

## CHAPTER IX

### Conclusions

The technology to measure corneal and total aberrations implemented and tested during this thesis have been applied in different studies. The results from these studies have led to the following conclusions:

1) When the wave aberration is dominated by the anterior corneal surface (i.e. aphakic eyes or keratoconus), the total aberration is very similar to the corneal aberration pattern, providing a cross-validation test for these techniques.

2) Measurements in a unilateral aphakic eye suggest a negligible contribution of the posterior corneal surface to the aberrations of a normal cornea (2% at most), and a compensatory role of the crystalline lens to the total spherical aberration in normal eyes.

3) Ocular aberrations, particularly spherical aberration, increase significantly after standard LASIK surgery. Although this change is primarily due to corneal aberrations, the actual change depends on the particular interactions of the cornea and lens. We found that 3<sup>rd</sup> and higher order total Root Mean Square (RMS) wave aberrations increase by a factor of 1.92, and the corresponding corneal aberrations by a factor of 3.72. Total spherical aberration changes 0.63  $\mu\text{m}$  on average, while corneal spherical aberration changes 0.74  $\mu\text{m}$ . Our results show a slight shift of the internal spherical aberration toward negative values, consistent with a change in the asphericity of posterior corneal surface with surgery.

4) Rigid Gas Permeable contact lenses can improve optical quality, particularly in subjects with a great amount of corneal aberrations, where we found up to 67% improvement. Measurements of corneal and total aberrations in individual eyes, allowed to assess the impact of corneal/internal balance in the degree of compensation, as well as the effects of lens flexure (or conformity) and the role played by the tear film “lens”.

5) Old patients (average age=70.6 $\pm$ 9) with implanted intraocular lenses have more degraded optical quality than young eyes (average age= 29 $\pm$ 3.7) and do not show significantly less aberrations than eyes before cataract surgery. Corneal aberrations tend

to increase after surgery, likely due to the incision effect. Total aberrations also increase by a lack of balance of the spherical aberration of the corneal by the spherical aberration of the intraocular lens. In vivo, in vitro and computer simulations concluded that conventional spherical IOLs show positive spherical aberrations ( $0.17 \pm 0.12 \mu\text{m}$  on average), proportional to the IOL power. Tilts and decentrations of the IOL induce an increase in comatic aberrations, although the actual values for combinations of tilt and decentration determine largely their impact.

Finally, we have also studied a technique to evaluate the gradient index structure of the crystalline lens leading to the following conclusion: Global optimization is a robust procedure in the gradient index evaluation in a test GRIN lens, even with complex profiles with no experimental errors. When experimental data are affected by errors, the accuracy in the reconstruction decreases significantly.

In summary, combined corneal and total aberrometry are useful tools for exploring the optical properties of the ocular components, and in particular, for quantifying the optical degradation imposed by corneal pathologies and different treatments, either surgical (i.e. corneal refractive surgery or IOL implantation) or non-surgical (i.e. RGP contact lenses).

The implications and possible future directions of the work presented in this thesis include:

- 1) Ocular components and their interactions change across individuals (and treatments), resulting in modifications of the corneal and total aberration pattern. The correlation of the optical aberrations with individual measurements of the geometrical and optical properties of the ocular components will result in an even more complete description and understanding of the imaging forming capabilities of the eye and the development of truly customized eye models.

- 2) There are differences in the aberration pattern in myopic eyes with respect to non myopic eyes. A deeper study of aberrations in myopic eyes, as opposed to hyperopic and emmetropic eyes may provide insight into the etiology of refractive errors and some clues for the most appropriate correction alternative.

- 3) The present thesis reports an increase of total and corneal aberrations with conventional LASIK surgery. The causes of the increase of the aberrations, in relation

to the laser ablation algorithms, laser efficiency and corneal biomechanics deserve further investigations.

4) It has been demonstrated that total and corneal aberrometry allow a detailed evaluation of optical quality with contact lenses, opening wide applications for the customization of lens parameters to improve performance, both with monofocal and multifocal contact lenses.

5) It has been proved that aberrometry allows to evaluate intraocular lenses in vivo, and predictions of optical quality with IOLs using individual eye models. Further studies along these lines may include the effect of tilts and decentrations of the IOLs measured in vivo, as well as new surgical procedures (i.e. micro-incisions) and new lens designs.

6) We have presented a technique based on global optimization to evaluate the gradient index structure of lenses. The future application this technique in the measurement of real crystalline lens GRIN presents important implications in the study of the mechanisms of accommodation and presbyopia.