A BETTER understanding of corneal biomechanics might allow for improved predictability of refractive surgery outcomes and may also improve the pre-operative identification of eyes at risk of developing ectasia after refractive surgery, according to W Lilliam J Dupps MD, PhD.

“Corneal biomechanical properties profoundly influence certain ocular measurements and interventional outcomes and may hold important clues to diagnosing and managing ocular diseases,” said Dr Dupps, speaking at a special Clinical Research Symposium on ‘What needs to be measured in refractive surgery?’ held during the XV Congress of the ESCRS.

He noted that recent advances in imaging and diagnostic technology are making it increasingly possible to derive valuable clinical information from the measurement of certain biomechanical properties of the cornea and ocular coat.

“The measurement of biomechanical properties can help us to make more informed judgements about a patient’s suitability for refractive surgery”

“We all acknowledge the primary importance of safety in refractive surgery. We need to be able to determine as best we can who is or is not a good candidate for refractive surgery, and especially whether they are likely to be at risk for ectasia after surgery. The measurement of biomechanical properties can help us to make more informed judgements about a patient’s suitability for refractive surgery,” said Dr Dupps, Cole Eye Institute, Cleveland, Ohio.

While much progress has been made in the field of ectasia research, Dr Dupps acknowledged that there are still many questions left unanswered.

“We would certainly like to get a better idea of the fundamental pathophysiology of ectatic diseases such as keratoconus. Although these are overtly biomechanical diseases, we have yet to define them in biomechanical terms,” he said.

He noted that one of the more disconcerting aspects of post-LASIK ectasia is the observation by Randleman et al that average onset of the disease is around 16 months after surgery, with some cases that present as late as 45 months postoperatively.

“We are dealing with a long-term problem and the presumptive mechanisms are still not very well understood. There is thought to be a final common pathway of biomechanical weakness that involves both biological predisposition and surgical risk factors,” he said.

He illustrated the complexity of the issue with reference to one patient whose corneal topography maps gave rise to some concern yet whose central corneal thickness was well within normal range.

“These types of patient make us sweat a little because we are faced with conflicting information. Our first thought when we look at the patient is to ask whether, given the information at hand, it is safe to perform any surgery on this patient at all. Once we get beyond this “binary” decision and decide to proceed, then we have to think about minimising the risk of postoperative instability, perhaps by opting for a surface treatment over a lamellar procedure. And finally, once we’ve put safety concerns behind us, we can think about optimising the patient’s optical outcome,” he said.

Dr Dupps noted that there are several different ways that the cornea might respond to the mechanical ‘insult’ of refractive surgery and that individual differences in mechanical properties could account for a wide range of responses, some normal and some pathologic.

These include simple elastic weakening of the kind one would expect from thinning a small area of a pressurised spherical shell. In keratoconus cases, the tensile strength of the cornea is altered and the collagen arrangement is disordered; preclinical variants might predispose to an aberrant elastic response even before definitive topographic or pachymetric abnormalities are seen. There may be abnormalities in the bending resistance of the cornea and the connections between lamellae in some corneas. In cases of late-onset ectasia, viscoelastic mechanisms such as creep and stress relaxation may be of paramount importance, he said.

In answer to the title question posed by the organising committee, Dr Dupps said that proxy variables are currently the most common method of estimating biomechanical properties.

“For example, we can measure central corneal thickness which is probably our primary proxy indicator of biomechanical rigidity, but this can fail us because it does not provide a direct rigidity measurement. Corneal topography is another common proxy for biomechanics. Also for a patient with contact lens warpage, the propensity of their corneas to warp may itself be some predictor of abnormal bending resistance,” he said. Other biomechanical proxies include measurements of residuum stromal thickness and resolution of topographic abnormalities or refractive instability over time, he added.

While proxies are undoubtedly of benefit in trying to detect patients at risk, they also have their limitations as diagnostic tools, said Dr Dupps.

“These are simple measurements and they are part of our standard routine. They don’t cost a lot; they are accessible and the technicians know how to obtain them. We also have a good idea of what the norm should be for a population. However, there is no disguising the fact that they are incomplete representations of the properties that we are trying to measure. And they are also confounded by factors that we are either not measuring or can’t control,” he said.

Measuring corneal hysteresis

Dr Dupps also reviewed the Ocular Response Analyzer (ORA, Reichert Ophthalmic Instruments Inc.), a device for measuring corneal hysteresis. The ORA utilises a high-speed, non-contact application process to obtain measurements of hysteresis as well as intraocular pressure values that account for patient-to-patient differences in certain biomechanical properties.

“Hysteresis is basically an indicator of the viscoelastic resistance of the cornea. As measured by the ORA, it appears to be a fairly independent biomechanical measurement that is not a function of intraocular pressure or central corneal thickness,” he said.

Ongoing studies show that subjects with known corneal abnormalities such as corneal edema or keratoconus not only exhibit low corneal hysteresis values but also demonstrate some characteristic ORA waveform qualities that may contain additional information about the disease state. However, significantly more study will be required to determine the utility of the instrument for identifying surgical candidates at risk for complications. Dr Dupps explained that the corneal hysteresis measurement also provides the basis for additional parameters such as the corneal-compensated intraocular pressure (ICP) and corneal resistance factor (CRF). IOPCC is an intraocular pressure measurement that is less affected by corneal properties than other methods of tonometry such as Goldmann application, while CRF appears to be an indicator of the overall corneal “stiffness” that is affected by corneal thickness.

Dr Dupps said that taking all the various ORA measurements into account might prove helpful in deciding on difficult cases.

“Currently, you might use this device as a tiebreaker. If a patient is a borderline candidate after our standard screening exam and they have a markedly abnormal hysteresis value or waveform compared to normal patients, that might well tip the balance in terms of not proceeding with the surgery,” he said.

Looking forward, Dr Dupps said that there are several enhancements in the pipeline that should make the ORA an even more useful diagnostic tool in the future.

“We need to further ‘mine’ the information contained in the ORA waveforms, and progress on this very problem is being made by Dr Cynthia Roberts and by Reichert. We also need to establish a conservative reference population for safe surgical candidacy, perhaps using ORA and other measurements from patients who actually did well after refractive surgery despite apparently at-risk characteristics. And finally we need to conduct more prospective studies to find out which measurements will prove to be most helpful in a clinical setting,” he said.

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