Prolate cornea: Is it possible?

Paolo Vinciguerra, M.D.¹, ²
Riccardo Vinciguerra, M.D.¹-³
Silvia Trazza, orth¹

¹Eye Center, Humanitas Clinical and Research Center
²Columbus, Ohio State University
³University of Insubria, Varese
The corneal shape

- Aspheric
- Steeper in the center
- Flatter in the periphery
- Shows a low corneal curvature gradient
- Characterized by positive Sph. Ab. compensated by crystalline lens
- This shape minimize aberration, reflex and allow the best image resolution even at the edge
- **Prolate**: Normal corneas are steeper centrally and flatter in periphery (low + Sph Ab.)

- **Oblate**: Flat centrally and steep in periphery (high + Sp. Ab.)

- **Hyperprolate**: Very steep in the center, very flat in periphery (High – Sph. Ab.)
What deteriorate images’ quality after refractive surgery?

- Sph. Ab. reduces contrast and resolution. Resolution is more reduced from the center to periphery. It is different for every wavelength.
- Coma (a skewed/asymmetric version of Sph. Ab.) induces double vision and halos.
- Chromatic aberration → not all colours are focused in the same plane.
Optical aberrations

- Equal orders reduce contrast sensitivity ($2^\circ$ - $4^\circ$ - $6^\circ$ ....) (Example Sph. Ab.)
- Odd orders reduce visual acuity ($3^\circ$ - $5^\circ$ - $7^\circ$) (Example Coma)
Sph. Ab. and induced chromatic Ab.
What does make coma increase after refractive surgery?

- If the ablation of Low order aberration (LOA) are not centered on visual axis (not the pupil center) coma increases.
- If the ablation of High Order Aberration (HOA) (where are measured) are not centered on pupil center all HOA increases.
- So we need a laser who tracks and ablate LOA on visual axis, and HOA on pupil center.
Coma and double vision after decentered treatment
Pupil size and Optical aberration 1°

- Sph. Ab. increase as the $r^4$ (example if the pupil double the Sph. Ab. Increase by factor of 16)
- Coma as $r^3$
- Astigmatism no influence
- Chromatic Aberration no influence
Image degradation from center to periphery
Pupil size and Optical aberration 2°

- So an aberrated eye not only has a reduction in contrast and resolution, but even has a reduction of image quality from center to periphery → “glaucoma like vision”
- Small pupils only partially compensate (it is not a matter of night vision)
- Aberrated eye are not easily able to recognize and identify what is out focus while non-aberrated eyes can (Bokeh)
Bokeh what is it?

- Bokeh has been defined as "the way the lens renders out-of-focus points of light"
- The image is sharp when perfectly focused
- What happens to the area that are out of focus?
- The image’s quality deteriorate progressively
- The degradation is different when HOA are present
Aims of a custom treatment

- Achieving post ablation aspherical cornea
- Preop astigmatism should be corrected to such an extent that it is no longer detectable in postop topography and wavefront maps
- If these two condition are fulfilled, a surface is created that is relatively insensitive to decenteration and pupil diameter (night vision)
1. Can you tell which eye underwent custom ablation?

Pt P.M.
1. Myopic Custom treatment

- Pre op: 1.0 -2.25 (-1.25) 175
- Post op: ODV 1.5 nat

Pt P.M.

2. Different pt. with untreated Myopic eye

- OSV 1.0 -4 sph
Hyperopia
Patient B

Pre op OSV 1,0 +2,50 sph
Post Op OSV 1,0 nat

O.Z. 7.4
What did we obtain in the past?

- Correction only in the central cornea
- Regression
- Little decentration (even with trackers)
- Slow visual recovery
- Halos
Optical zone

Small (oblate)

Medium (oblate)

Small prolate after hyperopia correction

Small iperprolate after astigmatism correction

Medium iperprolate after astigmatism correction
O.Z. equal to pupil diameter

Is pupil diameter not relevant?
Different pt. high myopia ➔ no haze, no MIT C

**Corneal thickness map**

![Corneal thickness map](image)

Pre op 6 mos Post op

**Total gradient map**

![Total gradient map](image)

Pre op ODV -6.25

6 mos Post op

**Tangential map**

![Tangential map](image)

6 mos Post op ODV 1.0 -0.50 sph

**Differential Corneal thickness map**

![Differential Corneal thickness map](image)

-117 μ

**Differential Total curvature gradient map**

![Differential Total curvature gradient map](image)
Why?

