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Editorials

Information fidelity in corneal topography

The refinement and computerisation of the keratoscope and the introduction of the colour coded contour map of corneal surface powers over the past decade have made videokeratography the standard of medical care for anterior segment specialists. The present clinical applications are significant and numerous. They include classification of corneal shape (normal, astigmat, ectasias, and so forth), screening and evaluation in keratorefractive surgery, assessment in cataract intraocular lens procedures, follow up after corneal transplantation, and contact lens fitting. With the growing trend toward applying videokeratography to contact lens fitting, the issue of the accuracy of corneal shape measurement becomes acutely important as Douthwaite points out in this issue of the *BJO* (p 797). However, no less important than instrument accuracy for measuring shape is the need for information fidelity in representing the optics of the cornea with power maps that are useful in routine clinical diagnosis, a distinction upon which this editorial will focus.

Accurate measurement of corneal shape relies upon a sophisticated mathematical approach because there is no exact mathematical solution to the general problem of reconstructing surfaces from reflection keratoscopy (placido disc imagery). The simplest approximations for reconstruction that were originally devised for use with the keratometer constrain corneal shape to spherical or even elliptical geometry. The most rigorous (and accurate) approaches involve extensive computations that require a considerable amount of time, even with the current calculational power of personal computers.[1] More efficient, highly accurate algorithms are likely to be developed as future generations of more powerful computers become available.

Shape accuracy

For the contact lens fitter, a videokeratoscope must be accurate in reporting exactly the true shape of the cornea; the reconstruction algorithms used must create sagittal height or depth numbers that closely match the actual corneal shape. The device must do this with a precision or tolerance that should be specified over the large distances covered by a worn contact lens. The reproducibility of the measurements should be within the needed precision so that repeated measurements do not lead to different recommendations regarding lens fit. The resolution or ability of the device to distinguish important shape changes between two points must be established so that data smoothing or low sampling density do not mask features such as peripheral corneal 'knees' or other anomalies. Finally, the device should gather data and report measurements for all of the corneal surface area over which a contact lens might ride. The accuracy, precision, reproducibility, and resolution of a particular videokeratoscope require independent evaluation, such as is carried out in the article by Douthwaite. It is from such beginnings that standards will evolve to provide an assurance of performance level among manufacturers and technologies in the field.

Information fidelity

While an accurate measure of corneal shape over a wide area is of prime importance for contact lens fitting, for the clinician concerned with the correlation of corneal shape to visual potential and early detection of certain pathologies, the direct examination of corneal shape without amplification is of limited value. Commonly, the necessary amplification is provided by the colour coded contour map of corneal surface powers. For the diagnostician, information fidelity, or the accuracy with which the instrument plays back corneal topography, becomes the overriding concern. The information content of the video image is related to the number of pixels that represent the corneal surface. A device that would use every available pixel could achieve the highest fidelity. In keratoscopy this is achieved by projecting as many closely spaced mires as can be resolved over the greatest corneal surface area. While good peripheral coverage is essential for contact lens fitting, good central corneal coverage is important for quality of vision evaluation.

It has become apparent that for the diagnostic classification of corneal topography, pattern recognition in the colour coded map contours and qualitative colour association to corneal powers are essential. In general diagnostic use, extreme accuracy of power, curvature, or height at any point may not be critical; however, serial evaluation of progressive topographic changes, as in keratoconus or contact lens warpage, is not possible without the repeatability that comes from accurate focus of the videokeratoscope. Nevertheless, more information is available from the corneal surface than is needed or even useful for classification of corneal topography; therefore, the use of a standardised scale that eliminates excess information (including noise) has been recommended.[2] With a range of 28·0 to 65·5 dioptres in 1·5 dioptre intervals, this scale has been used successfully to detect all topographic features of clinical significance.

Power calculations

The general question of instrument accuracy in videokeratography has been the focus of a number of validation efforts that aim to probe the limits of the measurements obtained (p 797).[1 3–11] There are two separate issues that are often incorrectly interchanged when instrument accuracy is discussed. One is the true accuracy of a videokeratoscope, which is measured in terms of its ability to report a set of three dimensional coordinates from a calibrated reference object that is exactly the same as the set of coordinate determined by independent measurement. The second issued, often confused with instrument accuracy, concerns the formulas used to convert the mire coordinates into shape, curvature, and/or power, which may vary from instrument to instrument. Currently, we find ourselves without a consensus on either terminology (some even use the term topology for topography) or the method for calculating corneal power. I continue to recommend that corneal power, D_c, be calculated from the measured local radius of curvature from the relation:

$$D_c=K_i/R_c$$

where D_c is the corneal power in dioptres, R_c is the local radius of curvature in mm, and K_i is the keratometric index (not refractive index) usually taken as 337·5 mm/dioptre. The term R_c can be calculated from successive mires as pointed out some years ago[12]; the proper term for this is the 'instantaneous radius of curvature' and this calculational method has received renewed attention of late.[13 14]

