Making Sense of Keratospeak II: Proposed Conventional Terminology for Corneal Topography

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In an attempt to improve communication in the field of corneal topography and measurement, I propose here some terminology usage that I hope will become conventional. (In Keratospeak I, I addressed the terminology used in refractive surgery.) The terms presented here refer to the corneal surface, its topography and related items, and do not cover corneal optics. This article is not intended as a dictionary. Some individuals have a vested interest in certain terms that may be their favorite, that may refer to the techniques or instruments they prefer, or that may simply sound more familiar and pleasant. I hope that these personal preoccupations will not preclude general agreement on current international terminology and usage. I look forward to the responses of readers of Refractive and Corneal Surgery to these proposals.

Those who feel that dickering over terminology is a waste of time might consider the consequences of unbridled keratospeak as expressed Dr. Stephen Klyce, the guest editor of this issue, “This issue of Refractive and Corneal Surgery is a corneagram for the keratophlic keratogram to better understand the cornea morphology with the keratolithic, keratoanthropic, keratemegalous, keratopendulous, keratophimotic, and schizokeratophrenic corneal anomalies using keratographs and keratographs that even the keratopsychotic keratodolt can interpret.”

MEASUREMENT OF CORNEAL CURVATURE AND SHAPE

Corneal Light Reflection

The image formed by light reflected from the convex anterior corneal surface is first called the Purkinje image, the corneal light reflex, or the corneal light reflection. This virtual, erect image is viewed during keratometry and keratoscopy and is located approximately 4 mm posterior to the surface of the cornea at the level of the anterior lens capsule. Because the reflected image size is determined by the curvature of the cornea (the greater the curvature, the smaller the image), it can be used to quantify corneal curvature and power.

Keratometer (Ophthalmometer)

This is a good example of how colloquial usage can set linguistic standards. "Keratometer" is the trade name of Bausch & Lomb, but like Xerox and Kleenex, the commercial term has taken on a generic use. The original designation by von Helmholtz (1853) for an instrument that measures the central corneal curvature was "ophthalmometer", a term still used outside the United States.

Keratometry (Ophthalmometry)

A keratometer measures corneal curvature in designated meridians by reflection of a mirror from small areas along an annulus 3 to 4 mm in diameter, centered around the apex of the cornea. Keratometry done outside the central cornea must be designated as parasentral or peripheral, using instruments such as the topographer or American Optical keratometer, neither of which is currently marketed.

Radius of Curvature and Refractive Power of the Cornea

The radius of curvature of the anterior and posterior corneal surfaces affect its refractive power (Figure 1). A shorter radius of curvature creates a steeper arc and greater refractive power. Conversely, a longer radius of curvature creates a flatter arc and less refractive power. All keratometers and
keratometers measure the size of the image reflected from the anterior surface of the cornea and calculate the radius of curvature of the anterior surface and the refractive power of the whole cornea, using 1.3375 as the "keratometric" index of refraction for the cornea instead of the true index of 1.376.² ³

**Keratometer**

An instrument that presents a series of mires, most commonly rings, to the corneal surface is a keratometer. Keratometers fitted with a still film camera are called photokeratometers; those fitted with a video camera are called videokeratometers. The term 'corneoscope' is the trade name used by the Kera Corporation.

**Keratoscopy**

Direct observation of the images of mires reflected from the surface of the cornea is keratoscopy, in the same sense that examination of the ocular fundus with an ophthalmoscope is ophthalmoscopy.

**Keratography**

The term keratography denotes a record or portrayal of the cornea in the same sense that angiography records the pattern of vessels. Currently, there are two methods of recording pictures (keratographs) of the mires reflected from the corneal surface. 1) With photographic film, one uses a photokeratoscope to produce a photokeratograph, a process called photokeratography (in the same sense that one uses a photomicroscope to take a photomicrograph). 2) With video recording, one uses a videokeratoscope to produce a videokeratograph, a process called videokeratography.

A keratograph can be interpreted qualitatively or quantitatively. A qualitative interpretation is done by visual inspection of the shape and spacing of the mires and has practical value in diagnosing corneal disorders such as keratoconus or in adjusting sutures after penetrating keratoplasty. Quantitative keratography is done by assigning numerical coordinate values to points on the mires and describing mathematically the curves that the points form. Complex formulas and algorithms are required for accurate quantitation of its topography. Quantitative is usually done with the assistance of a computer that uses image analysis programs and is located in a separate instrument (as in the Kera and Nidek systems -- both photokeratoscopes) or in the keratoscope itself (as in the Computed Anatomy, Visio and KeraView systems -- all computer-assisted videokeratoscopes).

**Topography**

Topography refers to the shape of surfaces, whether they be the surface of the earth or the surface of the cornea. The most common representation
is a topographic map on which the relative elevations of the surface are delimited by contour lines.

