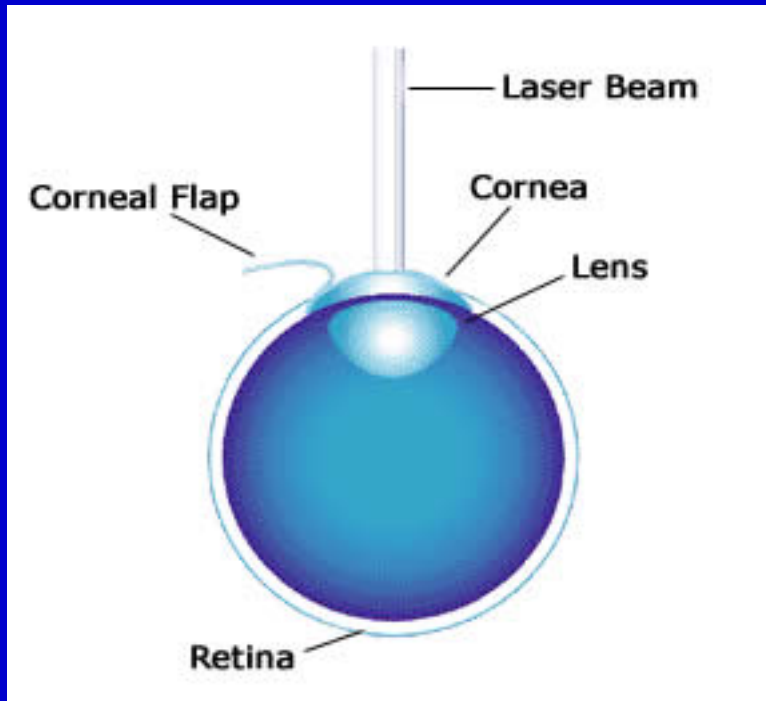
Eye's also suffer from higher order aberrations

- Aberrations prevent us from having perfect vision and blur images on the retina, especially when the pupil size is large (such as at night).



- Most of these aberrations cannot currently be corrected with glasses, contact lenses, or laser refractive surgery.

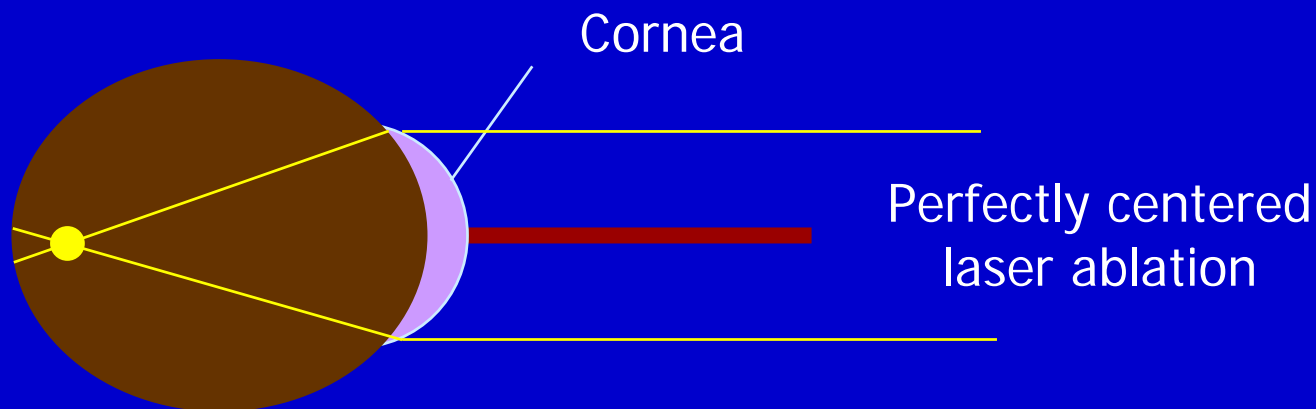
What happens during refractive surgery?



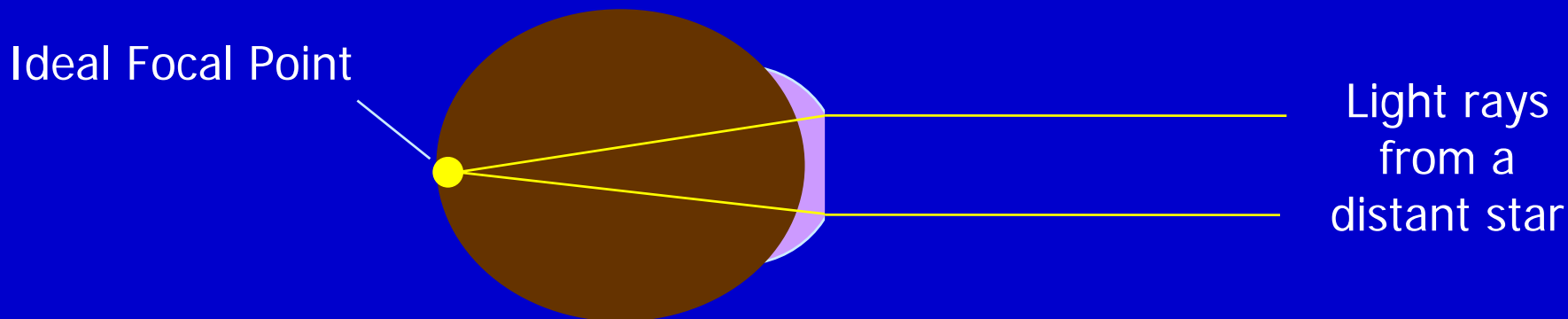
- Eye is numbed using anesthetic drops.
- Eyelid holder prevents blinking.
- Microkeratome creates a flap.
- Corneal flap is held back.
- Excimer laser removes predetermined amount of corneal tissue to re-sculpt the cornea.
- Flap placed back into position and naturally re-adheres.

