Digital Imaging and Communications in Medicine (DICOM)

Supplement 168

Corneal Topography Map Storage SOP Class

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Scope and Field of Application

This Supplement to the DICOM Standard introduces the Corneal Topography Map Storage SOP Class. It is related to devices that create and review ophthalmic corneal topography maps. This SOP Class will be used with several types of ophthalmic devices, alone and/or in conjunction with other DICOM IODs.

These ophthalmic devices produce curvature and/or elevation measurements of corneal anterior and posterior surfaces (e.g., maps that display corneal curvatures, corneal elevations, and corneal power, etc.). The principle methods used include reflection of light from the corneal surface (e.g. Placido ring topography) and multiple optical sectioning or slit beam imaging (e.g. Scheimpflug tomography). A monochrome image is generated and the measurements are mapped topographically as pseudo-color maps as a Palette Color LUT, and used extensively for diagnostic purposes by clinicians and to fit contact lenses in difficult cases.

Changes to NEMA Standards Publication PS 3.2-2011

Digital Imaging and Communications in Medicine (DICOM)

Part 2: Conformance

Item: Add to table A.1-2 categorizing SOP Classes:

The SOP Classes are categorized as follows:

Table A.1-2
UID VALUES

UID Value	UID NAME	Category
…	…	…
1.2.840.10008.5.1.4.1.1.82.1	**Corneal Topography Map Storage**	**Transfer**
…	…	…

Changes to NEMA Standards Publication PS 3.3-2011

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Part 3: Information Object Definitions

Add to normative reference to PS3.3 Section 2

ISO 19980 Ophthalmic instruments — Corneal topographers, second edition

Modify PS3.3 Table A.1-1 to add new IOD: Corneal Topography Map Object

IODs Modules	…	CM	…
Patient		M	
Clinical Trial Subject		U	
General Study		M	
Patient Study		U	
Clinical Trial Study		U	
General Series		M	
Clinical Trial Series		U	
Corneal Topography Map Series		M	
General Equipment		M	
Frame of Reference		M	
Enhanced General Equipment		M	
General Image		M	
Image Pixel		M	
Palette Color Lookup Table		M	
Corneal Topography Map Image		M	
Corneal Topography Map Analysis		M	
Ophthalmic Photography Acquisition Parameters		M	
Acquisition Context		M	
SOP Common		M	

Modify PS3.3 Annex A to Include Corneal Topography Map IOD

A.XX Corneal Topography Map Information Object Definition

A.XX.1 Corneal Topography Map IOD Description

The Corneal Topography Map IOD is generated by ophthalmic corneal topography mapping devices, such as reflection-based topography and elevation-based tomography instruments to generate curvature and/or elevation measurements of corneal anterior and posterior surfaces that are presented topographically using a monochromatic image and a pseudo-color map.

A.XX.2 Corneal IOD Entity-Relationship Model

The E-R Model in Section A.1.2 of this Part depicts those components of the DICOM Information Model that are referenced by the Corneal Topography Map IOD. Below the Series IE, only the Image IE is used.

A.XX.3 Corneal Topography Map IOD Modules

Table A.XX.3-1 specifies the Modules of the Corneal Topography Map IOD.

Table A.XX.3-1
CORNEAL TOPOGRAPHY MAP IOD MODULES

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Clinical Trial Series	C.7.3.2	U
	Corneal Topography Map Series	C.8.X.1	M
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Frame of Reference	Frame of Reference	C.7.4.1	M
Image	General Image	C.7.6.1	M
	Image Pixel	C.7.6.3	M
	Palette Color Lookup Table	C.7.6.3.1.6	M
	Corneal Topography Map Image	C.8.X.2	M
	Corneal Topography Map Analysis	C.8.X.3	M

	Ophthalmic Photography Acquisition Parameters	C.8.17.4	M
	Acquisition Context	C.7.6.14	M
	SOP Common	C.12.1	M

A.XX.4 Corneal Topography Map IOD Content Constraints

The following constraints on Image attributes take precedence over the descriptions given in the Module Attribute Tables.

A.XX.4.1 Prohibited Modules

The Curve Module, Overlay Module and VOI LUT Module shall not be used in a Standard Extended SOP Class of the Corneal Topography Map.

Add text to PS3.3 Annex C section C.7.4.1.1.2

C.7.4.1.1.2 Position Reference Indicator

……...

For a slide-related Frame of Reference, this is the slide corner as specified in C.8.12.2.1 and shall be identified in this attribute with the value “SLIDE_CORNER”. The slide-based coordinate system is described in C.8.12.2.1.

For a corneal vertex based Frame of Reference, this is the corneal vertex determined by the measuring instrument and shall be identified in this attribute with the value CORNEAL_VERTEX_R (for the right eye) or CORNEAL_VERTEX_L (for the left eye). The corneal vertex based coordinate system is described in C.8.X.3.1.4.

Update PS3.3 Annex C for Corneal Topography Map Modules

C.8.X Corneal Topography Map Modules

C.8.X.1 Corneal Topography Map Series Module

Table C.8.X.1-1 specifies the Attributes that identify and describe general information about the Corneal Topography Map Series.

Table C.8.X.1-1
CORNEAL TOPOGRAPHY MAP SERIES MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Modality	(0008,0060)	1	Type of equipment that created the maps in this Series. Enumerated Values: OPM See section C.7.3.1.1.1 for further explanation.

Referenced Performed Procedure Step Sequence	(0008,1111)	1C	Uniquely identifies the Performed Procedure Step SOP Instance to which the Series is related (e.g. a Modality or General-Purpose Performed Procedure Step SOP Instance). Only a single Item shall be permitted in this sequence. Required if the Modality Performed Procedure Step SOP Class, or General Purpose Performed Procedure Step SOP Class is supported.
>Include 'SOP Instance Reference Macro' Table 10-11			
Body Part Examined	(0018,0015)	1	Text description of the part of the body examined. Enumerated Values: EYE Note: Some IODs support the Anatomic Region Sequence (0008,2218), which can provide a more comprehensive mechanism for specifying the body part being examined.

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C.8.X.2 Corneal Topography Map Image Module

Table C.8.X.2-1 specifies the Attributes that describe an Image produced by corneal topography mapping devices.

Table C.8.X.2-1
90 **CORNEAL TOPOGRAPHY MAP IMAGE MODULE ATTRIBUTES**

Attribute Name	Tag	Type	Attribute Description
Instance Number	(0020,0013)	1	A number that identifies this instance.
Content Date	(0008,0023)	1	The date the data creation was started.
Content Time	(0008,0033)	1	The time the data creation was started.
Acquisition DateTime	(0008,002A)	1	The date and time that the acquisition of data that resulted in this image started. Note: The synchronization of this time with an external clock is specified in the Synchronization Module in Acquisition Time Synchronized (0018,1800).
Image Type	(0008,0008)	1	Image identification characteristics. See C.8.X.2.1.1 for specialization.

Samples Per Pixel	(0028,0002)	1	Number of samples (planes) in this image. See C.7.6.3.1.1 for further explanation. Enumerated Values: 1
Photometric Interpretation	(0028,0004)	1	Specified the intended interpretation of the pixel data. See C.7.6.3.1.2 for further explanation. Enumerated Values: PALETTE COLOR
Pixel Representation	(0028,0103)	1	Data representation of pixel samples. Enumerated Values: 0000H = unsigned integer
Include Basic Pixel Spacing Calibration Macro (Table 10-10)			
Pixel Aspect Ratio	(0028,0034)	1	Ratio of the vertical size and horizontal size of the pixels in the image specified by a pair of integer values where the first value is the vertical pixel size, and the second value is the horizontal pixel size.
Bits Allocated	(0028,0100)	1	Number of bits allocated for each pixel sample. Each sample shall have the same number of bits allocated. See PS 3.5 for further explanation. Enumerated Values: 8 16
Bits Stored	(0028,0101)	1	Number of bits stored for each pixel sample. Enumerated Values: 8 16
High Bit	(0028,0102)	1	Most significant bit for pixel sample data. Each sample shall have the same high bit. See PS 3.5 for further explanation. Enumerated Values: 7 (if Bits Stored (0028,0101) = 8) 15 (if Bits Stored (0028,0101) = 16)
Lossy Image Compression	(0028,2110)	1	Specifies whether an Image has undergone lossy compression. Enumerated Values: 00 = Image has NOT been subjected to lossy compression. 01 = Image has been subjected to lossy compression. See C.7.6.1.1.5 for further explanation.

Lossy Image Compression Ratio	(0028,2112)	1C	Describes the approximate lossy compression ratio(s) that have been applied to this image. See C.7.6.1.1.5 for further explanation. May be multivalued if successive lossy compression steps have been applied. Note: For example, a compression ratio of 30:1 would be described in this Attribute with a single value of 30. Required if Lossy Images Compression (0028,2110) is "01".
Lossy Image Compression Method	(0028,2114)	1C	A label for the lossy compression method(s) that have been applied to this image. See C.7.6.1.1.5 for further explanation. May be multivalued if successive lossy compression steps have been applied; the value order shall correspond to the values of Lossy Image Compression Ratio (0028,2112). Required if Lossy Images Compression (0028,2110) is "01".
Burned In Annotation	(0028,0301)	1	Indicates that the image does not contain burned in annotation to identify the patient and date the image was acquired. Enumerated Values: NO
Recognizable Visual Features	(0028,0302)	1	Indicates whether or not the image contains sufficiently recognizable visual features to allow the image or a reconstruction from a set of images to identify the patient. Enumerated Values: YES Note: Corneal topography is similar to finger prints as it is unique to individuals. Therefore, it could be used by a trained person or an expert system to identify the patient.

