Digital Imaging and Communications in Medicine (DICOM)

Supplement 110: Ophthalmic Tomography Image Storage SOP Class

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Foreword

Ophthalmic Tomography devices require a DICOM IOD for information exchange at a similar priority to ophthalmic photography devices. WG 9 examined existing DICOM tomography IODs, such as for enhanced MR and ultrasound. Some of the reasons these existing IODs are not adequate are:

a. Existing tomography IODs do not include general ophthalmology attributes such as those included in the OP IOD, and are in other ways specialized for other modalities. Ophthalmic context information is required for Ophthalmic Tomography information exchange.

b. Existing tomography IODs are specialized for their own non-ophthalmic modalities.

c. The OP IOD does not include the reference information required for tomography. The Frame of Reference module used by existing tomography IODs is also needed for an OPT IOD.

This Supplement to the DICOM Standard introduces a new IOD and SOP Class for ophthalmology tomographic imaging techniques. The new IOD will be used with several types of ophthalmic imaging devices that produce tomographic images of internal retinal structures, and also of the anterior chamber. Images created may be single frame or multi-frame. Ophthalmic tomographic imaging may incorporate dyes. The acquired images are always monochrome; pseudo-color presentation information may be applied through the use of a Palette LUT at a viewing station.

The ophthalmic tomographic imaging devices typically produce non-tomographic (fundus) reference images that may be represented using either the 8-bit or 16-bit Ophthalmic Photography Image Information Object.

This supplement is not intended to support ophthalmic ultrasound or scanning laser backscatter modalities, nor does it support derived ophthalmic images such as 3D renderings and thickness maps. Separate IODs may be introduced in the future for those purposes.

This Supplement proposes changes to the following Parts of the DICOM Standard:

PS 3.2 -	Conformance
PS 3.3 -	Information Object Definitions
PS 3.4 -	Service Class Specifications
PS 3.6 -	Data Dictionary
PS 3.16-	Content Mapping Resource
PS 3.17 -	Explanatory Information

PART 2 Addendum

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
…	…	…
1.2.840.10008.5.1.4.1.1.77.1.5.4	**Ophthalmic Tomography Image**	**Transfer**
…	…	…

Part 3 Additions

Modify PS3.3 Section 4

4 Symbols and Abbreviations

OPT Ophthalmic Tomography

Modify PS3.3 Table A.1-1 to add new IOD: Ophthalmic Tomography Object

IODs **Modules**	…	**OPT**	…
Patient		**M**	
Clinical Trial Subject		**U**	
General Study		**M**	
Patient Study		**U**	
Clinical Trial Study		**U**	
General Series		**M**	
Ophthalmic Tomography Series		**M**	
Clinical Trial Series		**U**	
…			
Frame of Reference		**C**	
Synchronization		**C**	
…			
General Equipment		**M**	
Enhanced General Equipment		**M**	
…			
Image Pixel		**M**	
Enhanced Contrast Bolus		**C**	
…			
Multi-frame Functional Groups		**M**	
Multi-frame Dimension		**M**	
…			
Acquisition Context		**M**	
Cardiac Synchronization		**C**	

Ophthalmic Tomography Image		**M**	
Ocular Region Imaged		**M**	
Ophthalmic Tomography Parameters		**M**	
Ophthalmic Tomography Acquisition Parameters		**M**	
…			
SOP Common		**M**	

Modify PS3.3 Annex A

A.XX Ophthalmic Tomography Image Information Object Definition

This Section defines an Information Object to be used with optical ophthalmic tomographic imaging devices, including optical coherence scanners and confocal scanning laser ophthalmoscopes, but excluding ophthalmic ultrasound devices.

A.XX.1 Ophthalmic Tomography Image IOD Description

The Ophthalmic Tomography Image IOD specifies a single-frame or a multi-frame image acquired on an Ophthalmic Tomography modality. This IOD can be used to encode both single and multi-frame ophthalmic images.

