Is there a fundamental limit of efficacy when aberrations arising from one point along visual axis (lens) are corrected at another point (cornea)?

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No financial interest.

Two fundamental assumptions of today's wavefront-driven treatment

- Aberrations from all points (cornea, lens, etc) along visual (Z) axis can be axially collapsed along the visual axis, and adequately represented by a two dimensional transverse map (in the XY plane), the wavefront map;
- No matter where along the visual axis the original aberration arises (say, at lens), it can be fully corrected at another point along the visual axis (say, at cornea). Namely, the axial distance separation between the point *where aberration arises* and the point *where aberration is corrected* does NOT matter.

Furthermore, let's ask this question…

- Is it a good idea, at all, to correct aberration from one axial Z point (lens), at another (cornea), since aberrations at different axial Z points (different ocular structures) have different temporal profile (changes over time)? What is the long-term visual consequence?

Specifically, for LASIK….

- Does a cornea-confined procedure such as LASIK perform equally well in correcting abnormalities on cornea vs. lens?

  If not, does today's whole-eye wavefront-based LASIK (I.e., correcting lenticular features as well at cornea) have a fundamental *limit* of efficacy since they is a finite distance of separation of axial locations of these two points along the visual axis?

- Furthermore, given that lens changes more rapidly over time (particularly in a patient over age 40-50) than the cornea, is it still a good idea, at all, to do LASIK to correct time-changing lenticular aberrations on the time-stationary cornea?

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Let's look at correcting one type of aberration: astigmatism

- Question: Does a cornea-confined procedure such as LASIK perform equally well in correcting corneal vs. lenticular astigmatism?
- I.e., does "where on the Z axis the astigmatism arises (say, the lens vs cornea)" make any difference when the location of treatment is restricted ONLY on one point along the Z axis (the cornea)?
- Here for simplicity we use "corneal astigmatism" to equate anterior corneal astigmatism

The study

- 61 eyes of 61 consecutive patients who had primary myopic LASIK;
- SE range: -4.157 to -6.705D;
- VISX;
- Single surgeon.

The question

- When using a cornea-confined procedure such as LASIK, to correct corneal astigmatism vs lenticular astigmatism, in which situation there is more untreated residual astigmatism left postop?

Testable hypothesis

Astigmatic correction by a cornea-based procedure such as LASIK performs BETTER for correcting corneal astigmatism (leaving *smaller* residual untreated cylinder postop), than for lenticular astigmatism.

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Study design

- Preop: cylinder R, corneal astigmatism K (Orbscan), and percentage of non-corneal (lenticular) astigmatism (R-K)/R;
  - Low lenticular astigmatism group (I) [low (R-K)/R value, n=42];
  - High lenticular astigmatism group (II) [high (R-K)/R value, n=19].
- Postop: analyze percentage of residual untreated cylinder R'/R (Index of Success).

Comparison of preop variables between the corneal (I) and lenticular (II) astigmatism groups

	Group I [(R-K)/R < 1.000]	Group II [(R-K) > 1.000]	P-values
Age	43.71	45.867	0.29
Pre-operative Spherical Equivalent	-5.419	-5.775	0.66
Pre-operative Cylinder (R)	1.355	0.742	0.0001

Table 2

	Averages		
	Group I [(R-K)/R < 1.000]	Group II [(R-K)/R > 1.000]	P-values
Fraction of Residual Cylinder (R'/R)	0.239	0.502	0.036

For Text:

	95% Confidence Interval	
	Group I [(R-K)/R < 1.000]	Group II [(R-K)/R > 1.000]
Age	40.473 to 46.947	43.628 to 48.106
Pre-operative Spherical Equivalent	-4.157 to -6.681	-4.839 to -6.705
Pre-operative Cylinder (R)	1.115 to 1.595	.585 to .899

Age, SE comparable, though magnitude of total preop astigmatism is higher in the low lenticular astigmatism group. Ming Wang, MD,PhD

Analysis – double-angle plot (since cylinder is 180 degree foldable) for analysis of astigmatic correction