How does refractive surgery correct myopic errors?

Before Correction - Myopic Eye



After Perfect Correction

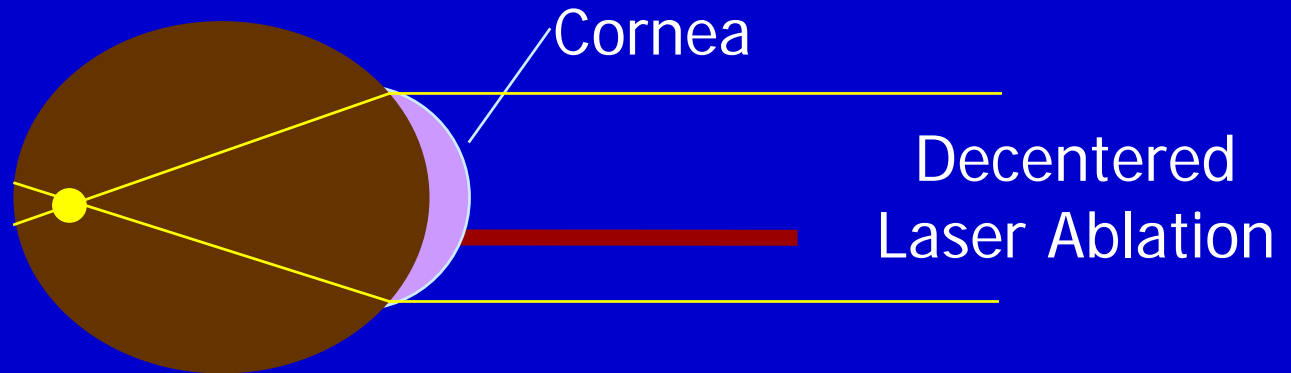


Effectiveness of LASIK treatments

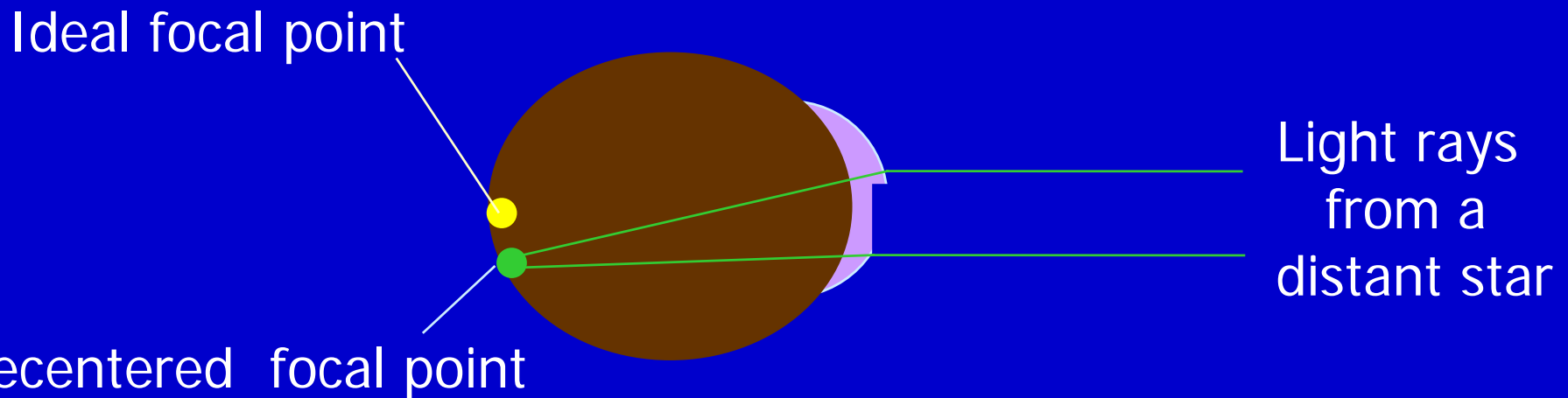
- Conventional refractive surgery corrects the eye's refractive errors (myopia, hyperopia and astigmatism)
- Customized refractive surgery: also attempts to correct the eye's higher order aberrations
- Refractive surgery increases higher order aberrations.
- There are several potential sources for the these induced higher order aberrations:
 - Cutting of the flap
 - Healing process
 - Decentrations due to eye and head movements
 - Decentrations due to shift in ablation treatment

Decentration of the laser ablation treatment

Before Correction - Myopic Eye



After Decentered Correction



Project Goals

- To determine what percentage of the overall amount of aberrations created after surgery are due to static shifts of the customized ablation treatment
- To find ways to reduce higher order aberrations caused by decentrations in refractive surgery.