A.XX.2 Ophthalmic Tomography Image 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 directly reference the Ophthalmic Tomography Image IOD. Table A.XX.3-1 specifies the Modules of the Ophthalmic Tomography Image IOD.

A.XX.3 Ophthalmic Tomography Image IOD Modules

Table A.XX.3-1
OPHTHALMIC TOMOGRAPHY IMAGE 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
	Ophthalmic Tomography Series	C.8.17.X1	M
Frame of Reference	Frame of Reference	C.7.4.1	C – Required if Ophthalmic Photography Reference Image available

	Synchronization	C.7.4.2	C – Required if Ophthalmic Photography Reference Image available
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Image	Image Pixel	C.7.6.3	M
	Enhanced Contrast/Bolus	C 7.6.4b	C – Required if contrast was administered
	Multi-frame Functional Groups	C.7.6.16	M
	Multi-frame Dimension	C.7.6.17	M
	Acquisition Context	C.7.6.14	M
	Cardiac Synchronization	C.7.6.18.1	C – Required if cardiac synchronization was used
	Ophthalmic Tomography Image	C.8.17.X2	M
	Ophthalmic Tomography Acquisition Parameters	C.8.17.X3	M
	Ophthalmic Tomography Parameters	C.8.17.X4	M
	Ocular Region Imaged	C.8.17.5	M
	SOP Common	C.12.1	M

A.XX.4 Ophthalmic Tomography Image IOD Content Constraints

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

A.XX.4.1 Contrast/Bolus Agent Sequence

For Contrast/Bolus Agent Sequence (0018,0012), the Defined Context Group is 4200.

A.XX.4.2 Overlay Plane Module and VOI LUT Module

The Overlay Plane Module and VOI LUT Module shall not be used in a Standard Extended SOP Class of the Ophthalmic Tomography Image.

Note: In order to annotate images, whether during acquisition or subsequently, SOP Instances of the Grayscale Softcopy Presentation State Storage or the Structured Report Storage SOP Classes that reference the image SOP Instance may be used.

Pseudo-color presentation information may be applied through the use of separate Pseudo-color Softcopy Presentation State SOP instances.

No standard mechanism is provided for inclusion of annotations within the image SOP Instance itself and implementers are discouraged from using private extensions to circumvent this restriction.

A.XX.4.3 Ophthalmic Tomography Image Functional Group Macros

Table A.XX.4.3-1 specifies the use of the Functional Group macros used in the Multi-frame Functional Group Module for the Ophthalmic Tomography Image IOD.

Table A.XX.4.3-1
OPHTHALMIC TOMOGRAPHY FUNCTIONAL GROUP MACROS

Function Group Macro	Section	Usage
Pixel Measures	C.7.6.16.2.1	M
Frame Content	C.7.6.16.2.2	M – May not be used as a Shared Functional Group.
Plane Position	C.7.6.16.2.3	C – Required if no Ophthalmic Photography Reference Image available; May be present otherwise
Plane Orientation	C.7.6.16.2.4	C – Required if no Ophthalmic Photography Reference Image available; May be present otherwise
Referenced Image	C.7.6.16.2.5	C – Required if Ophthalmic Photography Reference Image available.
Derivation Image	C.7.6.16.2.6	C – Required if the image or frame has been derived from another SOP Instance.
Frame Anatomy	C.7.6.16.2.8	M
Cardiac Trigger	C.7.6.16.2.7	C – Required if Cardiac Synchronization Technique (0018,9037) equals other than NONE May be present otherwise.
Contrast/Bolus Usage	C.7.6.16.2.12	C – Required if Contrast/Bolus Agent Sequence (0018,0012) is used. May not be used as a Shared Functional Group

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Modify PS3.3 Annex C for Ophthalmic Tomography Modality

C.7.3.1.1.1 Modality

Defined Terms for the Modality (0008,0060) are:

…

OCT	= Optical Coherence Tomography **(non-Ophthalmic)**	OPR	= Ophthalmic Refraction
OPV	= Ophthalmic Visual Field	OPM	= Ophthalmic Mapping
KO	= Key Object Selection	SEG	= Segmentation
REG	= Registration	**OPT**	**= Ophthalmic Tomography**

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Modify PS3.3 Annex C for Ophthalmic Tomography Modality

C.8.17 Ophthalmic Photography and Tomography Modules

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C.8.17.5 Ocular Region Imaged Module

Table C.8.17.5-1 contains IOD Attributes that describe the anatomy contained in an ~~**OP**~~ **Ophthalmic Photography or Ophthalmic Tomography** IOD.