Image Laterality	(0020,0062)	1	Laterality of object imaged (as described in Anatomic Region Sequence (0008,2218)) examined. Enumerated Values: R = right eye L = left eye Note: This Attribute is mandatory, in order to ensure that images may be positioned correctly relative to one another for display. Shall be consistent with any laterality information contained in Primary Anatomic Structure Modifier Sequence (0008,2230), if present. Note: Laterality (0020,0060) is a Series level Attribute and must be the same for all Images in the Series, hence it must be absent.
Include 'Real World Value Mapping Macro' Table C.7.6.16-12			*Defined Context ID for Measurement Units Code Sequence is 4267*
Include 'General Anatomy Mandatory Macro' Table 10-5			*The concept code for Anatomic Region Sequence (0008,2218) shall be (T-AA000, SRT, "Eye"), and Defined Context ID 244 shall be used for Anatomic Region Modifier Sequence (0008,2220).* *Defined Context ID 4266 shall be used for Primary Anatomic Structure Sequence (0008,2228). Only a single Item shall be permitted in this sequence.* Note: Although Primary Anatomic Structure Sequence (0008,2228) is Type 3, it is important to convey this information if able to be determined.

C.8.X.2.1 Corneal Topography Map Image Module Attribute Descriptions

C.8.X.2.1.1 Image Type

For Corneal Topography Maps, Image Type (0008,0008) is specified to be Type 1 and uses the following Defined Term for Value 3:

CORNEAL_TOPO Identifies a topographic map of the cornea

C.8.X.2.1.2 Corneal Topography Map Real World Value and Image Transformations

The Corneal Topography Map SOP Class supports a sequence of transformations that completely define the conversion of a stored image into a displayed image.

The sequence of transformations from corneal measurements to a displayable image is explicitly defined in a Figure C.8.X.2.1-1. This Figure also conveys the transformation to display the scaling of the color map using its Real World Value Macro (see Table C.7.6.16-12 for more details on the Real World Value Macro).

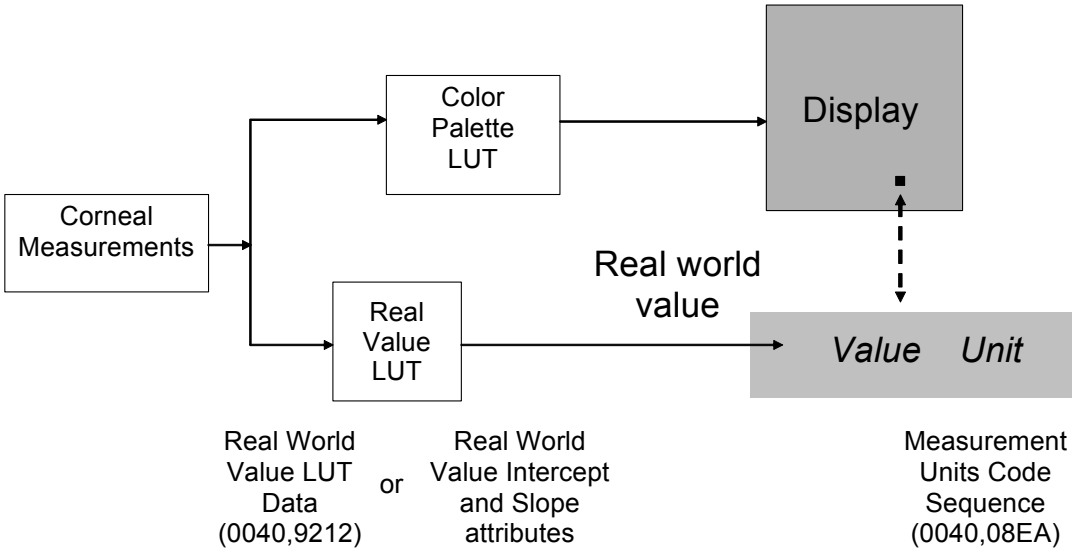

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Figure C.8.X.2.1-1
Corneal Topography Map Real World Value and Image Transformation Pipeline

An SCP of the Corneal Topography Map Storage SOP Class, when rendering SOP Instances of
110 the Class shall apply the image transformations (i.e. Palette Color LUT) and the Real World Value LUT to display the annotated color scale. The annotated color scale shall conform to the "ISO Standard 19980 - Ophthalmic instruments — Corneal topographers, second edition, section B.4 Standardized Colour Scale."

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C.8.X.3 Corneal Topography Map Analysis Module

Table C.8.X.3-1 specifies the Attributes that describe the corneal Topography map analysis.

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Table C.8.X.3-1
CORNEAL TOPOGRAPHY MAP ANALYSIS MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Ophthalmic Mapping Device Type	(0022,1415)	1	Describes the type of ophthalmic mapping acquisition device. See C.8.X.3.1.1 for further explanation. Defined Terms: REFLECTION = Reflection topography (i.e. placido, grid, etc.) SLIT_BASED = Slit based elevation tomography INTERFEROMETRY = E.g. Optical coherence tomography
Corneal Vertex Location	(0046,0202)	1	Location of the corneal vertex. This is used for the reference point for other Attributes within this SOP Instance and determined by the Image referenced in the Attribute Source Image Sequence (0008,2112). Given as column\row. Column is the horizontal offset and row is the vertical offset. Image relative position specified with sub-pixel resolution such that the origin at the Top Left Hand Corner (TLHC) of the TLHC pixel is 0.0\0.0, the Bottom Right Hand Corner (BRHC) of the TLHC pixel is 1.0\1.0, and the BRHC of the BRHC pixel is Columns\Rows (see figure C.10.5-1). The values must be within the range 0\0 to Columns\Rows. This location shall anchor the corneal vertex at the x, y and z coordinates of 0.0, 0.0, 0.0, in mm. See C.8.X.3.1.4 for further explanation.
Corneal Topography Surface	(0046,0201)	1	Identifies the surface of the corneal topography map. Enumerated Values: A = Anterior P = Posterior

Pupil Centroid X-Coordinate	(0046,0203)	1C	The horizontal coordinate of the centroid of the pupil relative to location of the cornea vertex specified in the Attribute Corneal Vertex Location (0046,0202), in mm, such that toward the right is positive. See C.8.X.3.1.4 for further explanation. Required if Attribute Corneal Topography Surface (0046,0201) is A (Anterior). Note: This Attribute is conveyed in mm from the corneal vertex because display applications will have zoom and 3-D rotational capabilities.
Pupil Centroid Y-Coordinate	(0046,0204)	1C	The vertical coordinate of the centroid of the pupil relative to location of the cornea vertex specified in the Attribute Corneal Vertex Location (0046,0202), in mm, such that up is positive. See C.8.X.3.1.4 for further explanation. Required if Attribute Corneal Topography Surface (0046,0201) is A (Anterior). Note: This Attribute is conveyed in mm from the corneal vertex because display applications will have zoom and 3-D rotational capabilities.
Equivalent Pupil Radius	(0046,0205)	1C	The average physical distance in mm from the pupil centroid specified in the Attributes Pupil Centroid X-Coordinate (0046,0203) and Pupil Centroid Y-Coordinate (0046,0204) to the measured perimeter of the pupil. Required if Attribute Corneal Topography Surface (0046,0201) is A (Anterior). Note: When the pupil is not able to be determined the typical estimate is 4mm.
Vertices of the Outline of Pupil	(0046,0208)	1C	A set of row/column vertices that outline the perimeter of the pupil. Two or more pairs of values follow and are the row and column coordinates of the other vertices that outline the perimeter of the pupil. For a two dimensional curve: X1, Y1, X2, Y2, etc. The first (X) dimension corresponds to the image column (horizontal offset), and the second (Y) dimension corresponds to the image row (vertical offset). This is a Polyline and the points are to be interpreted as an n-tuple list of end points between which straight lines are to be drawn. Required if Attribute Corneal Topography Surface (0046,0201) is A (Anterior).
Include 'Keratometric Measurements Macro' Table C.8.25.10-2			

Minimum Keratometric Sequence	(0046,0215)	1	A sequence that specifies the lowest power obtained when averaging individual meridian. Only one item shall be permitted. Note: The measurement is typically taken at 3-4 mm from the corneal vertex.
>Radius of Curvature	(0046,0075)	1	The radius of curvature of the principal meridian of the cornea, measured in mm.
>Keratometric Power	(0046,0076)	1	The refractive power of the cornea at the principal meridian, measured in diopters.
>Keratometric Axis	(0046,0077)	1	The meridian where the keratometric radius of curvature or power is measured, measured in degrees.
Simulated Keratometric Cylinder Sequence	(0046,0218)	1	A sequence that specifies simulated keratometric cylinder power of the corneal surface, measured in diopters. Only one item shall be permitted. Note: This information is obtained from the Steep and Flat Keratometric Axis readings.
>Keratometric Power	(0046,0076)	1	The refractive power of the cornea at the principal meridian, measured in diopters.
>Keratometric Axis	(0046,0077)	1	The meridian where the keratometric cylinder or power is measured, measured in degrees.
Average Corneal Power	(0046,0220)	1	The area-corrected average of the corneal power ahead of the entrance pupil, measured in diopters. Note: It is generally equal to the keratometric spherical equivalent except for decentered refractive surgical procedures. It is used in intraocular lens calculations.
Corneal I-S Value	(0046,0224)	1	Quantifies the inferior–superior dioptric asymmetry along the vertical meridian to discriminate Keratoconus, measured in diopters. Notes: 1. See Rabinowitz YS and McDonnell PJ. “Computer-assisted corneal topography in keratoconus. Refract Corneal Surg. 1989 Nov-Dec;5(6):400-8”. 2. If I-S > 1.4 D, the cornea may be classified as Keratoconus Suspect. If I-S > 1.9, enough asymmetry is present in the topography to classify the cornea as clinical Keratoconus.
Analyzed Area	(0046,0227)	1	The corneal surface area that can be analyzed, measured in mm squared.
Maximum Corneal Curvature Sequence	(0046,0211)	3	A Sequence to convey the maximum curvature and location of the measured corneal topography. Only a single Item is permitted in this sequence.