**Topographic Displays**

The mires used to study corneal shape have many configurations: circles, arcs, parallel lines, interference fringes, steps. Those most commonly used are circular rings. The concentric ring mires are commonly called Placido rings, but strictly speaking, that designation should describe only Placido's flat disc with the equally spaced circular black rings. Modern keratometer rings are designed differently. By convention, the rings are numbered from innermost to outermost. This can be confusing, because a specific ring (eg, ring 3) in different instruments may cover a different location on different corneas. Therefore, it is important to designate the diameter of a projected ring and indicate the area on the cornea which it covers.

There are four basic methods of displaying corneal topographic information: 1) the keratograph; 2) representation of the radius of curvature or dioptric power at various locations on the surface of the cornea, either in a fixed pattern on a “face plate” or at any location identified by a cursor in a computer-assisted videokeratoscope; 3) graphic three dimensional figures often with exaggerations to show changes in curvature; and 4) color-coded maps using colors to designate areas of uniform radius of curvature and refractive power. The most widely used system of color coding is reds and oranges to indicate steeper areas with greater refractive power and greens and blues to indicate flatter areas with less refractive power (LSU Topography System, Computed Anatomy Corneal Modeling System). A quantitative scale indicates the values corresponding to each color.

**SHAPE OF THE ANTERIOR CORNEA**

**Corneal Asphericity**

The anterior corneal surface is asymmetrically aspheric; that is, the radius of curvature changes from the center to the limbus and does so at a different rate along different semimeridians. Some day our simplified conception of the cornea as a spherocylindrical lens may be replaced by more accurate “shape factors”, mathematical indices or ray tracing diagrams. (See article by Dingeldein et al, pp 372-378.)

A useful simplification to understand the topography of the cornea is to consider the corneal curvature as a section of an ellipse. In most normal corneas, the central zone is steeper than the paracentral and peripheral zones, a configuration referred to as having a positive shape factor (positive because the radius of curvature becomes larger from the center to the periphery) and a prolate shape (the shape of a section across the steep end of an ellipse). The opposite topographic pattern rarely occurs in normal eyes but appears commonly after radial keratotomy: the central zone is flatter than the paracentral and peripheral zones, a configuration referred to as having a negative shape factor and an oblate shape (because it resembles a section across the flatter side of an ellipse) (Figure 1).

**Surface Zones of the Cornea**

A similar oversimplification takes place when the cornea is divided into surface zones (eg, “optical zone”, “apical zone”). None of these areas is discrete, because the cornea forms continuous curves. Nevertheless, for practical optical and anatomic purposes, we can divide the surface of the cornea into two overall regions: the central optical zone and the remainder of the cornea (sometimes called the periphery). The optical zone forms the foveal image through the entrance pupil of the eye; its size, shape and curvature vary among individuals. The rest of the cornea serves as a refracting surface for peripheral vision and for the foveal image when the pupil is widely dilated, as a mechanical structure, and as a source of cells during normal turnover and repair.

Conventionally, four concentric anatomic zones are recognized: (Figure 2) central optical zone, paracentral intermediate zone, peripheral transitional zone, and limbal zone (Figure 3).

**Central Zone**

The central zone is approximately 4 mm in diameter and has been called the apical zone, the corneal cap, the optical zone, the central spherical zone – all terms intended to designate this region of
the visual axis that passes from the center of the foveola through the nodal points of the eye. (Figure 2) Detailed discussion of these often confusing axes can be found in most standard opthalmic and physiological optics textbooks. For practical purposes, the center of the optical zone should be considered the intersection of the pupillary axis with the cornea, because the entrance pupil determines the image forming bundle of rays that reach the foveola.

The term “optical zone” is used with four different meanings in the context of refractive surgery. The first meaning is that just defined, the central more spherical portion of the normal cornea overlying the entrance pupil. The second meaning refers to the portion of a keratomileusis lenticule, epikeratoplasty lenticule or excimer laser surface ablation that creates the major refractive change; in this context, it is possible to decenter the “optical zone”. The third meaning is the central uncut clear zone in radial keratotomy; the term optical zone (OZ) is so engrained in the radial keratotomy literature that it is not likely to disappear, even though the preferred designation is “clear zone”. The fourth meaning is the diameter of any circular mark on the cornea, for example, a “7 mm optical zone” used for placement of transverse incisions; in this context, “optical zone” is truly a misnomer, and should be replaced by the simple designation “zone” or “zone mark”, as in “the transverse incisions were placed at the 7 mm zone”.

**Paracentral Zone**

The paracentral zone is an annulus approximately 4 to 7 mm in diameter and has been called the “mid”, “intermediate” or “mid-Peripheral” cornea. The term “mid-Peripheral” is a misnomer, because this zone does not occupy the middle of the periphery; a transverse incision made at the 6 mm zone is not “mid-Peripheral” because it is still within the central anatomic half of the cornea. The central and paracentral zones together comprise what contact lens fitters call the apical zone.

**Peripheral Zone**

The peripheral zone is an annulus from approximately 7 to 11 mm in diameter. This is the area in which the normal cornea flattens the most and becomes more aspheric. For this reason it has been called the transitional zone.

**Limbal Zone**

The limbal zone is the rim of cornea approximately 0.5 mm wide that abuts the sclera.