- Correction must include the whole cornea.
- O.Z. must be centered over the visual axis and not over the pupil center.
- In addition the ablation should be equidistant from the limbus.
- Cornea must be prolated.
- Low corneal curvature gradient.
Why should we give up to correct all HOA?
Because...

- Diagnostic tools are not good enough
- System do not provide enough resolution
- We do not trust the ablation’s software
- We like easy life
- My results are good enough! Why should I change?
Why is corneal shape so important?

- Aim to low curvature gradient that means low regression, immediate stability, and extremely low HOA
- Image quality good not only in the center
- Almost insensitive to pupil size

**NEW CONCEPTS**

**Corneal Curvature Gradient Map: A New Corneal Topography Map to Predict the Corneal Healing Process**

Paolo Vinciguerra, MD; Cynthia J. Roberts, PhD; Elena Albé, MD; Mario R. Romano, MD, PhD; Ashraf Mahmoud, BS; Silvia Trazza, Orth; Riccardo Vinciguerra, MD
Amaris o.z. 7.50

Pre op 1.0 -3.25 (-2.25)15

8 mos post op 1.0 -0.25 sph

Pre op 1.0 -5.00 (-2.75)160

8 mos post op 1.0 -0.50 sph
Target -1,00 o.z 7,70

Pre op 1,0 -6,50 (-3,50) 20

Post op 1,0 -1,25
Clinical Results  N=257

234 myopia
- 19< age>51
- 0,9<VA>1,0
- pre op:  -1,00<sph<-11,00
- pre op:  0,00<cyl<-5,00

23 hyperopia
- 25< age>57
- 0,9<VA>1,0
- pre op:  +0,75<sph<+4,00
- pre op:  0,00<cyl<-3,25
Clinical Results

Diopters

2,57
1,28
-0,26
0,24
0,25
0,21
0,22

Hyperopia

pre op
1 mos
3 mos
6 mos
12mos

Hyperopia
Clinical Results

Myopia

Diopters

<table>
<thead>
<tr>
<th>sph (-)</th>
<th>cyl (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15</td>
<td>0.25</td>
</tr>
<tr>
<td>0.07</td>
<td>0.19</td>
</tr>
<tr>
<td>0.11</td>
<td>0.14</td>
</tr>
<tr>
<td>0.18</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Pre op, 1 mos, 3 mos, 6 mos, 12 mos
Clinical Results  mean target -1,06 EqSph

BSCVA

Diopters

sph (-)  cyl (-)
Wf Corn OZ 5 mm Order 8

Myopia $\leq 6.00$ D

Myopia $\geq 6.00$ D

Ab Sph Tot  |  Astig Tot  |  Coma Tot  |  HOA tot
---|---|---|---
0.12 | 0.04 | 0.13 | 0.22
0.13 | 0.08 | 0.15 | 0.26

0.13 | 0.04 | 0.1 | 0.21
0.24 | 0.06 | 0.2 | 0.35

Ab Sph Tot  |  Astig Tot  |  Coma Tot  |  HOA tot
---|---|---|---
0.13 | 0.04 | 0.1 | 0.21
0.24 | 0.06 | 0.2 | 0.35
Wf Corn OZ 5 mm Order 8

Hyperopia

pre op
3 mos
6 mos

Ab Sph Tot
Astig Tot
Coma Tot
HOA tot

Micron
Prolate corneas post refractive surgery
A HINT FOR THE FUTURE...
What myopic ablation is?
How to eliminate red ring??

Truncated Hyperopia!

- It does not change central power
- Better transition without the need of additional ablation in the center
- Better corneal curvature gradient
Truncated hyperopia: results

ODV 1,0 -8,00 (-3,25)5

Pre op

Target -0,75/-1,00

Post op

1,0 -0,75 sph
Thank you for your attention

Paolo Vinciguerra
Istituto Clinico Humanitas, IRCS
University of Milan, Italy

info@vincieye.it