>Maximum Corneal Curvature	(0046,0212)	1	Maximum curvature in diopters of the measured corneal topography.
>Maximum Corneal Curvature Location	(0046,0213)	1	Location of the corneal maximum curvature. Given as column\row. Column is the horizontal offset and row is the vertical offset. Image relative position specified with sub-pixel resolution such that the origin at the Top Left Hand Corner (TLHC) of the TLHC pixel is 0.0\0.0, the Bottom Right Hand Corner (BRHC) of the TLHC pixel is 1.0\1.0, and the BRHC of the BRHC pixel is Columns\Rows (see figure C.10.5-1). The values must be within the range 0\0 to Columns\Rows.
Surface Regularity Index	(0046,0230)	3	Measures local fluctuations in corneal power (i.e. irregular astigmatism) over the pupil (no units). Note: This value would be about 0.4 for a cornea with good optical quality; at 1.5 and higher, vision falls below normal calculations.
Surface Asymmetry Index	(0046,0232)	3	This index sums the meridional mire-to-mire power changes over the entire corneal surface, increasing as topographic irregularities increase (no units).
Corneal Eccentricity Index	(0046,0234)	3	Index used to measure the eccentricity of the cornea (no units).
Keratoconus Prediction Index	(0046,0236)	3	Index used to indicate the presence of Keratoconus (no units) Note: It is obtained by discrete analysis of the corneal topographic data. (e.g., Invest Ophthalmol Vis Sci 35:2749-2757, 1994).
Decimal Potential Visual Acuity	(0046,0238)	3	The range of best spectacle-corrected distance that might be expected from a functionally normal eye with the topographical characteristics of the analyzed cornea, measured in decimal. Notes: 1. Typical examples--reference standard is 1, severe vision loss is 0.1. 2. See PS 3.17 Ophthalmic Refractive Reports Use Cases for guidance in converting Decimal Potential Visual Acuity to other customarily used display notation such as 20/20 in the US and 6/6 in Britain.

Corneal Topography Map Quality Evaluation	(0046,0242)	1C	Identifies the quality of the topography examination. Enumerated Values: ACCEPTABLE MARGINAL NOT_ACCEPTABLE Required if a quality rating value exists for the corneal topography map
Corneal Topography Map Type Code Sequence	(00046,0207)	1	The type of corneal topography map encoded in this SOP Instance. It specifies the meaning of the pixel values. Only a single Item shall be permitted in this sequence.
>Include 'Code Sequence Macro' Table 8.8-1. Defined Context ID is 4268			
Corneal Topography Mapping Normals Sequence	(0046,0210)	1C	Identifies the data set used for corneal topography mapping values from a normative data base. Required if a normative data base was used. Only a single Item shall be permitted in this sequence.
>Include 'Data Set Identification Macro' Table 10-22			
Source Image Sequence	(0008,2112)	1	The Image SOP Class/Instance pair of the Image that was used to generate this corneal topography map. Note: Attribute Corneal Vertex Location (0046,0202) in this corneal topography map has been generated by the source image and provides the registration of the Corneal Topography Map to the Source Image. See C.8.X.3.1.2 for further explanation. Only a single Item shall be permitted in this sequence.
>Include 'Image SOP Instance Reference Macro' Table 10-3			
>Purpose of Reference Code Sequence	(0040,A170)	1	Describes the purpose for which the reference is made, (i.e., the role the source image or frame(s) played in the generation of this image). Only a single Item shall be permitted in this sequence.
>>Include 'Code Sequence Macro' Table 8.8-1			*The code used shall be (*121322, *DCM, "Source image for image processing operation").*
Source Image Corneal Processed Data Sequence	(0046,0244)	1	Attributes which contain various power, elevation and wavefront measurements at specific points on the cornea of the SOP Instance referenced in Attribute Source Image Sequence (0008,2112). The Attributes are obtained from measurements of curvature or shape of the cornea. See C.8.X.3.1.3 for further explanation. One or more Items shall be present.

>Corneal Point Location	(0046,0247)	1	The x, y, and z coordinate of a point in the image within the cornea, in mm. Where the origin is conveyed by the Attribute Corneal Vertex Location (0046,0202). Note: For two dimensional maps z=0.
>Corneal Point Estimated	(0046,0248)	1	The point defined in Attribute Corneal Point Location (0046,0247) is an estimated point (i.e. interpolated or extrapolated; not an actual measured point). Enumerated Values: Y = Yes N = No
>Axial Power	(0046,0249)	1	Conveys corneal shape characteristics, in diopters. It is determined from the curvature, *r* in mm, of the equivalent sphere with the same slope at a given point on the surface. Axial power = *Km/r,* where Km is the Keratometric Index.
>Tangential Power	(0046,0250)	1	Determined from the curvature (2nd derivative = d2y/dx2) of a point on the cornea, in diopters; also called Instantaneous Power. Emphasizes irregular astigmatism (large variations in higher order aberrations).
>Refractive Power	(0046,0251)	1	Conveys the optical refraction properties of the cornea, in diopters. It is determined from ray tracing using Snell's Law to calculate the true refractive power. Note: It is used to evaluate ocular optics.
>Relative Elevation	(0046,0252)	1	Relative elevation, in micrometers, is calculated from the corneal surface distance from a reference surface (i.e. a sphere or ellipsoid) that intersects the corneal vertex. This value is determined from $z - z_{ref.}$ Where z is conveyed in Attribute Corneal Point Location (0046,0247) and z_{ref} is the elevation of the reference surface.
>Corneal Wavefront	(0046,0253)	1	Corneal wavefront, in micrometers, is calculated from the elevation data by fitting with the Zernike Series expansion. Note: This permits measurement of both low and higher order aberrations and provides the total amount of distortion of the Corneal Wavefront with a Root Mean Square (RMS) value.

C.8.X.3.1 Corneal Topography Map Analysis Module Attribute Descriptions

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C.8.X.3.1.1 Ophthalmic Mapping Device Type

For Ophthalmic Mapping Device Type (0022,1415), Reflection corneal topography, which measures corneal curvature directly, is based on the reflection of a specific pattern from the corneal surface. Placido-based topographers use variations of circular mires, while grid-based

topographers use a rectangular array of point reflections. Slit-based corneal tomography, which measures elevation directly, is based on the projection of multiple slit beams in succession through the cornea (and anterior segment). Some use the Schiempflug optical principle to achieve high resolution over a broad depth of field. Swept source OCT uses high speed scanning to produce its optical sections. Source images for these devices are shown in Figure C.8.X.3.1-1. Example A and B are for reflection types, C is an interferometry type, and D is a slit based type.

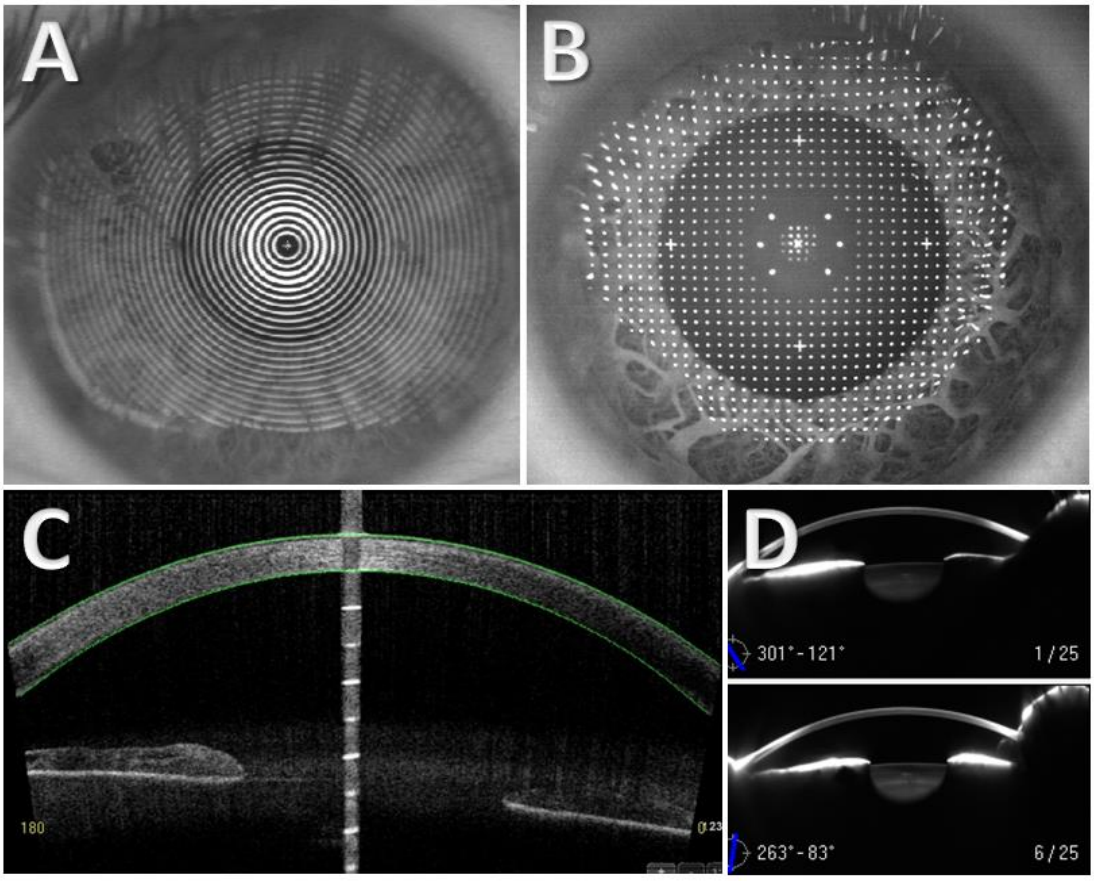

Figure C.8.X.3.1-1 Device types: A. Placido; B. Grid; C. OCT; D. Slit Based

C.8.X.3.1.2 Source Image Sequence

Equipment generating a corneal topography map image first obtains a source image. This image may be single frame or multi-framed such as when the Attribute Ophthalmic Mapping Device Type (0022,1415) is SLIT_BASED or INTERFEROMETRY. From this source image, the necessary measurement data is obtained to build the corneal topography map.

