THE EFFECT OF CHANGES IN ENTRANCE PUPIL MAGNIFICATION ON WAVEFRONT-GUIDED LASER CORRECTION OF REFRACTIVE ERROR AND HIGHER-ORDER ABERRATION

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The basic concept of wavefront-guided correction is that ablation must remove optical path variations across the pupil.

Aberration + Ablation = Perfection

But is it as easy as this?(!)
Numerous factors make the “aberration-free” result difficult to achieve

• Instability in ocular aberration (accommodation, tear changes etc)
• Limited accuracy of aberrometers
• Difficulties in specifying (reflection losses, hydration etc), controlling and centring the required ablation
• Biomechanical and healing changes in cornea
• Some less well recognised systematic optical problems???
The ablation affects only the corneal surface of the eye but the eye’s aberrations arise from all its components (and the aperture stop does not lie at the cornea). Changing the corneal radius affects the ray angles and incidence heights at later surfaces.
Aspects to be discussed (all get worse as the basic refractive correction increases)

- Effect of spectacle lenses on entrance pupil diameter
- The change in the magnification between the aperture stop and entrance pupil when corneal curvature changes after refractive correction
- The influence of the reference plane used in measuring the aberrations
- The effect of the direction of measurement on the apparent wavefront aberration
- (NB It is assumed that all the other practical problems have been overcome)
Effect of spectacle correction during myopic aberration measurement

The corneal area contributing to the measured aberration is larger than that of the effective entrance pupil (Campbell et al., J Vision 2002, 42, 29a)
Failure to allow for this effect may suggest that, for constant entrance pupil diameter, e.g., spherical aberration increases with myopic error.

Some published results may be affected in this way.
Change in entrance pupil after myopic ablation
Effect of myopic ablation on entrance pupil magnification

- The entrance pupil is the image of the edge of the iris (aperture stop) seen through the cornea. With “typical values (corneal radius 7.8 mm, ACD 3.6 mm) the magnification (entrance/aperture) is about 1.13X.
- After myopic ablation, the cornea is flatter and the magnification is reduced. The same size of aperture stop appears as a smaller entrance pupil (or the same size of entrance pupil corresponds to a bigger aperture stop)
- The new entrance pupil magnification is about 1.09X for a –10D correction, and the same diameter of entering beam passes through a larger diameter of crystalline lens (about 3.4% larger) than it did before
- If the original higher-order aberration arose at the cornea this doesn’t matter but if it arose at the lens, correction will be imperfect. Effects are greater as the order of the aberration increases
Entrance pupil magnification after correction: effects are not very sensitive to the assumed parameters of the eye

Values of corneal radius, ACD, ablation zone diameter (mm): Ser.1, 7.8, 3.6, 6; Ser.2, 7.8, 3.6, 7; Ser. 3, 7.4, 3.6, 6; Ser.4, 7.8, 4.0.
The exact effects may be affected by the type of aberrometer used, e.g. Hartmann-Shack or Laser Raytrace.

Out-of-the-eye

Rays A are marginal rays before ablation in myopic eye, rays B after ablation in “emmetropic” eye (same entrance/exit pupil size).

Into-the-eye
Possible solutions to problem

• Rescale dimensions of ablation? Difficult – it would be necessary to fully understand the balance between corneal and lenticular higher-order aberrations in individual eye

• Better? Carry out two-stage ablation, correcting the lower-order (refractive error) aberrations in the first pass, remeasuring residual aberrations in the now quasi-emmetropic eye, and correcting these in the second pass.
To be covered by David Atchison....

• The influence of the reference plane used in measuring the aberrations
• The effect of the direction of measurement on the apparent wavefront aberration