How is spherical aberration induced by laser refractive surgery?

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Positive spherical aberration is increased (decreased) after myopic (hyperopic) correction.

- Change in spherical aberration postOP – preOP (µm)
- 6 mm pupil
- $R=92\%$

- Attempted correction (D)

- Myopia (n = 32)
- Hyperopia (n = 17)

References:
- Moreno-Barriuso et al, IOVS, 42, 1396-1403 (2001)
- Llorente et al., ARVO abstract #2066 (2002)

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Corneal asphericity is increased after myopic correction.

Moreno-Barriuso et al, IOVS, 42, 1396-1403 (2001)
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Calculation of change in spherical aberration and corneal asphericity after refractive surgery

\[ C_{\text{postOP}}(r) = C_{\text{preOP}}(r, \ roc = 7.8\,\text{mm}, \ p = 0.7) - T_{\text{ablation}}(r) \]

Ablation profile (Munnerlyn algorithm or parabolic approximation)

\[ C_{\text{cornea}}(r, \ roc, \ p) = \frac{(1/\roc) \ r^2}{1 + \sqrt{1 - p (1/\roc)^2 \ r^2}} \]

Spherical aberration and corneal asphericity of pre- and post-OP cornea (6mm cornea)

Change in spherical aberration and corneal asphericity (postOP- preOP)
Spherical aberration change by refractive surgery tends to be opposed to theoretical expectation.
Corneal asphericity change by refractive surgery tends to be opposed to theoretical expectation.

Clinical data

PreOP cornea: roc = 7.8 mm, p = 0.7

6 mm cornea

Expected from Munnerlyn algorithm

Myopic correction

Hyperopic correction

Attempted correction (D)

Change in corneal asphericity (p)
Why is there discrepancy between theoretical expectation and clinical observation?

Hypothesis #1
Difference in ablation rate due to angular incidence of laser spot onto the cornea.

Hypothesis #2
Biomechanical response of the cornea
Hypothesis #1: Difference in ablation rate due to angular incidence of laser spot onto the cornea

![Diagram showing the relationship between corneal radius, angle of incidence, and ablation efficiency.]

Ablation efficiency vs. corneal radius

Spherical aberration change by refractive surgery can be explained by the effect of angular incidence of laser spot.

![Graph showing change in spherical aberration vs. attempted correction](image)
Corneal asphericity change by refractive surgery can be explained by the effect of angular incidence of laser spot.
Hypothesis #2: Biomechanical response of the cornea – central flattening and peripheral steepening
Hypothesis #2: Biomechanical response of the cornea – central flattening and peripheral steepening

Biomechanical response (D) = 7% × attempted correction (D)

PreOP cornea

PostOP cornea

PostOP cornea by biomechanics

Optical zone

Steepening zone

Flattening zone = Optical zone – 1mm

Steepening zone
Biomechanical response of the cornea increases (decreases) positive spherical aberration for myopic (hyperopic) corrections.
Biomechanical response of the cornea increases (decreases) corneal asphericity for myopic (hyperopic) correction.
Munnerlyn vs parabolic approximation
change in spherical aberration

Munnerlyn algorithm

Parabolic approximation

Variable ablation rate & myopic biomechanics (7%)

Fixed ablation rate

Variable ablation rate & opposite myopic biomechanics (25%)

Amount of correction (D)
Munnerlyn vs parabolic approximation
change in corneal asphericity

Munnerlyn algorithm

Parabolic approximation

Variable ablation rate & myopic biomechanics (7%)

Variable ablation rate & opposite myopic biomechanics (25%)

Fixed ablation rate
Customized ablation thickness to achieve a spherical aberration free eye after refractive surgery.

Our goal is to create spherical aberration free eye!!!

Customized Ablation Profile \((r, p_{\text{pre}}, \text{roc}_{\text{pre}}) = \)

\[
\frac{\text{preOP cornea} - \text{SA free postOP cornea (p=0.472)}}{+ \frac{SA_{\text{lens}} + SA_{\text{others}}}{(n-1)}}
\]

Ablation efficiency \((r, p_{\text{pre}}, \text{roc}_{\text{pre}})\)
Conclusion

• The theoretical eye model with taking into account ablation efficiency and corneal biomechanical response can explain how spherical aberration is induced by refractive surgery.

• Biomechanical response of the cornea in hyperopic correction may be opposite to that in myopic correction.

• This model can be incorporated into an ablation algorithm to avoid induced amounts of spherical aberration, improving the outcome of both conventional and customized treatments.