A typical source image may be generated by the Ophthalmic Photography 8 bit or 16 bit SOP Classes for device types of REFLECTION and SLIT_BASED. A typical source image for device type of INTERFEROMETRY would be Ophthalmic Tomography Image SOP Class.

Figure C.8.X.3.1-2 illustrates an example where the source image (left) is generated using a device type of REFLECTION. The corneal topography map and color scale is shown in the center (this is the output of this SOP Class). The right figure shows an example of the corneal topography map and color scale superimposed on the source image.

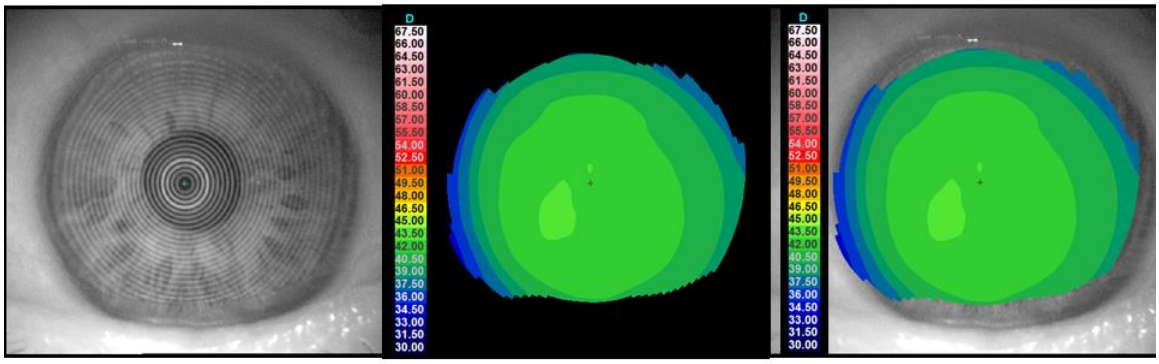

Figure C.8.X.3.1-2 Source Image (left), Corneal Topography Map Image (Center), Corneal Topography Map Presented as an Overlay on the Source Image (right)

C.8.X.3.1.3 Source Image Corneal Processed Data Sequence

The Source Image Corneal Processed Data Sequence (0046,0244) provides power, elevation and wavefront measurements taken at specific points of the Source Image. These Attributes were used to generate the corneal topography map and indices of this SOP Instance. This processed data can also be used to generate other corneal topography maps and indices.

C.8.X.3.1.4 Corneal Vertex Location

The Corneal Vertex Location (0046,0202) establishes the reference point for the corneal vertex. It is used as the frame of reference that establishes the spatial relationship for the corneal vertex (i.e. used within corneal topography maps) for a set of Images within a Series. It also allows Images across multiple Series to share the same corneal vertex Frame Of Reference.

The corneal vertex is the point located at the intersection of the patient's line of sight (visual axis) and the corneal surface. It is represented by the corneal light reflex when the cornea is illuminated coaxially with fixation.

Note: Since the criteria used to group images into a Series is application specific, it is possible for imaging applications to define multiple Series within a Study that share the same imaging space. Therefore the images with the same Frame of Reference UID (0020,0052) Attribute value share the same corneal vertex location within the patient's eye.

Figure C.8.X.3.1-3 illustrates the representation of corneal topography. The corneal vertex lies at the center of the rulers. Typical circular grids are 3, 5, 7, and 9 mm diameters centered on the vertex. The annotations in the figures are R, right; L, left; H = Head; F = Foot.

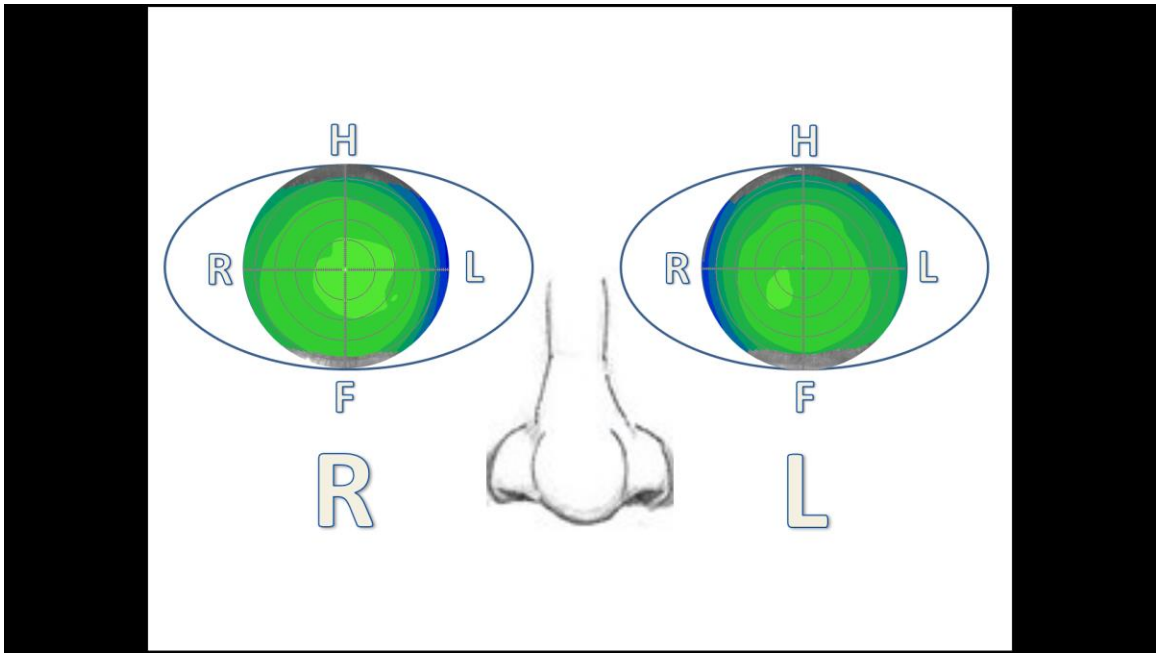

Figure C.8.X.3.1-3 Representation of Corneal Topography

Numerical position data shall use the Cartesian (i.e. two dimensional rectangular) coordinate system. The direction of the axes are determined by the Patient Orientation (0020,0020), see C.7.6.1.1.1 for further explanation.

Devices that internally capture data in polar coordinates will need to convert to Cartesian coordinates, see Figure C.8.X.3.1-4.

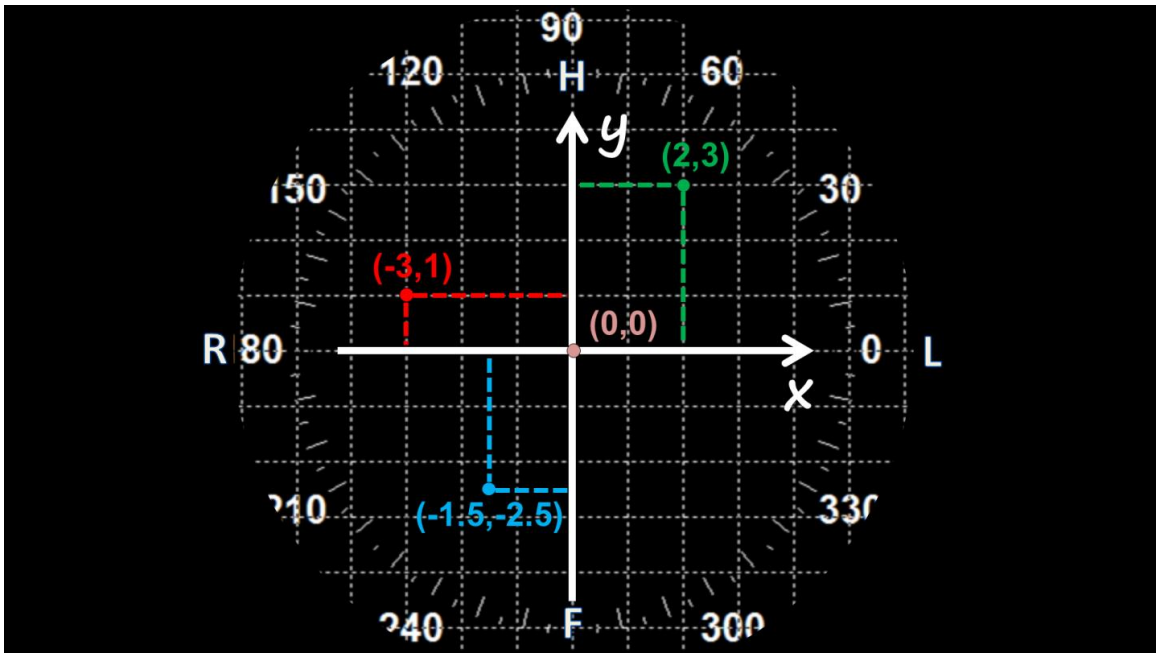

Figure C.8.X.3.1-4 Sample Coordinate Data Points

When using the 3 dimensional coordinates (X, Y, Z), the Z axis shall represent corneal elevation. Z shall be measured from the length of a vector normal to the plane that is normal to and intersects the corneal vertex at the intersection of the x, y, z, axes. It is shown in the diagram as "+" (0.0, 0.0, 0.0). The Z axis shall be positive towards the anterior direction of the eye; (i.e., it is a right-hand rule coordinate system. Thus the Z values (see Figure C.8.X.3.1-5) will be predominantly negative, as they are posterior to the plane of the corneal vertex.

