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Future shock: the long term consequences of refractive surgery

As anyone who has invested in the futures market, read *The Time Machine* by H G Wells, or implanted a closed looped anterior chamber lens can attest, accurately predicting the future can be a difficult and challenging task. With any new surgical technique or procedure there are implicit unknown long and short term risks and consequences. There is no exception in the rapidly changing technology, patient and doctor driven field of refractive surgery, the youngest subspecialty of ophthalmology and a discipline that is evolving at an astonishing pace.

There has been appropriate discussion about the effects of refractive surgery on qualitative aspects of vision such as optical aberration and impaired night vision.[1] The majority of refractive surgery procedures are performed on individuals currently between the ages of 30 and 50. As this population ages, there is also likely to be a significant impact on several other important aspects of ophthalmology that may not be as readily obvious, yet are worthy of careful thought and consideration. It is the goal of this commentary to focus on these areas.

Effect of refractive surgery on eye banking

Refractive surgery techniques induce changes in the curvature, thickness, shape, structural, and biochemical composition of the cornea. Screening potential donor tissue by slit-lamp biomicroscopy alone may not detect prior laser intrastromal keratomileusis (LASIK), photorefractive keratectomy (PRK), or automated lamellar keratoplasty (ALK) procedures. The use of such donor tissue, and the likely decentration of the flattened or, in the case of hyperopia, steepened optical zone in relation to the entrance pupil, may have profound effects on the refractive outcome of the corneal transplant recipient. Even if well centred over the entrance pupil, unexpected central corneal flattening or steepening may result in significant ametropia and anisometropia following penetrating keratoplasty or triple procedures using preoperated donor tissue.

We have recently reported on the efficiency of computerised videokeratography using a vertically oriented instrument and a specially designed globe fixator to screen potential cadaveric corneal donors.[2] Tangential and profile corneal topography maps may prove superior to standard axial formula derived maps in detecting lower dioptric ablations. A significant limitation to this technique is that it is currently restricted to screening whole globes and is not applicable to evaluating corneoscleral rims. There is a pressing need for further research to develop holders for testing corneoscleral rims, to assess handheld videokeratoscopes that can be used to acquire placido images before enucleation for later processing, as well as elevation mapping and non-placido based techniques for screening potential donor corneas. In light of the rapid increase in the number of refractive procedures performed worldwide, such studies should be given a high priority.

Effect of refractive surgery on intraocular pressure measurements

Numerous clinical studies have found a relation between corneal thickness and Goldmann-style tonometer readings.[3–6] In vivo manometric studies of applanation tonometry have similarly shown that corneal thickness has a significant influence on the accuracy of Goldmann-style applanation tonometry.[7–9] In manometric studies, Ehlers *et al*[7] and Whitacre *et al*[9] found a mean error of approximately 5 mm Hg and 3.5 mm Hg respectively in the Goldmann tonometer readings at a true intraocular pressure of 20 mm Hg for each 70 μm change in corneal thickness, with thinner corneas leading to underestimations and thicker corneas resulting in overestimations. Non-invasive clinical studies of patients with presumed low tension glaucoma have found decreased central corneal thickness,[4] while patients with presumed ocular hypertension have been found to have an increased central corneal thickness.[3 5 6] Other factors, such as the physical characteristics and distribution of the collagens and glycosaminoglycans composing the cornea or the presence or absence of such structures as Bowman's membrane, may also affect the resistance of the cornea to indentation.

PRK alters the structure, shape, and thickness of the cornea in vivo, and would therefore be expected to affect the accuracy of applanation tonometry. In a recent study, Mardelli and colleagues found a 0.5 mm Hg mean reduction in tonometer readings associated with a 23 μm reduction in the corneal thickness following PRK.[10] However, a correlation between the change in corneal thickness and the change in tonometer readings was not evident and this was presumed to be due to alteration in the resistance of the cornea to indentation with the removal of Bowman's membrane and the deposition of newly synthesised glycosaminoglycans and collagen material. In addition, the mean depth of ablation was relatively small (mean ablation of 23 μm). A relation between corneal thickness and tonometer readings might be more evident at higher depth of ablation, as when higher degrees of myopia are treated in LASIK or PRK surgery.

PRK causes a mild lowering of the Goldmann tonometer readings, and similar results are likely with LASIK. Definitive study of the magnitude of the effect of PRK on Goldmann tonometer readings will require comparison of Goldmann tonometer readings with manometry in vivo, and the observed effect may be greater at higher intraocular pressures.