120 **Table C.8.17.5 - 1**
OCULAR REGION IMAGED MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
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 B = both left and right eye 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 if image laterality is not the same for every image in the series.
Relative Image Position Code Sequence	(0022,001D)	3	The position of this image on the retina (as defined by a specified nomenclature; the nomenclature is implicit in the code used). Only one item shall be present.
>Include 'Code Sequence Macro' Table 8.8.1			Baseline Context ID 4207

Include 'General Anatomy Mandatory Macro' Table 10-5	Defined Context ID 4209 for Anatomic Region Sequence

Add to PS3.3 Annex C the Ophthalmic Tomography Modality Modules

C.8.17.X1 Ophthalmic Tomography Series Module

Table C.8.17.X1-1 specifies the Attributes that identify and describe general information about the Ophthalmic Tomography Series.

Table C.8.17.X1-1
OPHTHALMIC TOMOGRAPHY SERIES MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Modality	(0008,0060)	1	Type of equipment that originally acquired the data used to create the images in this Series. Enumerated Values: OPT See section C.7.3.1.1.1 for further explanation.
Series Number	(0020,0011)	1	A number that identifies this Series.
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). The Sequence shall have one Item. Required if the Modality Performed Procedure Step SOP Class or General Purpose Performed Procedure Step SOP Class is supported.
>Referenced SOP Class UID	(0008,1150)	1	Uniquely identifies the referenced SOP Class.
>Referenced SOP Instance UID	(0008,1155)	1	Uniquely identifies the referenced SOP Instance.

C.8.17.X2 Ophthalmic Tomography Image Module

Table C.8.17.X2-1 specifies the Attributes that describe an Image produced by Ophthalmic Tomography imaging modalities.

Table C.8.17.X2-1
OPHTHALMIC TOMOGRAPHY IMAGE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Image Type	(0008,0008)	1	Image identification characteristics.
Samples Per Pixel	(0028,0002)	1	Number of samples (planes) in this image. See C.7.6.3.1.1 for further explanation. Value shall be 1.

Acquisition Datetime	(0008,002A)	1	The date and time that the acquisition of data started. Note: The synchronization of this time with an external clock is specified in the synchronization Module in Acquisition Time synchronized (0018,1800) .
Acquisition Duration	(0018,9073)	1C	The scan time in seconds used to create all frames of an Ophthalmic Tomography image. Required if Image Type (0008,0008) Value 1 is ORIGINAL. May be present otherwise.
Acquisition Number	(0020,0012)	1	A number identifying the single continuous gathering of data over a period of time which resulted in this image.
Photometric Interpretation	(0028,0004)	1	Specifies the intended interpretation of the pixel data. Enumerated Value shall be: MONOCHROME2
Pixel Representation	(0028,0103)	1	Data representation of pixel samples. Enumerated Value shall be 0.
Bits Allocated	(0028,0100)	1	Number of bits allocated for each pixel sample. Each sample shall have the same number of bits allocated. Bits Allocated (0028,0100) shall be 8 or 16
Bits Stored	(0028,0101)	1	Number of bits stored for each pixel sample. Each sample shall have the same number of bits stored. Bits Stored (0028,0101) shall be 8, 12 or 16
High Bit	(0028,0102)	1	Most significant bit for pixel sample data. Each sample shall have the same high bit. High Bit (0028,0102) shall be one less than Bits Stored
Presentation LUT Shape	(2050,0020)	1	Specifies an identity transformation for the Presentation LUT, such that the output of all grayscale transformations defined in the IOD containing this Module are defined to be P-Values. Enumerated Values: IDENTITY - output is in P-Values.
Lossy Image Compression	(0028,2110)	1	Specifies whether an Image has undergone lossy compression (at a point in its lifetime). Enumerated Values: 00 = Image has NOT been subjected to lossy compression. 01 = Image has been subjected to lossy compression. Once this tag has been set to 01 it shall not be reset. If this tag is empty, no information is explicitly available. See C.7.6.1.1.5