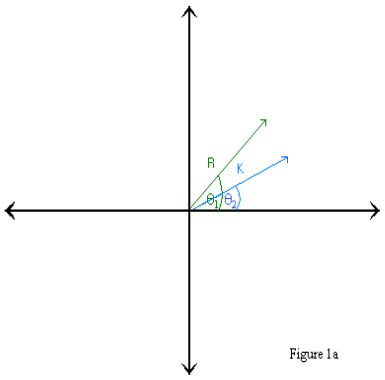

Figure 1a

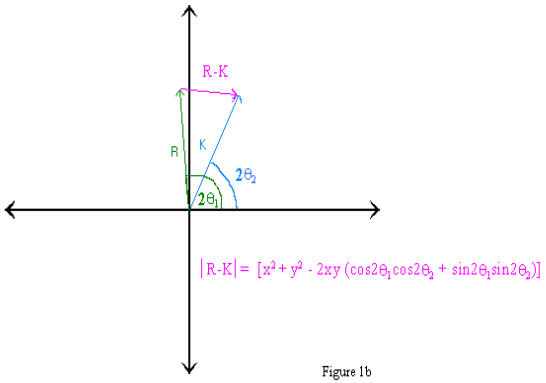

Figure 1b

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The result: Residual uncorrected astigmatism is twice as high in lenticular (II) than cornea (I) astigmatism group.