What we mean by shift of a customized ablation treatment.

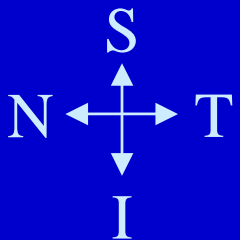
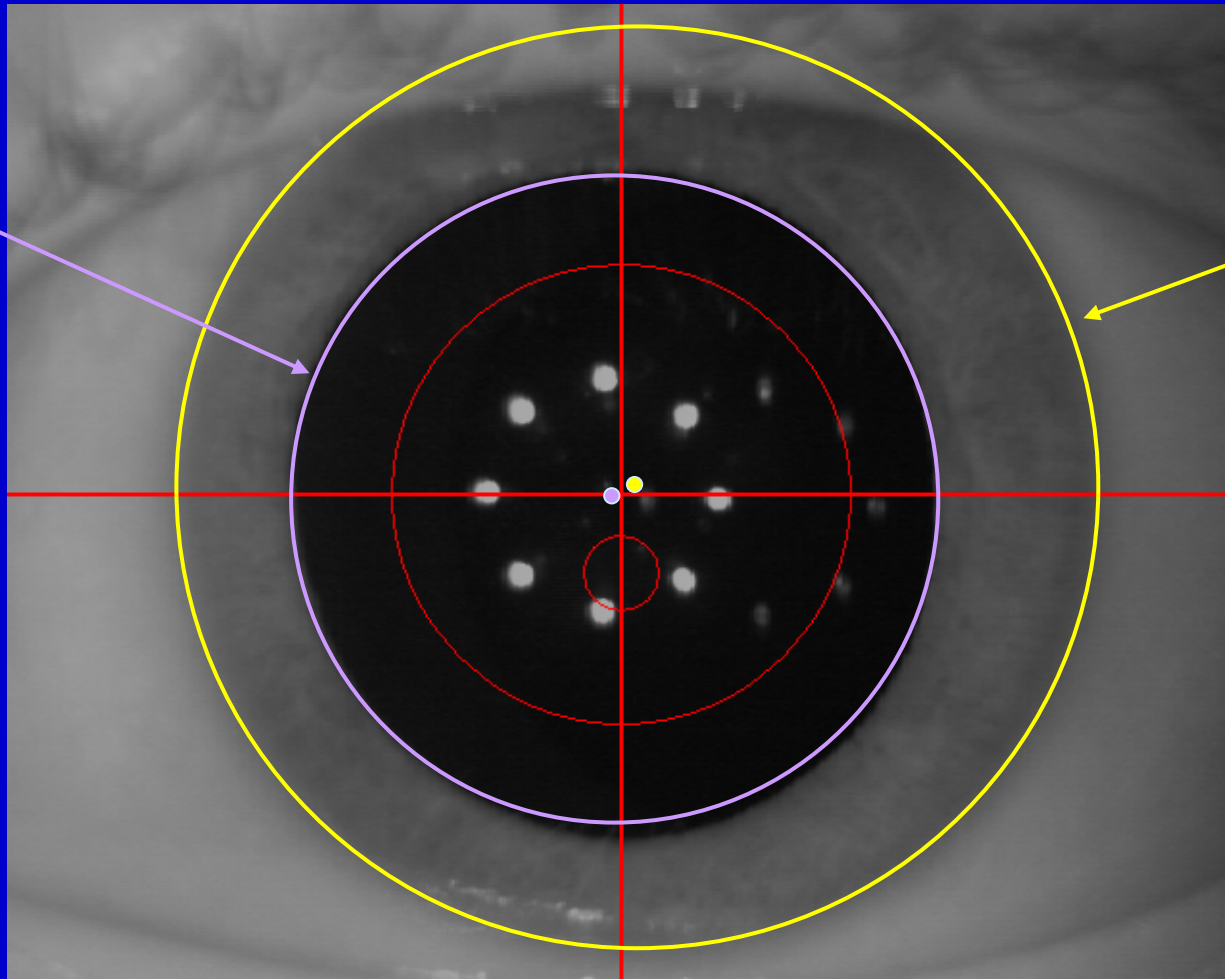
- Aberrations are measured over center of a dilated pupil (2.5% neosynephrine).
- LASIK is performed over an undilated pupil.
 - Patients more sensitive to lights when dilated
 - Easier for surgeon to center undilated pupil
 - Eye tracking easier with undilated pupil
- Shift of treatment occurs because the center of the dilated and undilated pupils are not in the same location in the eye.
- This decentration will induce additional higher order aberrations.