**Apex of the Cornea**

The apex of the cornea is the high spot of the cornea, the location of the greatest sagittal height on the surface. It is from this point that the corneal
light reflection emanates and therefore it is the point around which the keratoscopy rings center. The apex or high point of the normal cornea is close to the optical axis. However, in pathological states such as keratoconus and after corneal surgery, the apex may be displaced so that the keratoscopy rings no longer center around any clearly identifiable point or axis on the cornea, or over the entrance pupil. Thus, the patient may be looking through an area of the cornea, eccentric to that in the center of the keratography mires.

**DIRECTIONS ON THE CORNEA: MERIDIANS, SEMIMERIDIANS AND AXES**

Locations on the surface of the cornea are designated along meridians, lines that span the diameter of the cornea from one point on the limbus to the opposite point. Meridians are designated from 0° to 180°, proceeding counterclockwise starting at 3 o'clock for both the right and left eyes. (Figure 4)

The term axis designates the direction in a cylindrical lens along which there is no power; it is parallel to the focal line. Because clinicians align the axes of cylindrical lenses with meridians on the cornea, it is common practice to substitute the term “axis” for “meridian” when referring to directions on the cornea. Thus, clinicians commonly refer to the steep “axis” of a cornea when they mean steep “meridian”, a habit that is unlikely to change. When a clinician says that a correcting cylindrical lens is placed at a certain axis, he is simply using a shorthand way of saying that the axis of the cylinder is placed along a certain corneal meridian; this shorthand is used so commonly as to be acceptable. However, when clinicians refer to the “steep axis” or the “flat axis” of the cornea, the term axis is used incorrectly; the term meridian should be used when referring to the direction of corneal refractive power.

Designating meridians as 0° to 180° is conventional, but, unlike geographers, ophthalmologists have no north-south longitude lines to indicate a point along a meridian. Thus, if one refers to removing a tight corneal suture in the 90° meridian, it is not clear whether the activity

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Figure 4: Terminology describing meridional directions on the surface of cornea and axes of correcting cylindrical lenses.

Figure 5: Terminology describing locations on the cornea.
occurs in the 12 o'clock direction or in the 6 o'clock direction. Therefore, directions from the center of the cornea are designated as semimeridians and are located around the 360° circumference of the cornea in degrees, such as "the 225° semimeridian" (The term semimeridian is preferred, since both components are derived from Latin. The term "hemi-meridian" is a Greek-Latin hybrid, which etymologic purists eschew.) Another convention is to consider the cornea as the face of a clock so that 7:30 o'clock indicates the 225° semimeridian. This clock-hour system is too crude for refractive surgery, which requires more accuracy.

A specific point on the surface of the cornea is designated by indicating its location in millimeters from the center of the cornea along a semimeridian. For example, at 3 mm from the center along the 225° semimeridian the corneal power may be 41.00 D. The location of a transverse incision could be accurately described as follows: it was placed 3 mm from the center at the 6 mm zone perpendicular to the 225° semimeridian (in current jargon, "A T cut was made at the 6 mm optical zone at 7:30.").

**CORNEAL INCISIONS TO CORRECT ASTIGMATISM**

Incisions in the cornea to correct astigmatism are made transversely (perpendicularly) to the steep meridian – a transverse keratotomy ("T cut"), which can be either straight or arcuate. Transverse keratotomies to correct astigmatism after penetrating keratoplasty are commonly called relaxing incisions. Because straight transverse keratotomies are made tangential to the circumference of a specific delimiting zone, they are sometimes called ‘tangential’ incisions, but this term seems inappropriate.

**REFRACTION AND ASTIGMATISM**

Finally, I include some meat-and-potatoes terminology commonly used in the correction of refractive errors. Definitions and details are contained in standard textbooks.

**Refractive of the Eye**

Clinical refraction is the measurement of the spherocylindrical lens required to correct an ametropia.

**Cylinder Axis**

The axis of a cylindrical lens lies along the direction that produces no refractive power. The axis of a plus cylinder lens that corrects corneal astigmatism is oriented along the steepest corneal meridian; the axis of a minus cylinder is aligned with the flattest meridian.

**Astigmatism**

(Greek: A, privative + Stigma, point) The optical condition under which an eye cannot bring an image to a focal point, because the refractive power varies in different meridians. Naturally occurring astigmatism is sometimes mislabeled ‘congenital’ astigmatism, an error because it is not always present at birth.

**Regular Astigmatism**

A deviation of the ocular refraction or the corneal surface from spherical, such that the radius of curvature changes gradually from one meridian to the next.

**Irregular Astigmatism**

Variation in corneal curvature such that the amounts or orientations of the greatest and least curvatures vary across the refractive aperture. This cannot be completely corrected by a cylindrical spectacle lens.

**Net Change in Astigmatism**

The total change in astigmatism between two refractions or two keratometric measurements, regardless of the change in the axis of the correcting cylinder.

**Total Induced Astigmatism**

The difference in the amount of astigmatism at the preoperative axis and the amount of astigmatism at the postoperative axis, as calculated by vector analysis.

**REFERENCES**