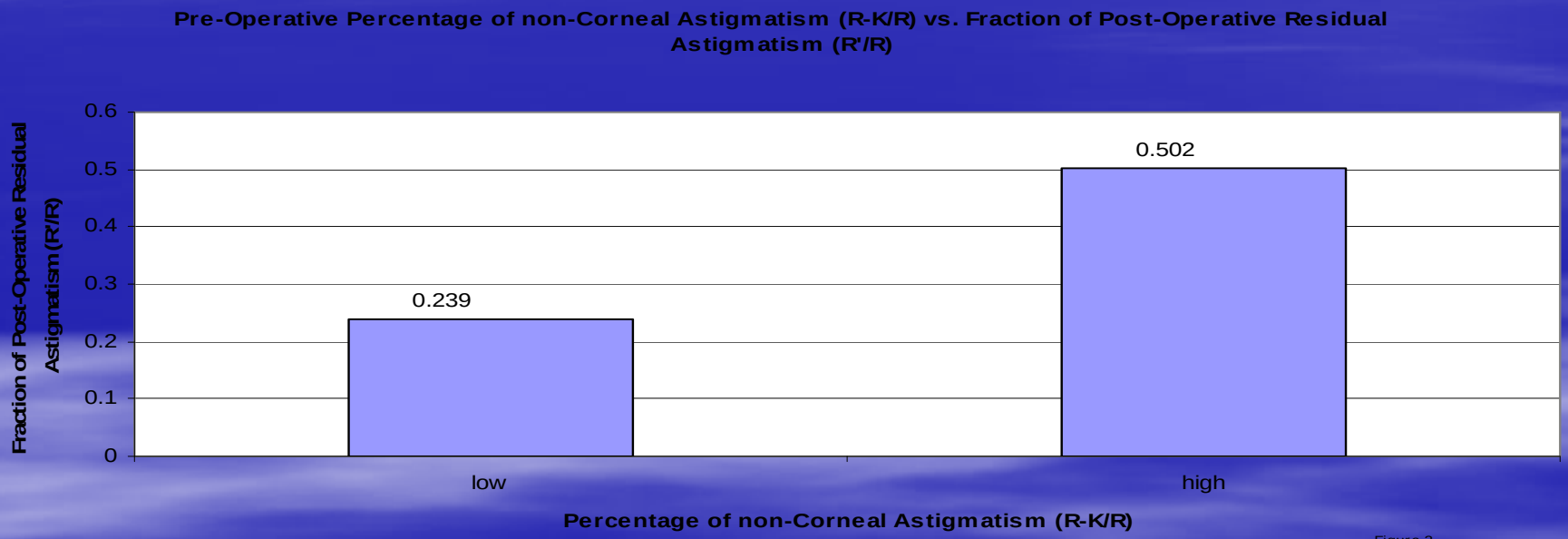

Figure 3

Index of success **P < 0.05.**

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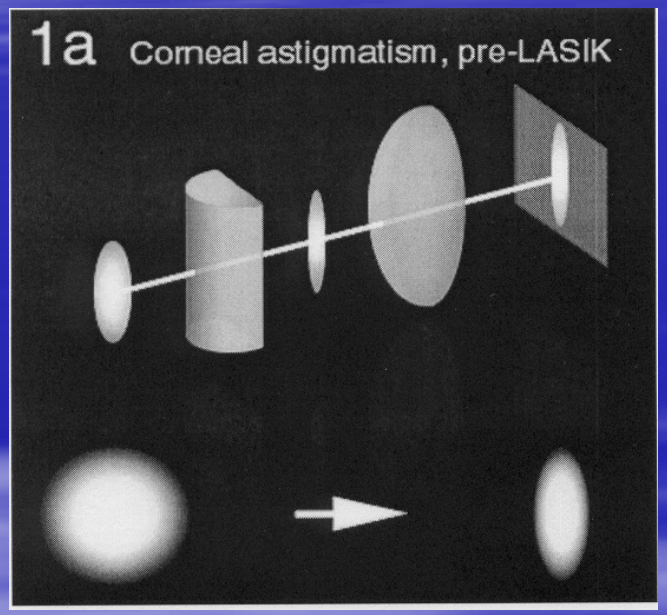
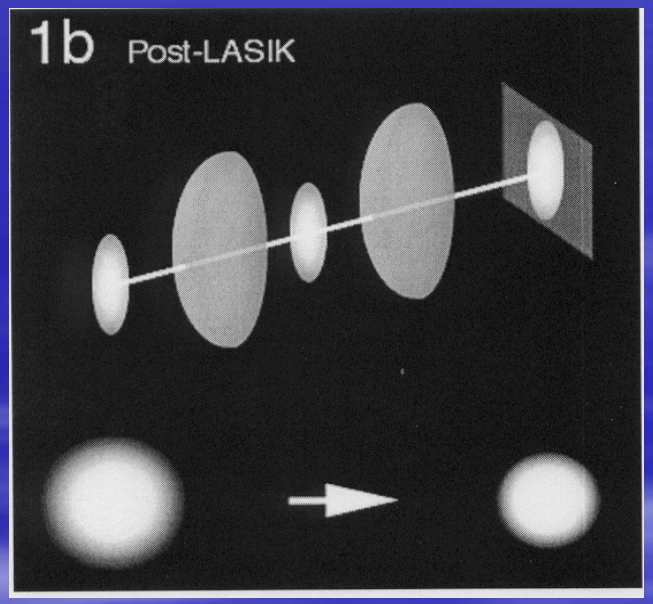
Diagrammatic summary of result

1) Cornea-confined LASIK treating corneal astigmatism
Good result.





Circular incoming light.

End result: a nice circular image on retina, lesser amount of residual uncorrected cylinder.

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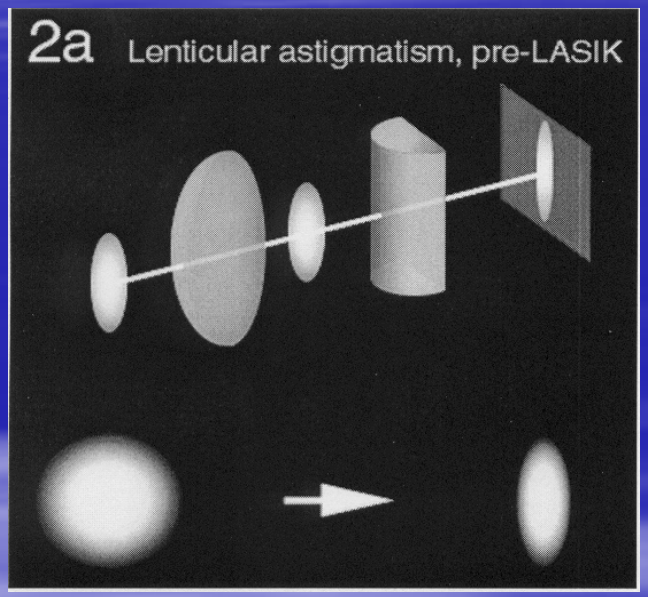
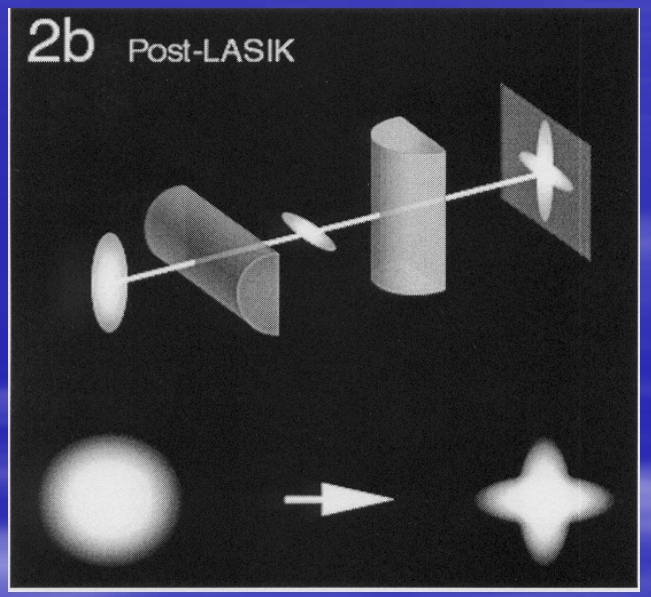
Diagrammatic summary of result con't