Pupil and Limbus Centers: Dilated Eye

Subject ML, OS

Dilated
Pupil

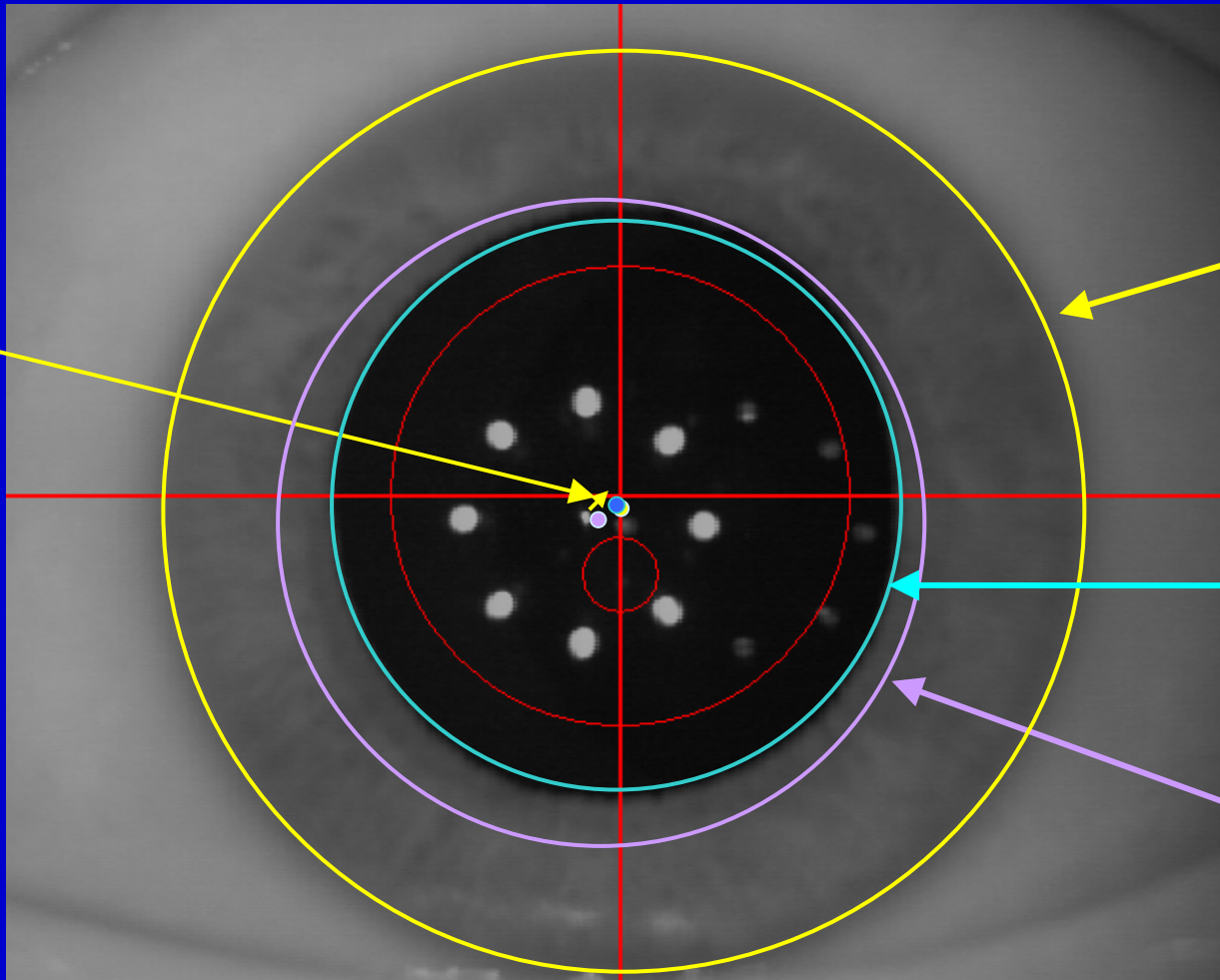
Limbus



Pupil and Limbus Centers: Undilated Eye

Subject ML, OS

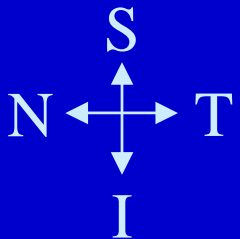
Decentration
of ablation



Limbus

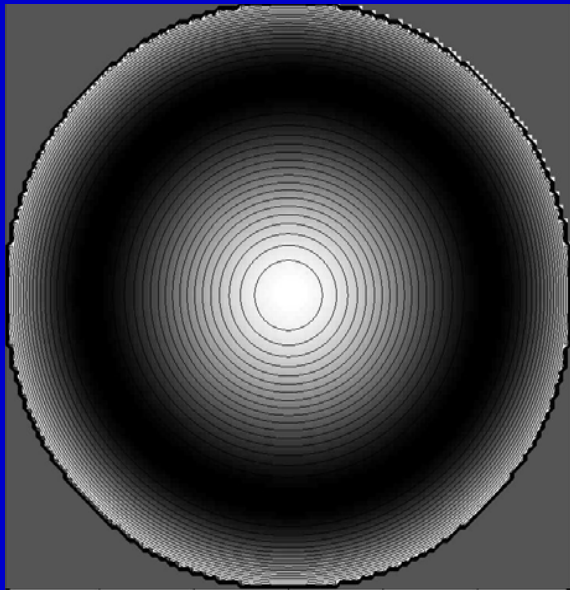
Undilated