Lossy Image Compression Ratio	(0028,2112)	1C	Describes the approximate lossy compression ratio(s) that have been applied to this image. Required when compression has been applied. See C.7.6.1.1.5 for further explanation. May be multivalued if successive lossy compression steps have been applied. Notes: 1. For example, a compression ratio of 30:1 would be described in this Attribute with a single value of 30. 2. For historical reasons, the lossy compression ratio should also be described in Derivation Description (0008,2111).
Lossy Image Compression Method	(0028,2144)	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 multi-valued 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 Image Compression (0028,2110) has a value of "01". Note: For historical reasons, the lossy compression method should also be described in Derivation Description (0008,2111).
Burned In Annotation	(0028,0301)	1	Indicates whether or not image contains sufficient burned in annotation to identify the patient and date the image was acquired. Enumerated Value: NO
Concatenation Frame Offset Number	(0020,9228)	1	Offset of the first frame in a multi-frame image of a concatenation. Value shall be 0.
In-concatenation Number	(0020,9162)	1	Identifier for one SOP Instance belonging to a concatenation. Value shall be 1.
In-concatenation Total Number	(0020,9163)	1	The number of SOP Instances sharing the same Concatenation UID(0020,9161). Value Shall be 1.

The value constraints on Concatenation Frame Offset Number (0020,9228), In-concatenation Number (0020,9162), and In-concatenation Total Number (0020,9163) have the effect of requiring the entire image to be in one concatenation.

C.8.17.X3 Ophthalmic Tomography Acquisition Parameters Module

Table C.8.17.X3-1 describes patient clinical conditions related to an Ophthalmic Tomography image acquisition.

Table C.8.17.X3-1
OPHTHALMIC TOMOGRAPHY ACQUISITION PARAMETERS MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Axial Length of the Eye	(0022,0030)	2	Axial length of the eye in mm.
Horizontal Field of View	(0022,000C)	2	The horizontal field of view in degrees
Include 'Ophthalmic Acquisition Parameters Macro' Table C.8.17.X3-2			

Table C.8.17.X3-2
OPHTHALMIC ACQUISITION PARAMETERS MACRO

Attribute Name	Tag	Type	Attribute Description
Refractive State Sequence	(0022,001B)	2	The refractive state of the imaged eye at the time of acquisition. Zero or one Item shall be present. Zero length means the refractive state was not measured.
> Spherical Lens Power	(0022,0007)	1	Sphere value in diopters
> Cylinder Lens Power	(0022,0008)	1	Cylinder value in diopters
> Cylinder Axis	(0022,0009)	1	Axis value in degrees
Emmetropic Magnification	(0022,000A)	2	Emmetropic magnification value (dimensionless). Zero length means the emmetropic magnification was not measured.
Intra Ocular Pressure	(0022,000B)	2	Value of intraocular pressure in mmHg. Zero length means the pressure was not measured
Pupil Dilated	(0022,000D)	2	Enumerated Values: YES NO If this tag is empty, no information is available.
Mydriatic Agent Sequence	(0022,0058)	2C	Information about the agent administered. Required if the value of Pupil Dilated (0022,000D) is YES. Zero or more items may be present. Note: An empty sequence indicates that an agent was used for dilation, but the name was not entered.
>Mydriatic Agent Code Sequence	(0022,001C)	1	The actual agent administered to dilate the pupil. One item shall be present.
>>*Include 'Code Sequence Macro' Table 8.8-1*			Baseline Context ID is 4208.
>Mydriatic Agent Concentration	(0022,004E)	3	The concentration of the agent.
>Mydriatic Agent Concentration Units Sequence	(0022,0042)	1C	Units of measure for the Mydriatic Agent Concentration. Required if Mydriatic Agent Concentration (0022,004E) is present. One item shall be present.
>>*Include 'Code Sequence Macro' Table 8.8-1.*			Defined Context ID is 3082

Degree of Dilation	(0022,000E)	2C	The degree of the dilation in mm. Required if the value of Pupil Dilated (0022,000D) is YES.