2) Cornea-confined LASIK treating lenticular astigmatism

Not so good result.





Circular incoming light.

End result: an imperfect image on retina, higher amount of residual *uncorrected* cylinder.

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Conclusion of the study

Cornea-confined procedure such as LASIK performs better in correcting corneal than lenticular astigmatism.

Correcting lenticular astigmatism on the cornea (which works by creating a “reverse astigmatism” on the corea) does not work as well since it leaves more untreated residual astigmatism postop

Implication of this study

- It is better to correct the problem "at its source" (i.e., correct *corneal* problem *at the cornea*);

  - Current LASIK result (eg, astigmatic correction which has lesser efficacy) contains pts with high lenticular astigmatism – limitation of efficacy?

  - Regarding where we should correct astigmatism, at IOL (toric IOL), or at cornea (LASIK/PRK or LRI)? The answer should be: where does the astigmatism come from in the first place? At lens? Then correct at lens; at cornea? We should correct at cornea.

Implication of this study con't

- The current wavefront approach, i.e., correcting *everything* (including aberrations on the lens) on the cornea, may have a ***fundamental LIMIT of efficacy*** since there is ***a FINITE axial distance separation*** between the point of aberration source and point of correction.

  - Example of fundamental limit of efficacy in biology: the ultimate spatial resolution of corneal wound healing is perhaps limited by the single cell size ("Biological Planck Constant");

- The axial distance between the point *where aberration arises* and the point *where aberration is corrected* DOES make a difference, and the correction efficacy is mathematically maximized when that distance is collapsed to zero.

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Discussion

- And furthermore, how about the fact that aberrations arising from different temporal points (ie, different ocular structure) have different temporal profile (i.e., difference in the speed of change over time, of say, cornea vs lens)?

Since, lens can "walk off" more easily (than cornea) over time….

- For eyes with high lenticular astigmatism (eg, older age), does it really make sense to apply once-in–a-lifetime "DC" (*time-stationary*) cornea treatment (LASIK) based on information that contains an "AC" (*time-changing)* component (the lens)?
- Does today's wavefront-based treatment approach really make sense in those 40-50 yo who has high lenticular aberration, i.e., creating "reverse aberration patterns" on the time-stationary cornea, when the time-changing lens can just "escape" later and "walk" off, leaving a generation of patients, years from now, with *iatrogenically created irregular cornea* and with continuously reduced vision over time (which gets even worse after CE)?

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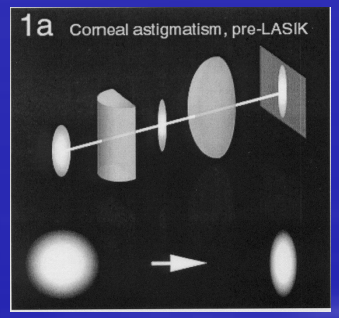
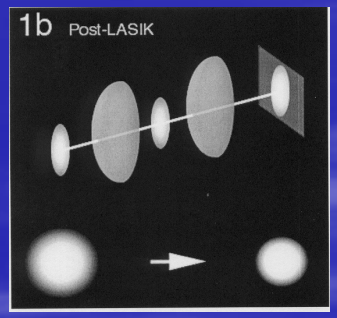
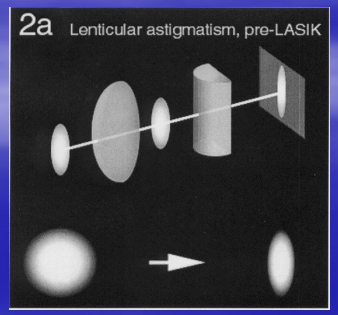
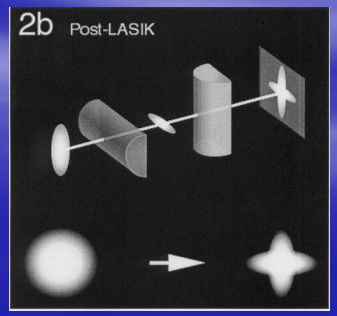
For some 40-50 yo, do you really want them to be 20/10 for just two years (custom), or 20/25 for 20 years (conventional)?