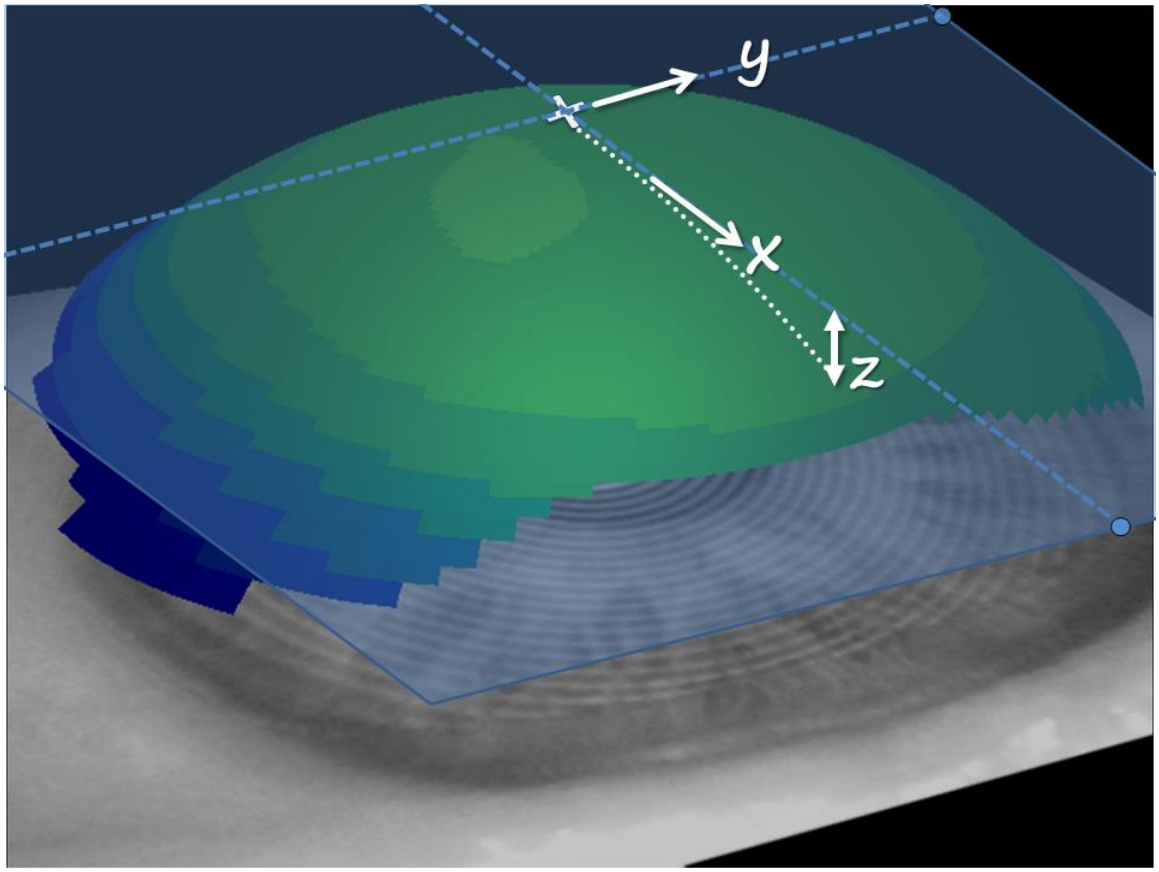

Figure C.8.X.3.1-5 Schematic of the 3-Dimensional Representation of Corneal Elevation

Changes to NEMA Standards Publication PS 3.4-2011

Digital Imaging and Communications in Medicine (DICOM)

Part 4: Service Class Specifications

Add to PS3.4 Annex B.5.

B.5 Standard SOP Classes

Table B.5-1
STANDARD SOP CLASSES

SOP Class Name	SOP Class UID	IOD (See PS 3.3)
…		
Corneal Topography Map Storage	**1.2.840.10008.5.1.4.1.1.82.1**	**Corneal Topography Map**

Add to Annex B.5.1 for Corneal Topography Map Storage SOP Class

B.5.1.X Corneal Topography Map Storage SOP Class

The Corneal Topography Map SOP Class encodes a topographic representation of the curvature and/or elevation measurements of corneal anterior and posterior surfaces (e.g., maps that display corneal curvatures, corneal elevations, and corneal power, etc.).

For a device that is both a SCU and a SCP of the Corneal Topography Map Storage SOP Class, in addition to the behavior for the Storage Service Class specified in B.2.2, the following additional requirements are specified for Corneal Topography Map Storage SOP Classes:

— A SCP of this SOP Class shall support Level 2 Conformance as defined in Section B.4.1.

Note: This requirement means that all Type 1, Type 2, and Type 3 Attributes defined in the Information Object Definition and Private Attributes associated with the SOP Class will be stored and may be accessed.

Add to PS3.4 Annex I.4.

I.4 Media Standard Storage SOP Classes

Table I.4-1
Media Storage Standard SOP Classes

SOP Class Name	SOP Class UID	IOD (See PS 3.3)
…		
Corneal Topography Map Storage	**1.2.840.10008.5.1.4.1.1.82.1**	**Corneal Topography Map**

Changes to NEMA Standards Publication PS 3.6-2011

Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

Add to PS3.6 Annex A

UID Value	UID NAME	UID TYPE	Part
…			
1.2.840.10008.5.1.4.1.1.82.1	**Corneal Topography Map Storage**	**SOP Class**	**PS 3.4**

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Add the following data elements to PS 3.6:

Tag	Name	Keyword	VR	VM
(0046,0201)	Corneal Topography Surface	CornealTopographySurface	CS	1
(0046,0202)	Corneal Vertex Location	CornealVertexLocation	FL	2
(0046,0203)	Pupil Centroid X-Coordinate	PupilCentroidXCoordinate	FL	1
(0046,0204)	Pupil Centroid Y-Coordinate	PupilCentroidYCoordinate	FL	1
(0046,0205)	Equivalent Pupil Radius	EquivalentPupilRadius	FL	1
(0046,0207)	Corneal Topography Map Type Code Sequence	CornealTopographyMapTypeCodeSequence	SQ	1
(0046,0208)	Vertices of the Outline of Pupil	VerticesOfTheOutlineOfPupil	IS	2-2n
(0046,0210)	Corneal Topography Mapping Normals Sequence	CornealTopographyMappingNormalsSequence	SQ	1
(0046,0211)	Maximum Corneal Curvature Sequence	MaximumCornealCurvatureSequence	SQ	1
(0046,0212)	Maximum Corneal Curvature	MaximumCornealCurvature	FL	1
(0046,0213)	Maximum Corneal Curvature Location	MaximumCornealCurvatureLocation	FL	2
(0046,0215)	Minimum Keratometric Sequence	MinimumKeratometricSequence	SQ	1
(0046,0218)	Simulated Keratometric Cylinder Sequence	SimulatedKeratometricCylinderSequence	SQ	1
(0046,0220)	Average Corneal Power	AverageCornealPower	FL	1
(0046,0224)	Corneal I-S Value	CornealISValue	FL	1
(0046,0227)	Analyzed Area	AnalyzedArea	FL	1
(0046,0230)	Surface Regularity Index	SurfaceRegularityIndex	FL	1
(0046,0232)	Surface Asymmetry Index	SurfaceAsymmetryIndex	FL	1
(0046,0234)	Corneal Eccentricity Index	CornealEccentricityIndex	FL	1

(0046,0236)	Keratoconus Prediction Index	KeratoconusPredictionIndex	FL	1
(0046,0238)	Decimal Potential Visual Acuity	DecimalPotentialVisualAcuity	FL	1
(0046,0242)	Corneal Topography Map Quality Evaluation	CornealTopographyMapQuality Evaluation	CS	1
(0046,0244)	Source Image Corneal Processed Data Sequence	SourceImageCornealProcessed DataSequence	SQ	1
(0046,0247)	Corneal Point Location	CornealPointLocation	FL	3
(0046,0248)	Corneal Point Estimated	CornealPointEstimated	CS	1
(0046,0249)	Axial Power	AxialPower	FL	1
(0046,0250)	Tangential Power	TangentialPower	FL	1
(0046,0251)	Refractive Power	RefractivePower	FL	1
(0046,0252)	Relative Elevation	RelativeElevation	FL	1
(0046,0253)	Corneal Wavefront	CornealWavefront	FL	1

Add new rows and modify CID 4264 in PS 3.6 Annex A Table A-3

235 **Table A-3**
CONTEXT GROUP UID VALUES

Context UID	Context Identifier	Context Group Name
...	...	……
1.2.840.10008.6.1.965	**4267**	**Corneal Topography Mapping Units for Real World Value Mapping**
1.2.840.10008.6.1.966	**4268**	**Corneal Topography Map Value Type**
…..		
1.2.840.10008.6.1.940	4264	Ophthalmic ~~**Thickness**~~ Map Purposes of Reference

Changes to NEMA Standards Publication PS 3.16-2011

Digital Imaging and Communications in Medicine (DICOM)

Part 16: Content Mapping Resource

Add the following definitions to Part 16 Annex B DCMR Context Groups (Normative)

CID 4210 Ophthalmic Tomography Acquisition Device

Context ID 4210
Ophthalmic Tomography Acquisition Device
Type: Extensible Version: ~~20110825~~ 20131014

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
….	….	…
DCM	**111945**	**Elevation-based corneal tomographer**
DCM	**111946**	**Reflection-based corneal topographer**
DCM	**111947**	**Interferometry-based corneal tomographer**

CID 4267 Corneal Topography Mapping Units for Real World Value Mapping

Context ID 4267
Corneal Topography Mapping Units for Real World Value Mapping
Type: Extensible Version: 20131014

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
UCUM	um	micrometer
UCUM	diop	diopters
UCUM	mm	mm

CID 4268 Corneal Topography Map Value Type

Context ID 4268
Corneal Topography Map Value Type
Type: Extensible Version: 20131014

Coding Scheme Designator	Code Value	Code Meaning
DCM	111940	Corneal axial power map
DCM	111941	Corneal instantaneous power map
DCM	111942	Corneal refractive power map
DCM	111943	Corneal elevation map
DCM	111944	Corneal wavefront map