Update in PS3.3 Annex C the Ophthalmic Photographic Acquisition Parameters Module

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Table C.8.17.4-1
OPHTHALMIC PHOTOGRAPHY ACQUISITION PARAMETERS MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Patient Eye Movement Commanded	(0022,0005)	2	Enumerated Values: YES NO
Patient Eye Movement Command Code Sequence	(0022,0006)	1C	Coded value for patient movement or orientation, which is the intent, and not necessarily the result, based on what the patient is capable of. Required if the value of Patient Eye Movement Commanded (0022,0005) is YES. A single item shall be present in this sequence.
Horizontal Field of View	(0022,000C)	2	The horizontal field of view in degrees
>Include 'Code Sequence Macro' Table 8.8.1			Baseline Context ID is 4201
~~**Refractive State Sequence**~~	~~**(0022,001B)**~~	~~**2**~~	~~**The refractive state of the imaged eye at the time of acquisition. Zero or one Item shall be present. Absence of an item means the refractive state was not measured.**~~
~~**> Spherical Lens Power**~~	~~**(0022,0007)**~~	~~**1**~~	~~**Sphere value in diopters**~~
~~**> Cylinder Lens Power**~~	~~**(0022,0008)**~~	~~**1**~~	~~**Cylinder value in diopters**~~
~~**> Cylinder Axis**~~	~~**(0022,0009)**~~	~~**1**~~	~~**Axis value in degrees**~~
~~**Emmetropic Magnification**~~	~~**(0022,000A)**~~	~~**2**~~	~~**Emmetropic Magnification value (dimensionless).**~~ ~~**Zero length means the emmetropic magnification was not measured.**~~
~~**Intra Ocular Pressure**~~	~~**(0022,000B)**~~	~~**2**~~	~~**Value of pressure. Value in mmHg.**~~ ~~**Zero length means the pressure was not measured.**~~
~~**Pupil Dilated**~~	~~**(0022,000D)**~~	~~**2**~~	~~**Enumerated Values:**~~ ~~**YES**~~ ~~**NO**~~
~~**Mydriatic Agent Code Sequence**~~	~~**(0022,001C)**~~	~~**2C**~~	~~**The agent administered to dilate the pupil. Required if the value of Pupil Dilated (0022,000D) is YES.**~~

			~~**Zero or more items may be present.**~~
~~***>Include 'Code Sequence Macro' Table 8.8.1***~~			~~**Baseline Context ID is 4208**~~
~~**Degree of Dilation**~~	~~**(0022,000E)**~~	~~**2C**~~	~~**The degree of the dilation in mm**~~ ~~**Required if the value of Pupil Dilated (0022,000D) is YES.**~~
Include 'Ophthalmic Acquisition Parameters Macro' Table C.8.17.X3-2			

160 ***Add to PS3.3 Annex C the Ophthalmic Tomography Modality Modules***

C.8.17.X4 Ophthalmic Tomography Parameters Module

Table C.8.17.X4-1 describes the parameters and characteristics of the acquisition device related to an Ophthalmic Tomography image acquisition.

