Understanding corneal properties

David Fleischmann, **Carolin Truckenbrod** and **Dr Simon Barnard** describe the Corvis ST, a new instrument for assessing intraocular pressure that reflects the influence of the cornea

New from Oculus and based on the same Scheimpflug technology as the Pentacam, the Corvis ST is the latest instrument to help us understand and measure the biomechanical properties of the cornea. It is a non-contact tonometer that measures not only intraocular pressure but also corneal thickness and provides additional information about biomechanical properties of the cornea.

Data is gathered using a non-contact tonometer air-jet and a high-speed Scheimpflug camera which captures 4,330 frames per second of the corneal distortion during the applanation process. The Scheimpflug geometry (angle between film plane and objective plane) allows for a focused slit image through the cornea.

It is well known that IOP measurements by Goldmann applanation tonometry (GAT) and non-contact tonometry (NCT) are influenced by the corneal thickness of the cornea. Not so well known is that the IOP measurements are even more affected by the biomechanical properties of the cornea. The results of a theoretical study suggest that the potential error of IOP readings can be huge: the theoretically predicted values between a stiff and a weak cornea can differ up to 10mmHg.[1] Based on the measured IOP, the biomechanical properties and the corneal thickness, the Corvis ST has the potential to determine a highly accurate value close to the 'true IOP'. The Corvis ST can also be used to monitor changes of the deformation response of the cornea caused by, for example, corneal ectasia and corneal cross-linking.

Figure 1 The Corvis ST unit

The Corvis ST fits on a standard slit-lamp table and is connected via USB to a Windows storage system. The construction of the equipment felt solid, with a good level of responsiveness to positioning controls – all done through a standard slit-lamp-style joystick. There is a resistive touch screen panel with manual buttons next to it for additional input. While the touch screen is pleasantly responsive, a click stick, whose main purpose is selecting images, may also be used to enter patient data.

Once patient data has been entered into the database the scan mode is entered using the touch screen or central button on the joystick. Height and vertex adjustment are both done through the joystick, with the machine lowering and raising the chinrest as required; manual control of the chinrest position is also available. Adjustment is very intuitive, with real-time onscreen arrows guiding the user on what alignment adjustments to make. Once in the optimal position the Corvis ST will automatically take the measurements, thus negating operator variance.

How it works

The air jet of the NCT forces the cornea through several distinct phases shown on the Scheimpflug images. The ingoing phase shows the cornea passing from resting shape, through applanation into a concave shape, followed shortly by what is described as an oscillation phase, before lastly entering the outgoing phase, which features a second point of applanation prior to the cornea returning to its natural resting state. IOP calculations are performed at the first point of applanation, ie before any corneal concavity occurs

Analysis of the results, which takes approximately seven seconds, generates three graphs showing deformation amplitude of the cornea, applanation length and corneal velocity over time. A data table below the graphs shows various biomechanical property values in addition to intraocular pressure and corneal pachymetry (Figure 2).