CID 4264 Ophthalmic ~~Thickness~~ Map Purposes of Reference

Context ID 4264
Ophthalmic ~~Thickness~~ Map Purposes of Reference
Type: Extensible Version: 20110825

CID 4266 Ophthalmic Anatomic Structure Reference Point

Context ID 4266
Ophthalmic Anatomic Structure Reference Point
Type: Extensible Version: ~~20110825~~20131014

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
….	…….	…….
SRT	**T-AA215**	**Entire Cornea**

Add the following definitions to Part 16 Annex D DICOM Controlled Terminology Definitions (Normative)

Annex D DICOM Controlled Terminology Definitions (Normative)

Code Value	Code Meaning	Definition	Notes
…	…	…	
111940	**Corneal axial power map**	**A two dimensional representation of the axial curvature of the cornea. Axial curvature is calculated from the reciprocal of the distance from a point on a meridian normal at the point to the corneal topographer axis. Also known as sagittal curvature.**	

111941	Corneal instantaneous power map	A two dimensional representation of the instantaneous curvature of the cornea. Instantaneous curvature is calculated from the reciprocal of the distance from a point on a meridian normal at the point to the center of curvature of that point. Also called tangential curvature.	
111942	Corneal refractive power map	A two dimensional representation of the refractive power of the cornea. Corneal refractive power is calculated using Snell's Law.	
111943	Corneal elevation map	A two dimensional representation of the elevation of the cornea. Elevation is calculated as the distance from a point on the corneal surface to a point on a reference surface along a line parallel to the corneal topographer axis. For the purpose of visualization the reference surface is usually a sphere or an ellipse.	
111944	Corneal wavefront map	A two dimensional representation of a wavefront aberration surface of the cornea. Wavefront aberration surface is calculated from the corneal elevation data fit with either the Zernike polynomial series or the Fourier Series. Maps generally display total aberrations and selectable higher order aberrations.	
111945	Elevation-based corneal tomographer	A device that measures corneal anterior surface shape using elevation-based methods (stereographic and light slit-based). Rasterstereography images a grid pattern illuminating the fluorescein dyed tear film with 2 cameras to produce 3D. Slit-based devices scan the cornea, usually by rotation about the instrument axis centered on the cornea vertex.	
111946	Reflection-based corneal topographer	A reflection-based device that projects a pattern of light onto the cornea and an image of the reflection of that pattern from the tear film is recorded in one video frame. Light patterns include the circular mire pattern (Placido disc) and spot matrix patterns. Sequential scanning of light spots reflected from the corneal surface is also used requiring multiple video frames for recording.	
111947	Interferometry-based corneal	An Interference-based device that projects a beam of light onto and	

	tomographer	**through the cornea. Light reflected from within the cornea is combined with a reference beam giving rise to an interference pattern.** **Appropriately scanned, this imaging is used to construct 3-dimensional images of the cornea from anterior to posterior surfaces. An example of this is swept source OCT.**	

Changes to NEMA Standards Publication PS 3.17-2011 Digital Imaging and Communications in Medicine (DICOM)

Part 17: Explanatory Information

Add to PS3.17 Annex Y

Annex Y Corneal topography and tomography maps (Informative)

Y.1 Introduction

Several ophthalmic devices produce curvature and/or elevation measurements of corneal anterior and posterior surfaces (e.g., maps that display corneal curvatures, corneal elevations, and corneal power, etc.). The principle methods used include reflection of light from the corneal surface (e.g. Placido ring topography) and multiple optical sectioning or slit beam imaging (e.g. Scheimpflug tomography). The measurements are mapped topographically as pseudo-color maps, and used extensively for diagnostic purposes by clinicians and to fit contact lenses in difficult cases. The underlying data from these measurements is also used to guide laser sculpting in keratorefractive surgery.

Y.2 Corneal Topography Scales and Color Palettes

The method for presenting corneal topography maps with pseudo-colored images has been studied extensively. Contour maps are effective for diagnostic purposes. The proper scaling is important so that clinically important detail is not obscured as well irrelevant detail masked. This can be done with a scale that has fixed dioptric intervals. The choice of color palette to represent different levels of corneal power is equally important. There must be enough contrast between adjacent contour colors to provide pattern recognition; it is the corneal topography pattern that is used for clinical interpretation. A color palette can be chosen so that lower corneal powers are represented with cooler colors (blue shades), while higher corneal powers are represented with the warmer colors (red shades). Green shades are used to represent corneal powers associated with normal corneas. The standard scale is shown in Figure Y.2-1.

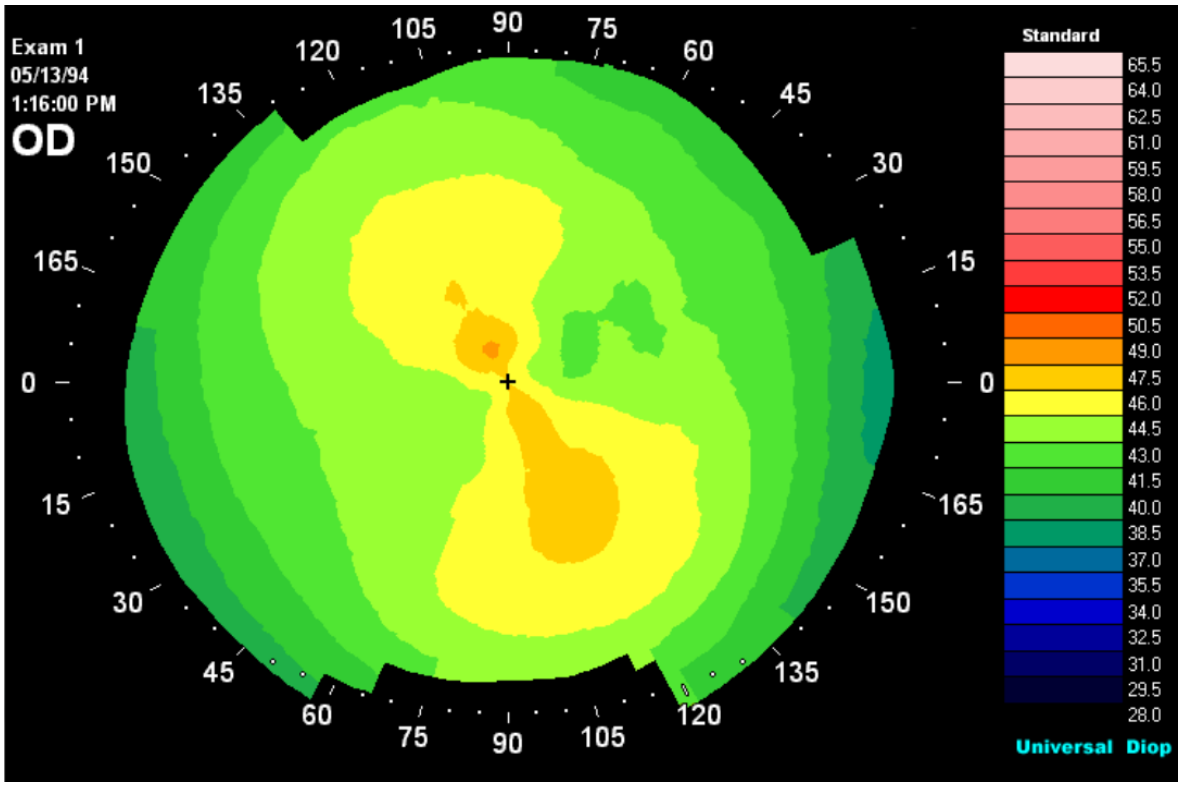

Figure Y.2-1 - Scale and Color Palette for Corneal Topography Maps

Y.3 Corneal Topography Examples

Quantitative measurements of anterior corneal surface curvature (corneal topography) are made with the Placido ring approach. Patterns on an illuminated target take the form of mires or a grid pattern. Their reflection from the anterior corneal surface tear film, shown in Figure Y.3-1, is captured with a video camera. Their positions relative to the instrument axis are determined through image analysis and these data are used to calculate anterior corneal curvature distribution.