Pupil

Dilated
Pupil



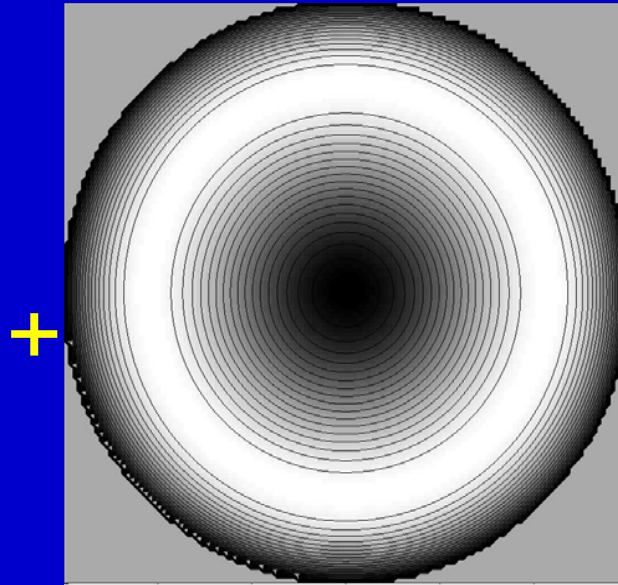
Example - Perfect Centration

Pre-op:
Spherical



Rms = 1.0 μm

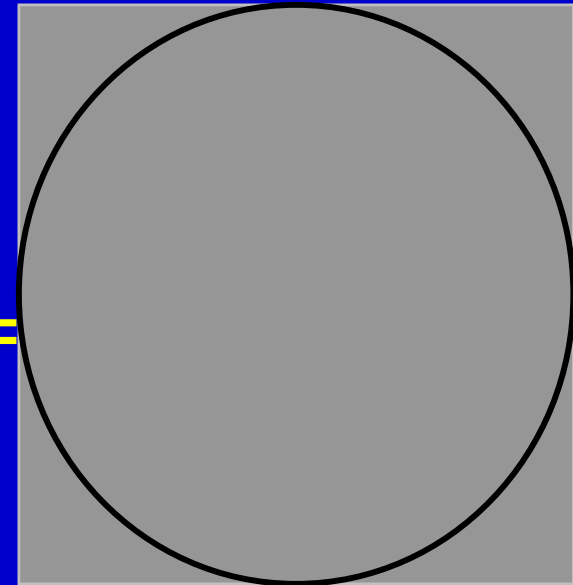
Perfect correction and
alignment



+

=

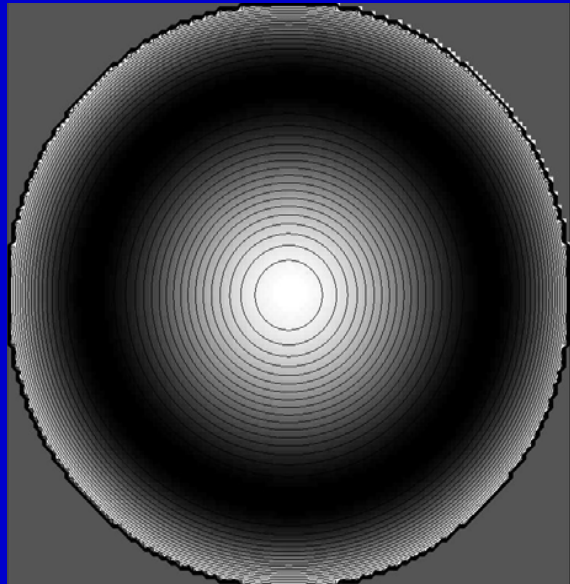
Post-op:
No aberrations



6 mm pupil