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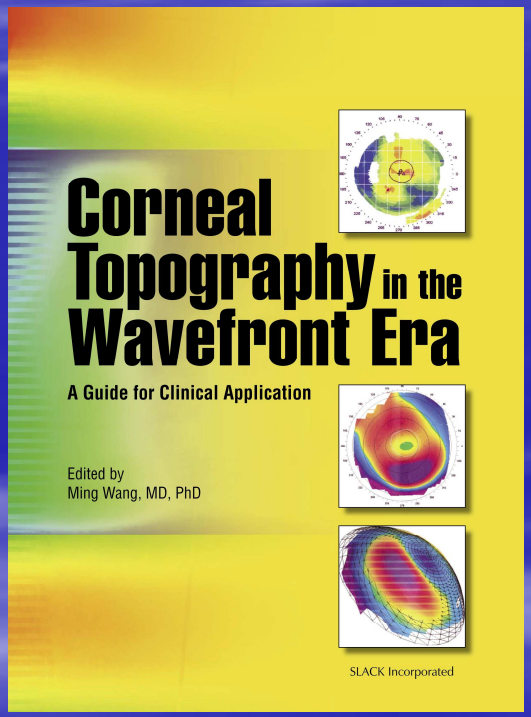
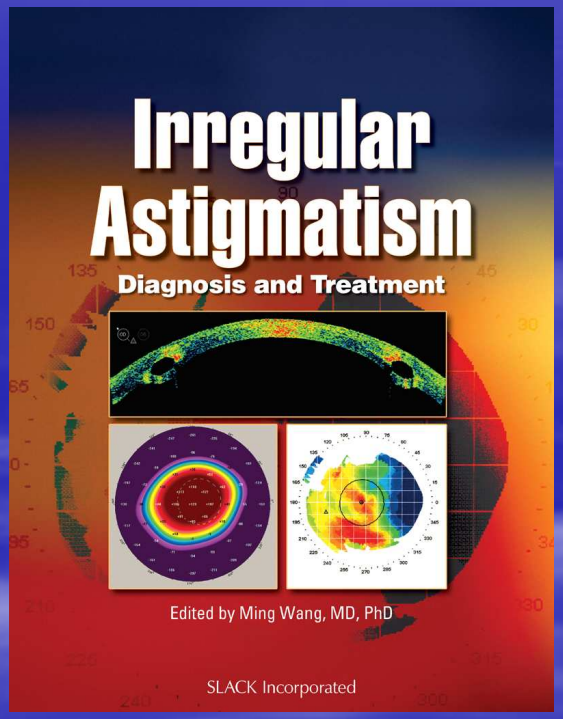
Related textbooks





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Take-home messages

- There is perhaps a fundamental finite axial distance separation between aberration plane and correction plane can create a limit of efficacy of correction, so problems should be corrected at its source;
- Whole-eye wavefront-driven LASIK maybe should be used, only in young patients;
- For patients at age 40-50 or older, they need to know the possible short life-expectancy of super vision given that iatrogenic aberrant corneas (in order to cancel the aberration of lens) will be created by a cornea-confined procedure such as LASIK and visual quality can possibly deteriorate *faster* than an age-controlled who never has had any whole-eye wavefront-based procedure on the cornea;
- A subset of these age 40-50 or older patients (who have higher than normal lenticular aberration) need to be identified and we should avoid doing corneal procedure such as LASIK on these patients.

Long-term consequence of what we do now

Let's try to avoid creating iatrogenically irregular cornea ***now***, in some of these 40-50 or older patients, which may have ***long-term*** visual consequence.

Thank you!

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