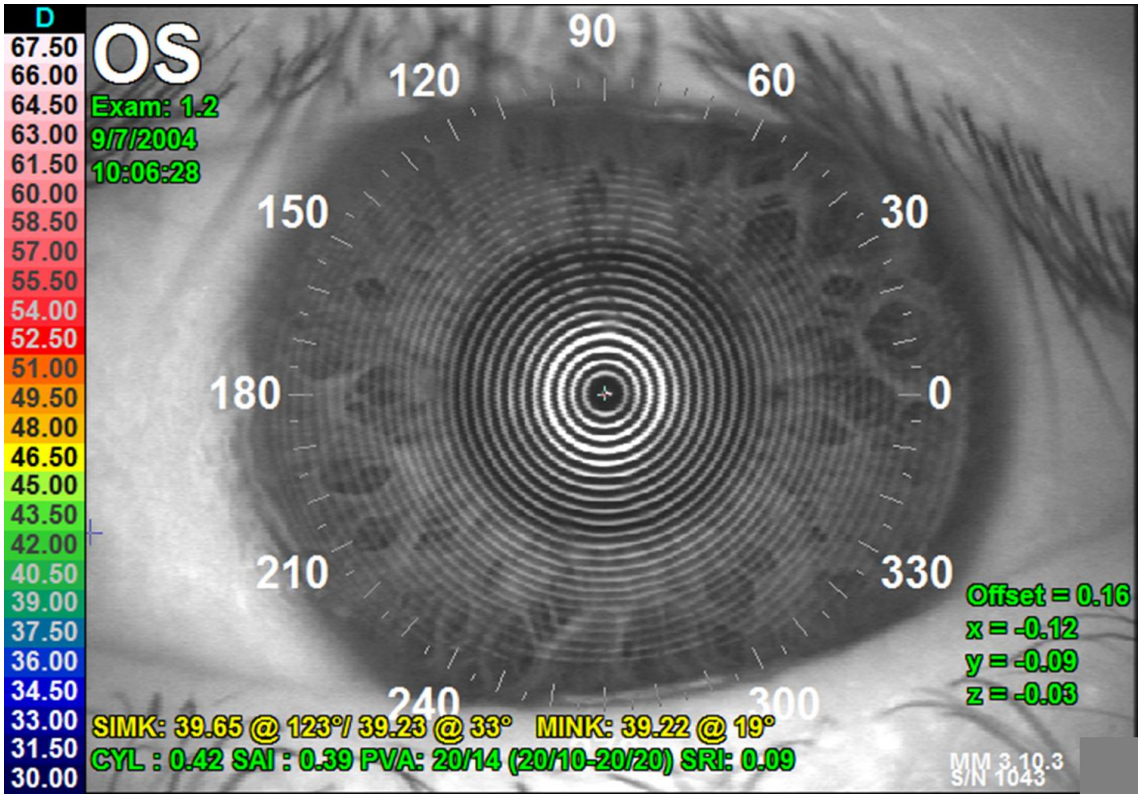

Figure Y.3-1 - Placido Ring Image example

Corneal curvature calculations are accomplished with three different methods that provide corneal powers. The axial power map, shown in Figure Y.3-2, is most useful clinically for routine diagnostic use as the method of calculation presents corneal topography maps that match the transitions known for corneal shape—the cornea is relatively steep in its central area, flattening toward the periphery. This figure shows an example where the map is superimposed over the source image based upon the corneal vertex Frame of Reference. The Blending Presentation State SOP Class may be used to specify this superimposed processing.

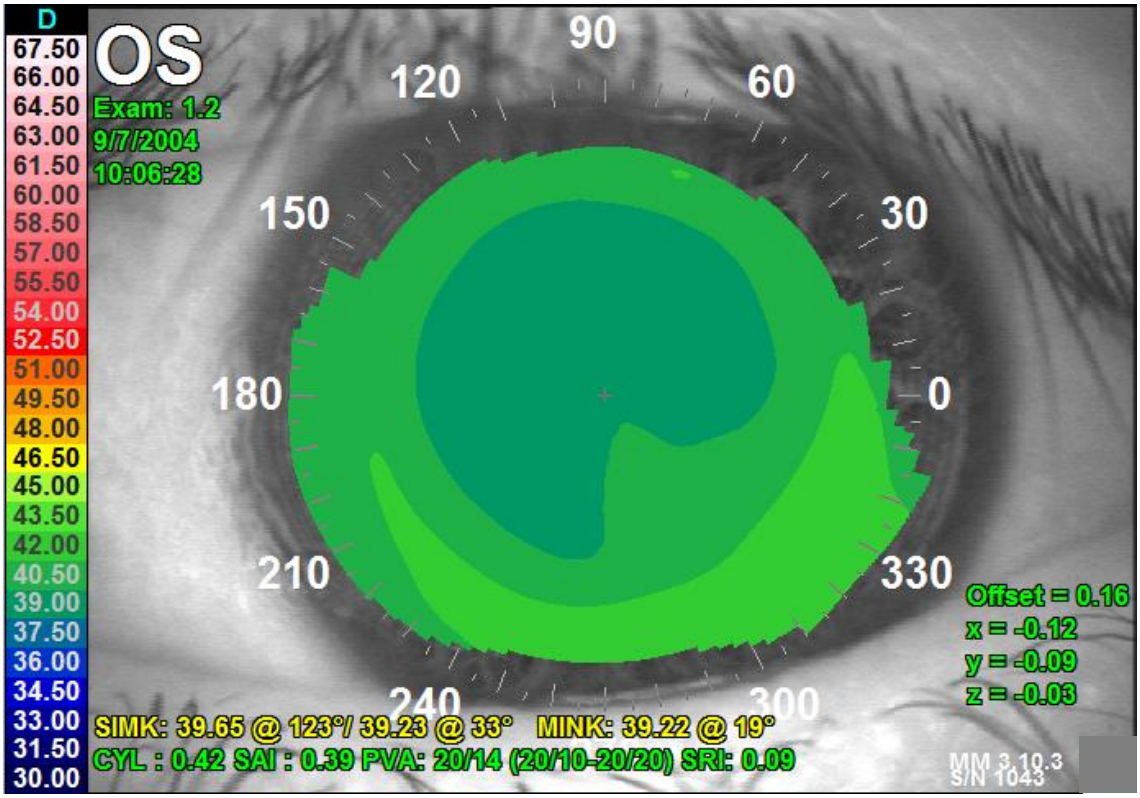

Figure Y.3-2 - Corneal Topography Axial Power Map Example

The instantaneous power map, shown in Figure Y.3-3, reveals more detail for corneas that have
330 marked changes in curvature as with the transition zone that rings the intended optical zone of a refractive surgical procedure.

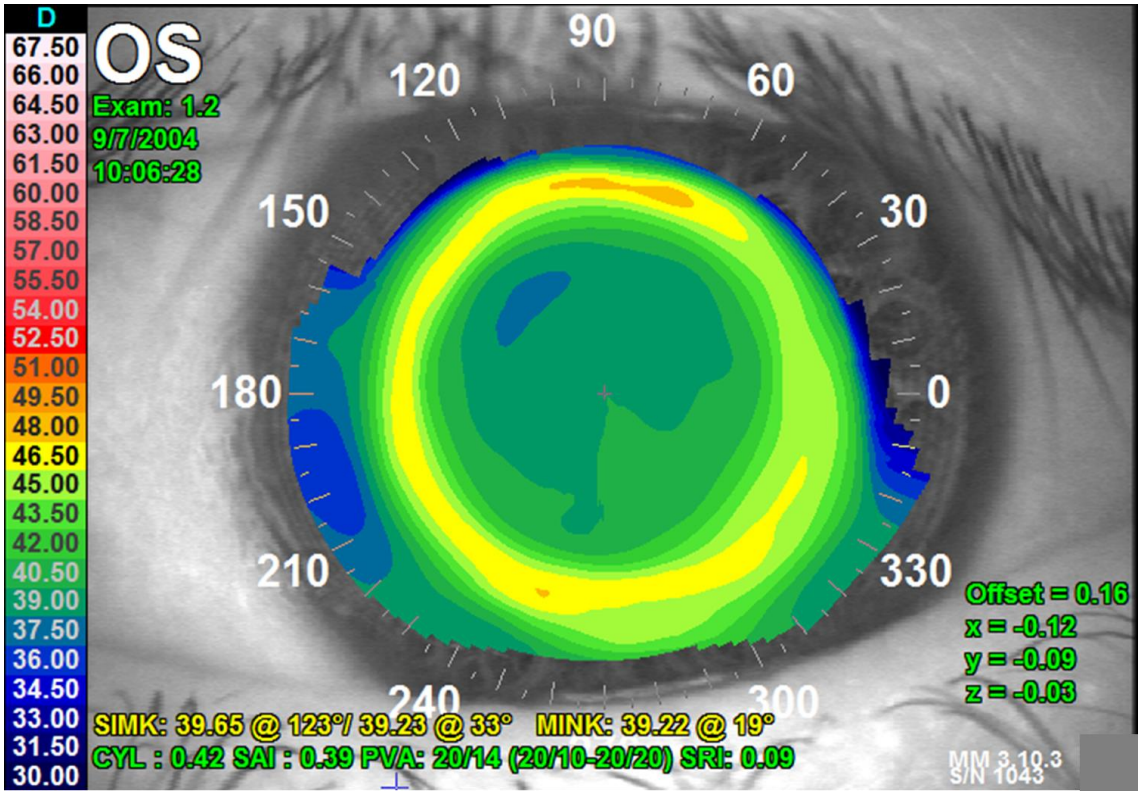

Figure Y.3-3 - Corneal Topography Instantaneous Power Map Example

The refractive power map, shown in Figure Y.3-4, uses Snell's Law of refraction to calculate corneal power to reveal, for example, uncompensated spherical aberration.

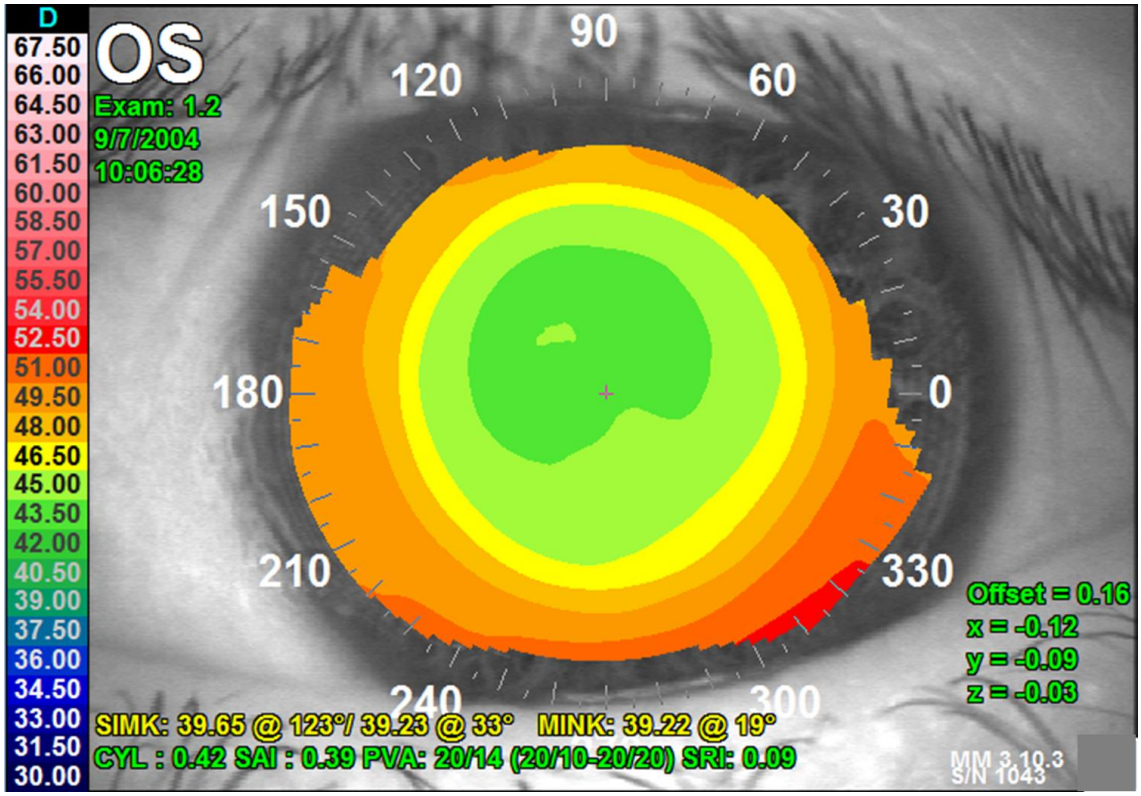

Figure Y.3-4 - Corneal Topography Refractive Power Map Example

The height map, shown in Figure Y.3-5, displays the height of the cornea relative to a sphere or ellipsoid.