165 **Table C.8.17.X4-1**
OPHTHALMIC TOMOGRAPHY PARAMETERS MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Acquisition Device Type Code Sequence	(0022,0015)	1	Describes the type of acquisition device. A single item shall be present in the sequence.
>Include 'Code Sequence Macro' Table 8.8-1			Baseline Context ID is 4210
Light Path Filter Type Stack Code Sequence	(0022,0017)	2	Filters used in the light source path. Zero or more items may be present in the sequence.
>Include 'Code Sequence Macro' Table 8.8-1			Baseline Context ID is 4204
>Light Path Filter Pass-Through Wavelength	(0022,0001)	3	Nominal pass-through wavelength of light path filter in nm
>Light Path Filter Pass Band	(0022,0002)	3	Pass band of light path filter in nm. This Attribute has two Values. The first is the shorter and the second the longer wavelength relative to the peak. The values are for the – 3dB nominal (1/2 of peak) pass through intensity. One of the two Values may be zero length, in which case it is a cutoff filter.
Detector Type	(0018,7004)	1	Type of detector used for creating this image. Defined terms: CCD = Charge Coupled Device CMOS = Complementary Metal Oxide Semiconductor PHOTO = Photodetector INT = Interferometer
Illumination Wave Length	(0022,0055)	1C	Wavelength of the illuminator in nm. Required if Acquisition Device Type Code Sequence (0022,0015) contains an item with the value (A-00FBE, SRT, "Optical Coherence Tomography Scanner"). May be present otherwise.
Illumination Power	(0022,0056)	1C	Power of the illuminator in microwatts at corneal plane. Required if Acquisition Device Type Code Sequence (0022,0015) contains an item with the

			value (SRT, A-00FBE,"Optical Coherence Tomography Scanner"). May be present otherwise.
Illumination Bandwidth	(0022,0057)	1C	Bandwidth of the illuminator in nm. Required if Acquisition Device Type Code Sequence (0022,0015) contains an item with the value (A-00FBE, SRT, "Optical Coherence Tomography Scanner"). May be present otherwise.
Depth Spatial Resolution	(0022,0035)	1C	The inherent limiting resolution in microns for depth of the acquisition equipment for high contrast objects for the data gathering and reconstruction technique chosen. If variable, the value at the center of the scanning volume. Required if Acquisition Device Type Code Sequence (0022,0015) contains an item with the value (A-00FBE, SRT, "Optical Coherence Tomography Scanner"). May be present otherwise.
Maximum Depth Distortion	(0022,0036)	1C	Maximum distortion in depth direction in % of Depth Spatial Resolution. Required if Acquisition Device Type Code Sequence (0022,0015) contains an item with the value (SRT, A-00FBE,"Optical Coherence Tomography Scanner"). May be present otherwise.
Along-scan Spatial Resolution	(0022,0037)	1C	The inherent limiting resolution in microns of the acquisition equipment in the direction of a row. Required if Acquisition Device Type Code Sequence (0022,0015) contains an item with the value (A-00FBE, SRT, "Optical Coherence Tomography Scanner"). May be present otherwise.
Maximum Along-scan Distortion	(0022,0038)	1C	Maximum distortion in along-scan direction in % of Along-scan Spatial Resolution. Required if Acquisition Device Type Code Sequence (0022,0015) contains an item with the value (A-00FBE, SRT, "Optical Coherence Tomography Scanner"). May be present otherwise.
Across-scan Spatial Resolution	(0022,0048)	1C	The inherent limiting resolution in microns of the acquisition equipment perpendicular to the slice. Required if Acquisition Device Type Code Sequence (0022,0015) contains an item with the value (A-00FBE, SRT, "Optical Coherence Tomography Scanner"). May be present otherwise.
Maximum Across-scan Distortion	(0022,0049)	1C	Maximum distortion in across-scan direction in % of cross-scan Spatial Resolution. Required if Acquisition Device Type Code Sequence (0022,0015) contains an item with the value (A-00FBE, SRT, "Optical Coherence Tomography Scanner"). May be present otherwise.

C.8.17.X5 Ophthalmic Tomography Functional Group Macros

C.8.17.X5.1 Ophthalmic Frame Location Macro

170 Table C.8.17.X5-1 specifies the attributes of the Ophthalmic Frame Location Functional Group Macro. This is used to provide a frame location relative to one or more referenced images. This macro describes a frame perpendicular or parallel to the reference image; it describes column

locations for frames that are scanned either uniformly along a line segment, or with a non-uniform spacing along any trajectory in the reference image.