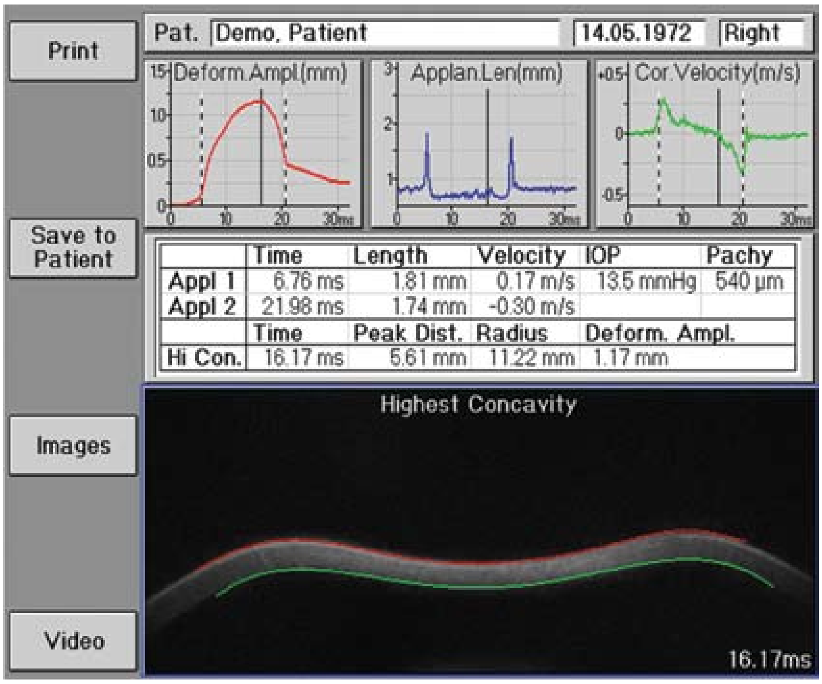

Figure 2 Composite data presentation

Applanation 1 is measured as time ▶

Figure 3 Applanation first achieved

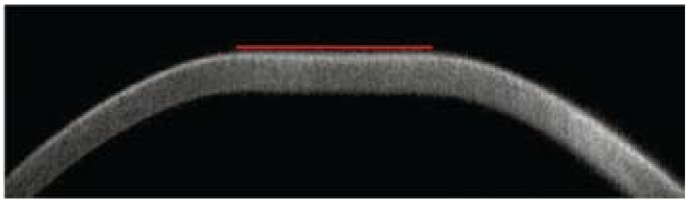

Figure 4 Second applanation after relaxation of the cornea from a concave state (note a shorter length of applanation)

taken to reach applanation and as a length (Figure 3). Applanation 2 is measured on the way back both as a time and a length (Figure 4).

The highest concavity or the deepest point the cornea travelled to is measured in terms of time, radius of curvature and the peak distance (Figure 5). The radius of curvature at highest curvature seems to be an important parameter because it was significantly different in eyes with keratoconus than in normal eyes based on some initial studies of Ambrosio *et al.*[2] In addition first results indicate a significant difference of this value before and after cross-linking but further data have to be collected to prove this.

IOP and pachymetry are measured, although at this time the IOP is not compensated for the effect of corneal thickness. Although the IOP is not corrected, theoretical, experimental and clinical studies are on the way to provide a correction value based on the biomechanical properties of the cornea. Findings suggest the IOP should not be corrected based on the corneal thickness alone as the influence of the corneal thickness on the IOP depends strongly on the biomechanical properties and can be very different for individual patients.[1]

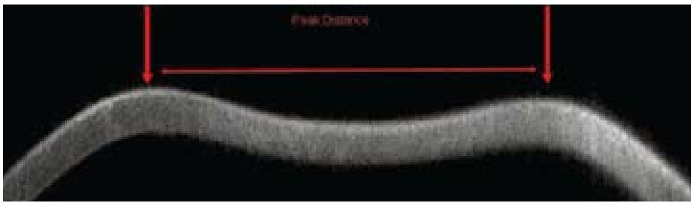

Figure 5 Peak distance measurement

How does this help our understanding of corneal biomechanics?

The Corvis ST can be used to monitor changes in the deformation response of the cornea. In ectatic corneas the viscoelastic properties of the cornea differ from those in normal corneas, so the parameters that describe the deformation response of the cornea can be used to distinguish between normal and ectatic corneas. Studies are being done at present to determine the stiffness of the cornea from the data gathered. In addition a combination value from the different parameters can be useful to separate normal eyes from keratoconus eyes and even eyes with *forme fruste* keratoconus as shown by Renato Ambrosio.[3] The combination of tomographic data (Pentacam) with biomechanical data will further help to identify patients with a higher risk of developing an ectasia after refractive surgery.

Biomechanical properties of the cornea are also changed after corneal cross-linking. Although corneal cross-linking has been established in clinical practice for a couple of years, it is very difficult to determine whether the cornea has become stiffer due to cross-linking. With the Corvis ST we can see significant changes in the deformation response of the cornea after cross-linking. Therefore the Corvis ST has the potential to quantify the effect of corneal cross-linking. Currently it is possible to visualise the effect of corneal cross-linking on the deformation characteristics and on the parameters that describe these characteristics. In future it will be possible to quantify this effect by the increase in stiffness due to corneal cross-linking.

The Corvis ST is potentially an instrument that makes understanding biomechanical corneal properties *in vivo* possible. Having used the Corvis ST over one week it was evident that from a hardware perspective it is an impressive instrument. We compared casually data from the Corvis on a small series of patients, with tonometry readings from our Pascal and Keeler tonometers and corneal thickness measurements from our OCT. Our initial impression is that these appear to correlate well; however, we did not carry out a formal study as we had the instrument for a very limited period.

The database management on the instrument itself is currently limited and the use of a compatible Windows-based computer/laptop is essential. Our limited comparison of the Corvis with the other instruments, particularly the Pascal DCT, suggests it shows promise with regard to accuracy and repeatability. Pachymetry measurement was consistent with the central corneal thickness obtained through anterior segment HD-OCT analysis.

Corneal biomechanical properties appear to be an important factor in the prediction of not only outcomes in corneal refractive surgery but also in the prediction of the precipitation of keratoconic development. The need for technology that allows analysis and display of corneal biomechanical properties in a practice setting will become more pressing in the next few years and the Corvis ST definitely goes a long way to addressing this. ●

References

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