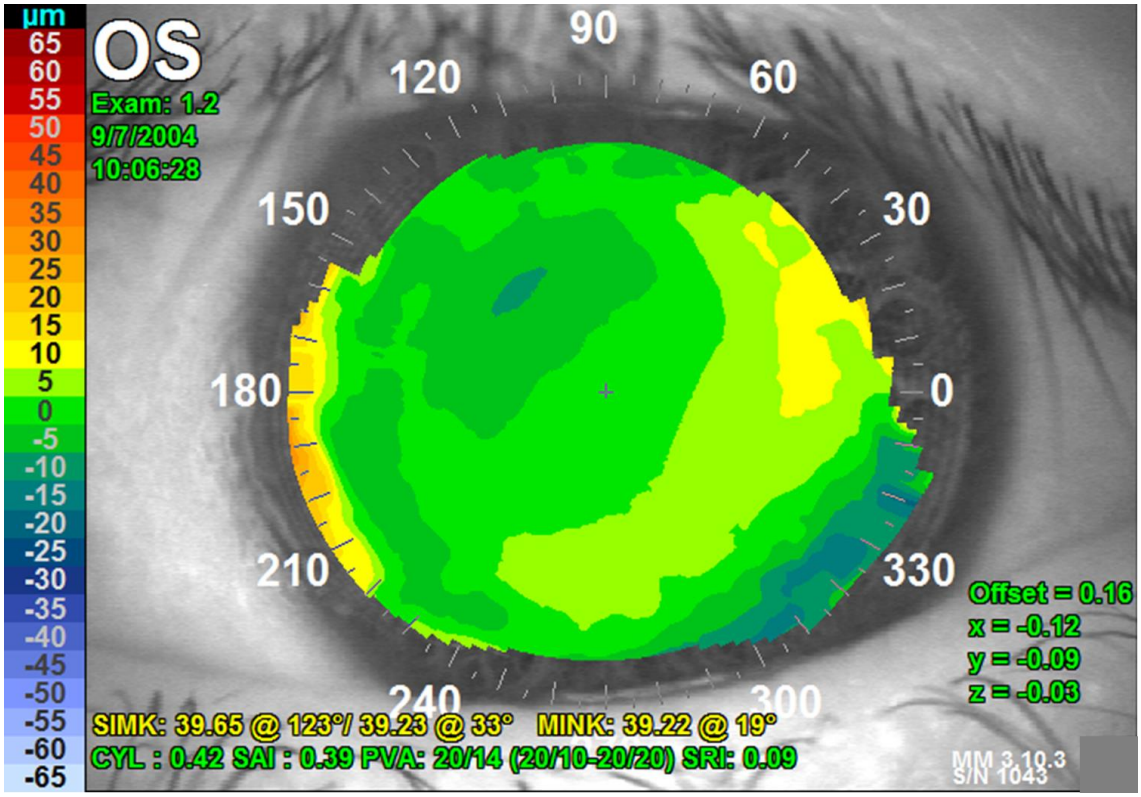

Figure Y.3-5 - Corneal Topography Height Map Example

Y.4 Contact Lens Fitting Examples

Knowledge of the anterior corneal shape is helpful in the fitting of contact lenses particularly in corneas that are misshapen by trauma, surgery, or disease. A contact lens base curve inventory or user design criteria are provided and these are used to evaluate contact lens fit and wear tolerance using a simulated clinical fluorescein test, shown in Figure Y.4-1. The fluorescein pattern shows the contact lens clearance over the cornea. Numbers indicate local clearance in micrometers.

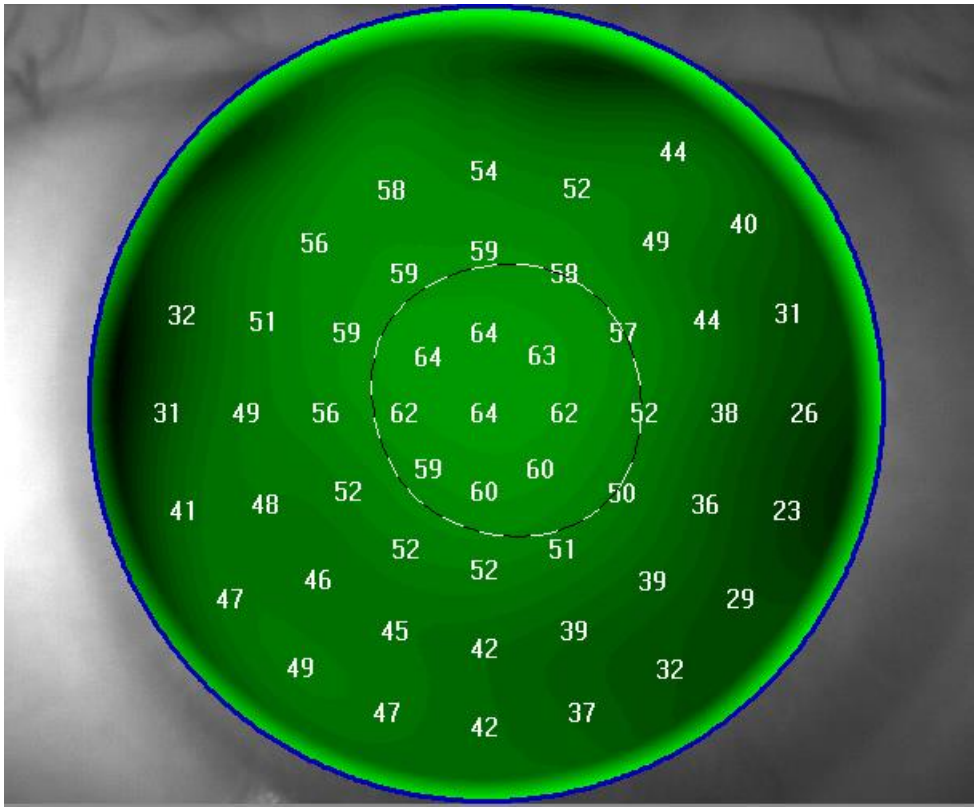

Figure Y.4-1 - Contact Lens Fitting Simulation Example

Y.5 Wavefront Map Example

Ocular wavefront produces a measurement of optical path difference (OPD) between ideal optical system and the one being measured. Typically the OPD is measured and displayed in units of microns. Wavefront maps can be produced from the corneal surfaces, most often the front surface, since this is the major refracting surface in the eye account for about 80% of the ocular power.

Wavefront maps can be calculated directly from corneal elevation data most often using the Zernike polynomial fitting series. With this method, corneal optical characteristics such as astigmatism, spherical aberration, and coma can be calculated. Generally, the lower order (LO) aberrations (offsets, refractive error and prism) are eliminated from display, so that only the higher order (HO) aberrations remain, shown in Figure Y.5-1.

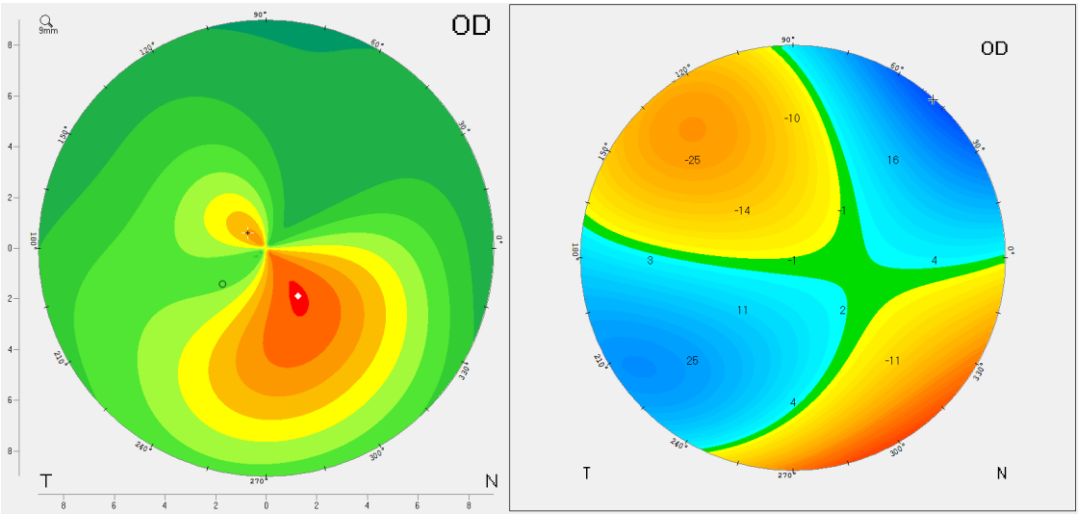

Figure Y.5-1 – Corneal Axial Topography Map of keratoconus (left) with its Wavefront Map showing higher order (HO) aberrations (right). Numbers indicate deviations from a perfect optical element.