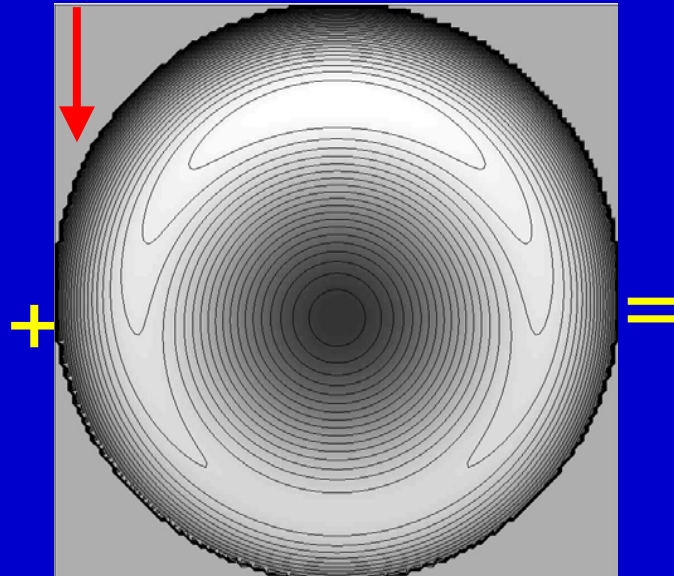
Example - Decentration

Pre-op:
Spherical

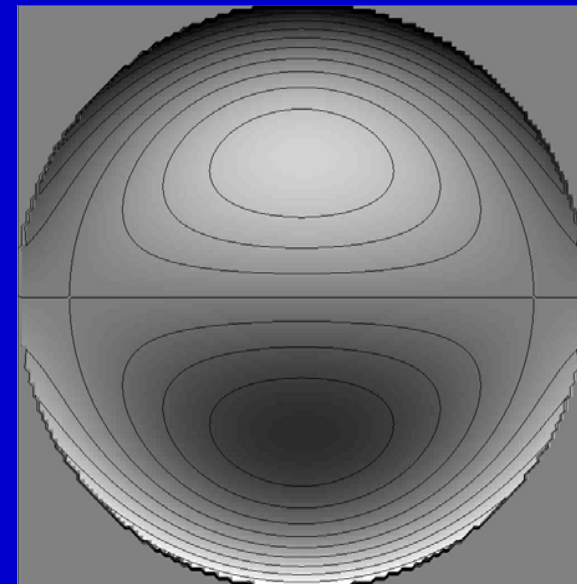


Rms = 1.0 μm

Correction decentered by
0.2 mm



Post-op:
Vertical Coma



Rms = 1.05 μm
6 mm pupil

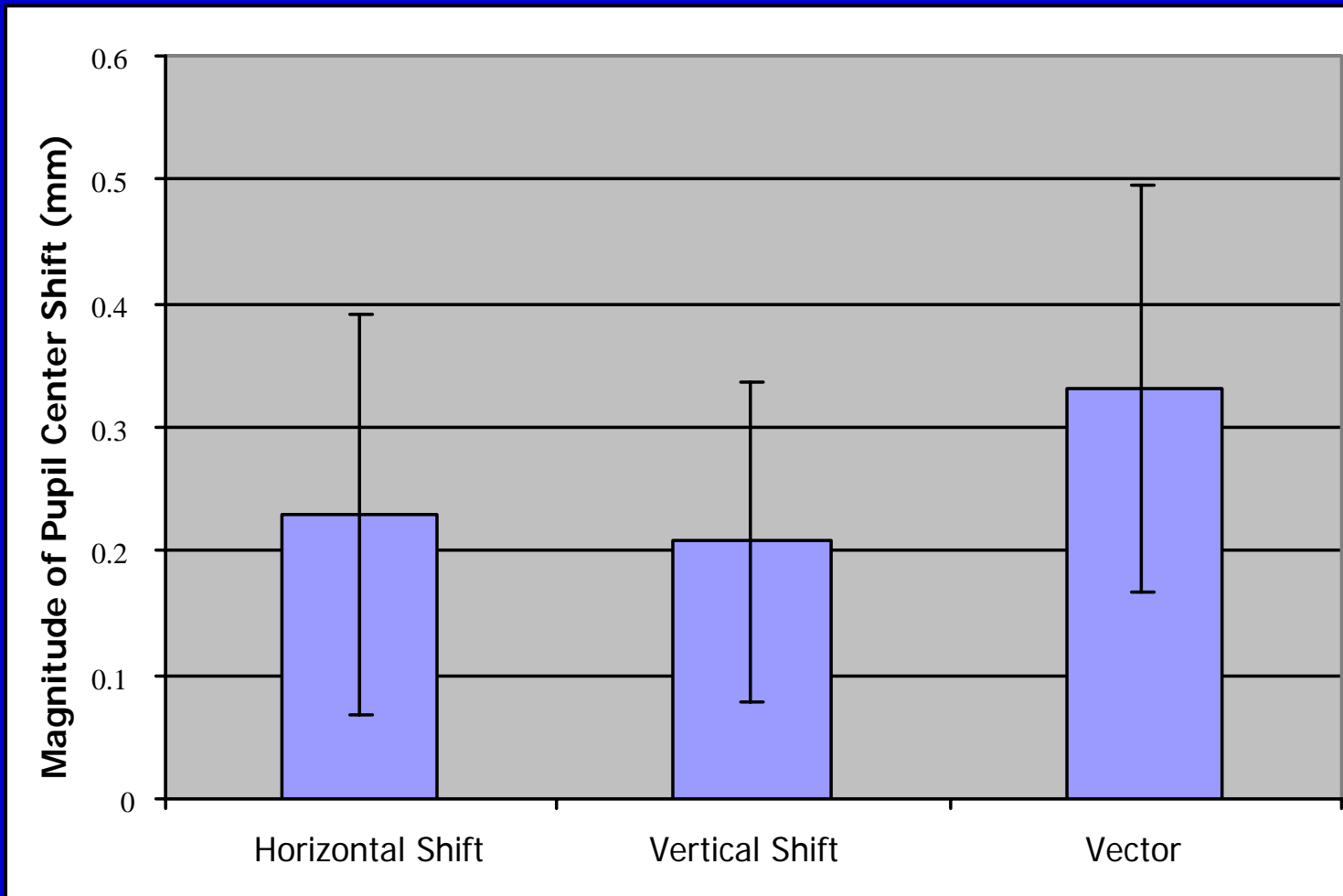
Aberrations induced by decentration!

