The effect of decentration on lower- and higher-order aberrations after myopic photorefractive keratectomy (PRK) in a cat model

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Objective

- models of decentration effects in the literature assume Munnerlyn’s algorithm or perfect wavefront-guided ablation
- modeling of decentration effects using ”real” WFE changes
  - change of LOA
  - change of HOA
  - change of theoretical optical quality (VSOTF)
  - LOA / HOA interaction (simulated subj. Rx)


Methods: cat model

• **wavefront sensing** (H/S sensor) in the awake-behaving state (spacing 300 µm)

• **5 eyes** of 5 domestic shorthair cats (*Felis cattus domesticus*) received **PRK for Myopia** (Planoscan, B & L)

<table>
<thead>
<tr>
<th>eye</th>
<th>treatment [D]</th>
<th>OZ [mm]</th>
<th>followup [weeks]</th>
</tr>
</thead>
<tbody>
<tr>
<td>c1005_OD</td>
<td>-6</td>
<td>8</td>
<td>24</td>
</tr>
<tr>
<td>c2001_OS</td>
<td>-6</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td>c2006_OS</td>
<td>-6</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td>c5005_OD</td>
<td>-10</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>c5026_OD</td>
<td>-10</td>
<td>6</td>
<td>12</td>
</tr>
</tbody>
</table>

Methods: WFE simulation

• step 1: calculation of centered WFE differences
  – center position: maximum defocus change over 6 mm
  – WFE difference calculation over 9 mm using a Zernike decomposition (10\textsuperscript{th} order) at center position
Methods: WFE simulation

• step 2: simulation of decentration
  – sub-aperture of 6 mm
Methods: WFE simulation

- step 2: simulation of decentration
  - sub-aperture of 6 mm
  - 6th-order Zernike decomposition

\[ x' = x + \Delta x \]
\[ y' = y + \Delta y \]
Methods: WFE simulation

• step 2: simulation of decentration
  – sub-aperture of 6 mm
  – 6\textsuperscript{th}-order Zernike decomposition
  – 100 µm steps (maximum range 3000 µm)

$$
\Delta W (x', y') \\
\text{(decentered)} \\
6.0 \text{ mm PD}
$$

$$
\Delta x = 0 \mu m \\
\Delta x = 500 \mu m
$$

$$
\Delta W (x, y) \\
\text{(centered)} \\
9.0 \text{ mm PD}
$$

$$
x' = x + \Delta x \\
y' = y + \Delta y
$$
Methods: WFE simulation

• step 2: simulation of decentration
  – sub-aperture of 6 mm
  – 6\textsuperscript{th}-order Zernike decomposition
  – 100 \( \mu \text{m} \) steps (maximum range 3000 \( \mu \text{m} \))
Methods: WFE simulation

• step 2: simulation of decentration
  – sub-aperture of 6 mm
  – 6th-order Zernike decomposition
  – 100 µm steps (maximum range 3000 µm)
Methods: WFE simulation

- step 2: **simulation of decenteration**
  - sub-aperture of 6 mm
  - 6th-order Zernike decomposition
  - 100 μm steps (maximum range 3000 μm)
  - 709 positions per eye
Methods: WFE simulation

• step 3: simulation of optical quality and interaction for a typical treatment situation
  – visual Strehl ratio based on the OTF (VSOTF) for the eye with best spherocylindrical correction (VOL-Pro 7.14)
  – simulated endpoint of the subjective refraction, based on the VSOTF (interaction effects)
Results I: decentration affects LOA changes

c5026 OD, -10 D / 6 mm
Results II: decentration affects HOA induction

c5026 OD, -10 D / 6 mm
Results II: decentration affects HOA induction

c5026 OD, -10 D / 6 mm
Results III: HOA / LOA interaction

c5026 OD, -10 D / 6 mm
Results III: HOA / LOA interaction

differences between 2\textsuperscript{nd} order and VSOTF-based refraction

\begin{figure}
\centering
\includegraphics[width=\textwidth]{diagram.png}
\end{figure}
Results IV: optical quality (BCVSOTF)

c1005 OD  c2001 OS  c5005 OD

c2006 OS  c5026 OD
Results IV: optical quality (BCVSOTF)

c5005 OD, -10 D / 6 mm

c5026 OD, -10 D / 6 mm
Summary

- The induction of HOA and LOA varied among different meridians.
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• there was a **high intersubject variability** for interaction effects
Summary

• the induction of HOA and LOA varied among different meridians

• there was a high intersubject variability for interaction effects

• the impact of micro-decentrations <200 µm is likely to limited in most cases but there was variability
Thank you!

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Implications

- comparison of different treatment modalities
- relative contribution of biological vs. optical effects (PMMA model)
- contribution of pupil diameter
Methods: WFE simulation

• step 3: simulation of optical quality and interaction for a typical treatment situation
Methods: WFE simulation

- step 3: simulation of optical quality and interaction for a typical treatment situation

\[ \Delta W (x', y') \]

standardized preoperative mean WFE

\[ W (x_{0\text{pre}}, y_{0\text{pre}}) \]
Methods: WFE simulation

• step 3: *simulation of optical quality and interaction* for a typical treatment situation

standardized preoperative mean WFE $W(x_{0\,\text{pre}}, y_{0\,\text{pre}})$

$\Delta W(x', y')$

simulated postoperative WFE $W(x', y')$
Methods: WFE simulation

- step 3: simulation of optical quality and interaction for a typical treatment situation
  - visual Strehl ratio based on the OTF for the eye with best sphero-cylindrical correction (BCVSOTF, VOL-Pro 7.14)
Methods: WFE simulation

• step 3: simulation of optical quality and interaction for a typical treatment situation
  – VSOTF for the eye with best sphero-cylindrical correction (BCVSOTF, VOL-Pro 7.14)
Methods: WFE simulation

• step 3: **simulation of optical quality and interaction** for a typical treatment situation
  – **VSOTF** for the eye with best sphero-cylindrical correction (BCVSOTF, VOL-Pro 7.14)
  – **simulated** endpoint of the **subjective refraction**, based on the VSOTF (interaction effects)