Topographic standards

No matter what the specific application, there is a need to formulate definitions and to set standards for corneal topography that manufacturers can use as guidelines and that clinicians can use to evaluate the numerous options among corneal topography instruments. A committee of the American National Standards Institute (ANSI) has been formed for this purpose. Independently, the International Society for Refractive Surgery has embarked upon a parallel course to establish guidelines. The former committee has a strong engineering component while the latter committee has a strong clinical component. Crossover between the work of these committees could help to establish the groundwork that would be evaluated by the International Standards Organisation. Nearly a decade has passed since the colour coded map was first presented[15]; it is time for the topography community to come together to ensure that corneal topographic devices will have the fidelity necessary to provide the best medical care possible.

There continue to be nay sayers who claim that corneal topography analysis is overrated ('give me a sturdy keratometer and I'll show you the Compleat Diagnostician'). Certainly the technology to measure corneal shape has not reached an evolutionary plateau; raster stereography and light interference techniques, in addition to refinements in keratoscope based devices, could provide delightfully surprising improvements. Based upon current use, however, I believe that computer automated analysis of corneal topography is here to stay because it provides a richness of diagnostic information that cannot, at this time, be obtained in any other way.

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1 Wang J, Rice DA, Klyce SD. A new reconstruction algorithm for improvement of corneal topographical analysis. *Refract Corneal Surg* 1989; **5:** 379–87.
2 Wilson SE, Klyce SD, Husseini ZM. Standardized color-coded maps for corneal topography. *Ophthalmology* 1993; **100:** 1723–7.
3 Wang J, Rice DA, Klyce SD. Analysis of the effects of astigmatism and misalignment on corneal surface reconstruction from photokeratoscopic data. *Refract Corneal Surg* 1991; **7:** 129–40.
4 Wilson SE, Verity SM, Conger DL. Accuracy and precision of the corneal analysis system and the topographic modeling system. *Cornea* 1992; **11:** 28–35.
5 McCarey BE, Zurawski CA, O'Shea DS. Practical aspects of a corneal topography system. *CLAO J* 1992; **18:** 248–54.
6 Koch DD, Wakil JS, Samuelson SW, Haft EA. Comparison of the accuracy and reproducibility of the keratometer and the EyeSys corneal analysis system model I. *J Cataract Refract Surg* 1992; **18:** 342–7.
7 Maguire LJ, Wilson SE, Camp JJ, Verity S. Evaluating the reproducibility of topography systems on spherical surfaces. *Arch Ophthalmol* 1993; **111:** 259–62.
8 Legeais JM, Ren Q, Simon G, Parel JM. Computer-assisted corneal topography: accuracy and reproducibility of the topographic modeling system. *Refract Corneal Surg* 1993; **9:** 347–57.
9 Antalis JJ, Lembach RG, Carney LG. A comparison of the TMS-1 and the corneal analysis system for the evaluation of abnormal corneas. *CLAO J* 1993; **19:** 58–63.
10 Roberts C. The accuracy of 'power' maps to display curvature data in corneal topography systems. *Invest Ophthalmol Vis Sci* 1994; **35:** 3525–32.
11 Roberts C. Characterization of the inherent error in a spherically-biased corneal topography system in mapping a radially aspheric surface. *J Refract Corneal Surg* 1994; **10:** 103–11.
12 Klyce SD. Computer-assisted corneal topography: high resolution graphical presentation and analysis of keratoscopy. *Invest Ophthalmol Vis Sci* 1984; **25:** 1426–35.
13 Carones F, Venturi E, Brancato R, Morico A, Gobbi PG. Instantaneous curvature evaluation of the ablation edge after spheric and aspheric excimer laser PRK for myopia. *Invest Ophthalmol Vis Sci* 1995; **36** (Suppl): S704.
14 Roberts C. Analysis of the inherent error of the TMS-1 topographic modelling system in mapping a radially aspheric surface. *Cornea* 1995; **14:** 258–65.
15 Maguire LJ, Singer DE, Klyce SD. Improved high resolution graphic presentation of computer analyzed keratoscope photographs. *Invest Ophthalmol Vis Sci* 1986; 27 (Suppl): 15.