Procedure

- Took pictures of the pupil and iris of 7 pre-LASIK subjects (13 eyes) when undilated and dilated (neosynephrine).
- Pupil center found for both conditions relative to the limbus center
- Decentration = shift in pupil center from a dilated to undilated pupil
- Shack-Hartmann wavefront sensor used to measure the wave aberrations over the dilated pupil for each patient preoperatively.
- Calculated aberrations induced solely due to a shift in the location of the center of the pupil in a *customized* LASIK procedure (Guirao et al., JOSA A, 18(5), 2001).
- Measured 6-month post-operative wave aberrations

Magnitudes of pupil center shift

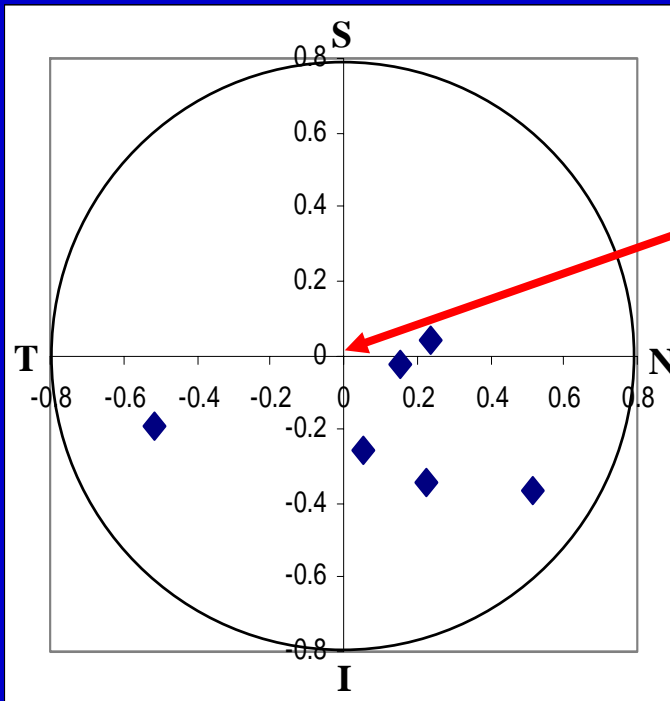
- Range of vector magnitudes: 0.08 mm to 0.631 mm
- Average vector magnitude: $0.33 \text{ mm} \pm 0.165 \text{ mm}$



Shifts in pupil center

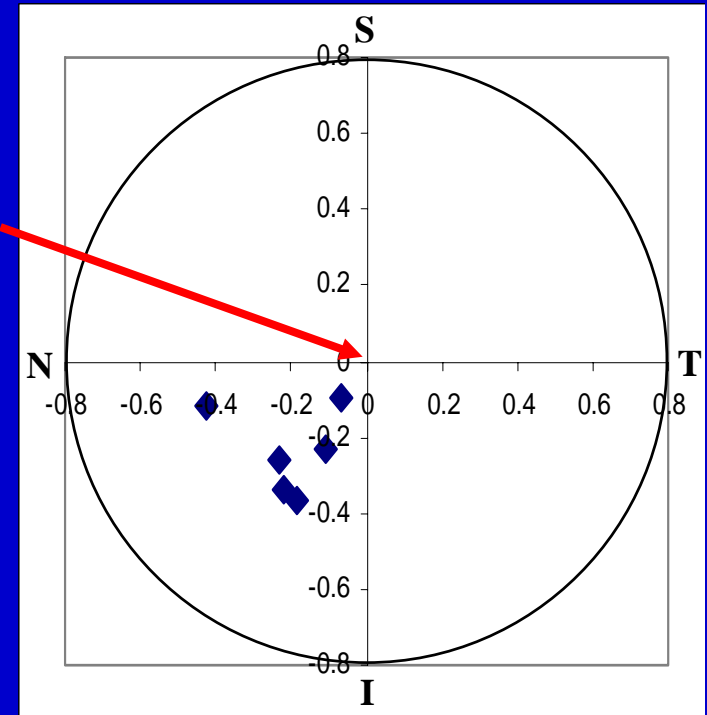
- Pupil center tended to shift in the inferior-nasal direction when the pupil dilated.