The small change in intraocular pressure measurement following PRK is probably not enough to alter a therapeutic decision in an individual patient known to have glaucoma. However, it might delay the recognition that glaucoma is present if a tonometer reading of 21 mm Hg is used as a screening tool for initiating an evaluation of a patient as an ocular hypertensive or glaucoma suspect.

Effect of refractive surgery on intraocular lens calculations

As the population of patients who have had refractive surgery grows and ages, increasing numbers will inevitably go on to have cataract extraction and intraocular lens implantation. Currently, there are no long term or large series reported of phacoemulsification following refractive surgery. Small case series of cataract surgery following radial keratotomy[11–13] and a single report of phacoemulsification following photorefractive keratectomy,[14] however, do serve to highlight the following principles.

In general, the third generation theoretic formulas, such as the Holladay, Hoffer Q, or SRK/T, appear to improve the accuracy of intraocular lens calculations following refractive surgery when compared with regression formulas such as the SRK or SRK II. Newer formulas may also become available for these special cases, which may better predict the effective lens position.

Much of the error inherent in the intraocular lens calculations following keratorefractive surgery stems from difficulties in accurately estimating the corneal power of the eye. Many of the instruments used to measure corneal power assume central sphericity and a radius of curvature of the posterior cornea 1.2 mm steeper than the anterior radius. Following different forms of keratorefractive surgery, there may be significant irregular astigmatism or asphericity. This may be particularly troublesome in cases of radial keratotomy with a small optical zone. Most IOL calculations use a net index of refraction of 1.333 and the anterior radius of the cornea to estimate net corneal power. However, in PRK or LASIK, there is a flattening of the anterior corneal surface with little or no impact on the posterior radius. This change in relation leads to inaccurate estimations of net corneal power by videokeratography, where a net index of refraction of 1.33 will overestimate the change in the central refractive power of the cornea by 14% following LASIK or PRK.[15] In the future, measurements of both the anterior and posterior corneal curvature, the relation of both to the entrance pupil, selective weighting to allow for the Stiles–Crawford effect, and employment of videokeratography algorithms that are more sensitive to spherical aberration may further enhance the accuracy of this measurement.

Corneal power can be determined by calculation if preoperative and postoperative keratometry is known, by a plano hard contact lens over-refraction with a known base curve contact lens in patients whose cataract does not preclude accurate refraction, by computerised videokeratography, and by automated and manual keratometry.[15] The calculation method requires knowledge of keratometry and refraction before and after the keratorefractive procedure and the stabilised postoperative refraction must be measured before the development of myopic shift from nuclear sclerosis. Manual keratometry is generally considered to be the least accurate of these methods, because it measures only four points approximately 1.5 mm from the corneal apex. This measured zone may be more peripheral to the central flattened area, especially following small optical zone radial keratotomy, leading to a lower power intraocular lens calculation and postoperative hyperopia. The cornea may also develop marked, albeit transient flattening, shortly after phacoemulsification in eyes that have had radial keratotomy.[12 13] Whereas large hyperopic shifts and diurnal changes have not been reported following cataract surgery in patients with previous PRK[14] or LASIK, manual or automated keratometry will both overestimate the change in central refractive power following these procedures.[15] The optimal method of determining the keratometric value derived from computerised videokeratography for intraocular lens determinations may vary for each procedure, and the image acquisition itself may also benefit from autofocusing and other advances in technology that may standardise the accuracy and the reproducibility of the measurements.

Finally, long term effects of PRK and LASIK on the stability of refraction are not known, and these could have an impact on intraocular lens calculations and the selection of the postoperative target of refraction. For example, it has been shown that a subset of radial keratotomy patients develop progressive hyperopic shift and against the rule astigmatism with time.[16] In addition, some patients with preoperative lenticular astigmatism have been treated with radial and astigmatic keratotomy, or LASIK or PRK with concurrent laser or incisional astigmatic surgery. Such patients may have a suboptimal outcome following phacoemulsification with intraocular lens implantation or require additional refractive surgery or modified cataract surgery, since the intraocular lens implant will not have the astigmatic properties of their crystalline lens.

Conclusion

As advances continue in refractive surgery, it behoves ophthalmic subspecialists to try and project the future impact and consequences of these procedures. In this commentary, we have given our best assessment of some of the likely long term consequences of refractive surgery on eye banking, intraocular pressure measurements, and intraocular lens calculations. Further research is needed in this area, which could have a profound impact on the public health of an aging population.

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