Right Eye



Center of undilated pupil

Left Eye

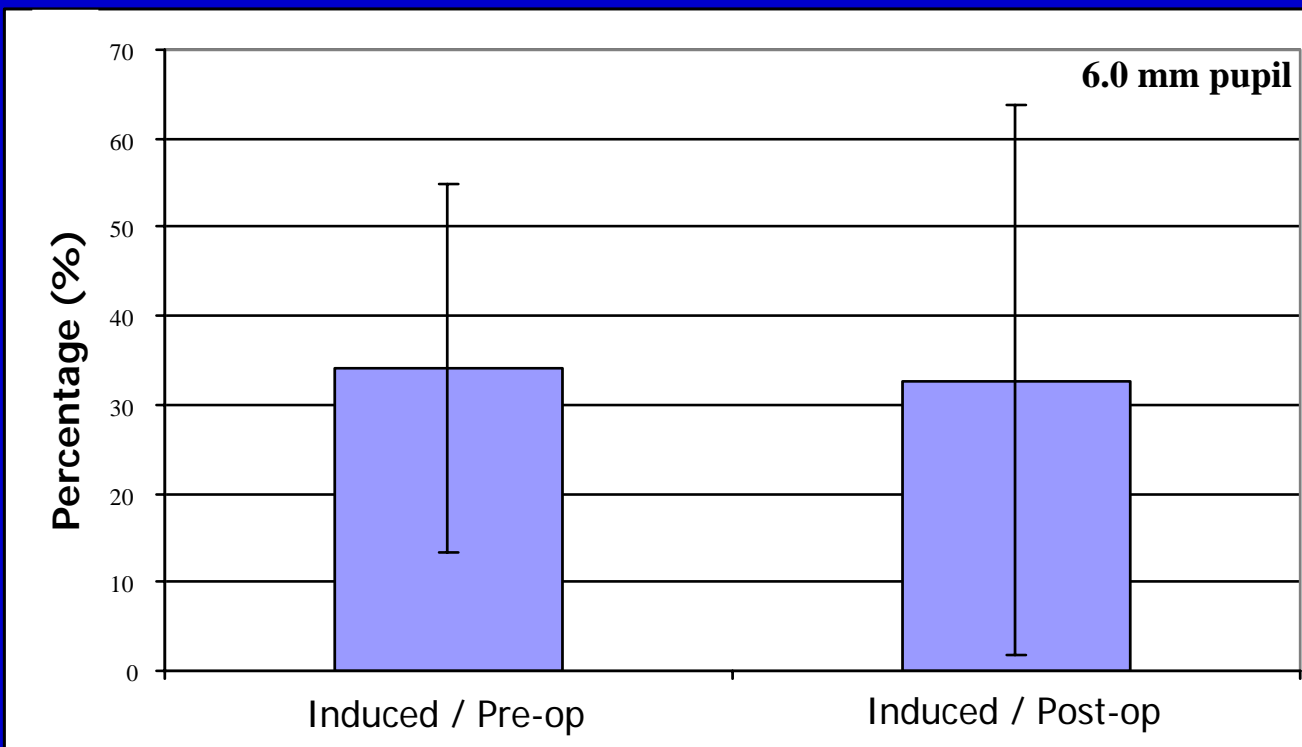


◆ Center of dilated pupils

- Decentration of ablation is in the superior-temporal direction.

Aberrations theoretically induced due to decentrations

- Calculated ratio of theoretically induced higher order Rms to pre- and post-op higher order Rms
 - Range of % of post-op: 7% to 119.3%
 - Average % of post-op: 33 ± 30.9 %



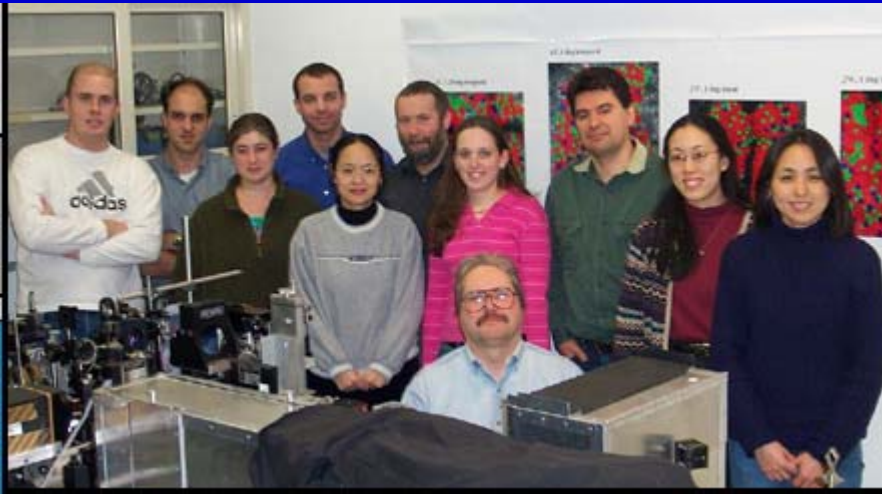
Conclusions

- Shift in pupil center from dilated to undilated:
 - Average magnitude: $0.33 \text{ mm} \pm 0.165 \text{ mm}$
 - Range of magnitudes: 0.08 mm to 0.631 mm
 - Tended to be in the superior-temporal direction
- Decentration of customized ablation induces higher order aberrations
- Percentage of aberrations that could theoretically be accounted for by decentration:
 - Average percentage of post-op: $33 \pm 30.9\%$
- Potential solution to reduce induced aberrations:
 - Reference the customized treatment with respect to the limbus and NOT the center of the pupil.

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