Table C.8.17.X5-1
Ophthalmic Frame Location Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Ophthalmic Frame Location Sequence	(0022,0031)	1	Specifies the column locations for this frame in terms of locations on a referenced image. One or more items shall be present.
>Include 'Image SOP Instance Reference Macro' Table 10-3			Defined Term for Purpose of Reference is (121311, DCM, "Localizer")
>Reference Coordinates	(0022,0032)	1	Image coordinates for the points on the referenced image that correspond to the points on this frame. See section C.8.17.X5.1.1.
>Depth of Transverse Image	(0022,0041)	2C	Relative position in microns signifying the location of a Transverse image in the z-axis. Required if Ophthalmic Image Orientation (0022,0039) is TRANSVERSE.
>Ophthalmic Image Orientation	(0022,0039)	1	Enumerated Values: LINEAR NONLINEAR TRANSVERSE

C.8.17.X5.1.1 Reference Coordinates

A frame can be described in terms of its "position" on another image. In the case of ophthalmic tomography (OPT) images with longitudinal orientation, the OPT image corresponds to a vertical slice along a trajectory on the referenced image. Each column of the OPT frame is nominally perpendicular to the image. Therefore, each column of the OPT frame can also correspond to a particular pixel on an associated image. It is normal in OPT analysis to indicate the location of the OPT slice by showing the corresponding pixel locations on the image. For Transverse frames, the position is indicated by two corners of a rectangle.

Note: The simple geometric relationship modules are not practical to use for describing the relationship between OPT and retinal photography images. The retinal surface is highly curved, and the optical path is influenced by the lens and other eye structures. It is impractical to measure all of the geometric and optical properties of the eye to the degree needed to establish the relationship by geometric computation. It is easy to capture a retinal image and the slice path on that image as part of the OPT acquisition.

The OPT columns for a retinal slice are not strictly perpendicular to the retina and there are minor systematic distortions as a result. This DICOM functional group does not attempt to capture the data needed to measure or correct for these effects, except for the presence of the Maximum Along-scan Distortion Attribute (0022,0038).

The relationship between the columns in the image frame and the reference image are illustrated in Figure C.8.17.X5-1.

Frames can be captured using a linear scan with uniform column spacing. This permits the column position to be described by giving the endpoints of the line segment that was scanned. Figure C.8.17.X5-1 shows such a scan labeled as "OCT Frame 1". When describing this frame

using the Linear Column Locations Functional Group Macro, the sequence attributes would contain:

a. The Attributes of the Image SOP Instance Reference Macro would point to a frame of the reference image.
b. The Reference Coordinates (0022,0032) would contain values that give the row and column coordinates for the image pixel on the referenced image that corresponds to the first column of the OPT Frame 1 and the row and column coordinates that corresponds to the last column of the OPT Frame 1.

Frames can also be taken along curved paths, or with non-uniform spacing. These frames cannot be described by just the two endpoints. These frames are described by specifying the referenced image pixel coordinates for each column in the frame. The frame labeled “OCT Frame 2” illustrates this kind of relationship. The Non-linear Column Locations Functional Group Macro description for this frame would contain:

a. The Attributes of the Image SOP Instance Reference Macro would point to a frame of the reference image.
b. The Reference Coordinates (0022,0032) would contain 2N integer values. Their contents would be:

1-2 (e,f)
…. other values
2L-1, 2L (g,h)
….. other values
2N-1, 2N (x,y)

A three dimensional OPT raster scan image would be described by a series of Linear Column Location Sequences, one for each frame.

Note: One expected use of column location is the automatic generation of annotation graphics display. The slice location can be indicated and dynamically controlled on the reference image while examining the observed slices. This replaces the relatively inflexible practice of creating a modified retinal image with burned in annotation to indicate the slice locations.

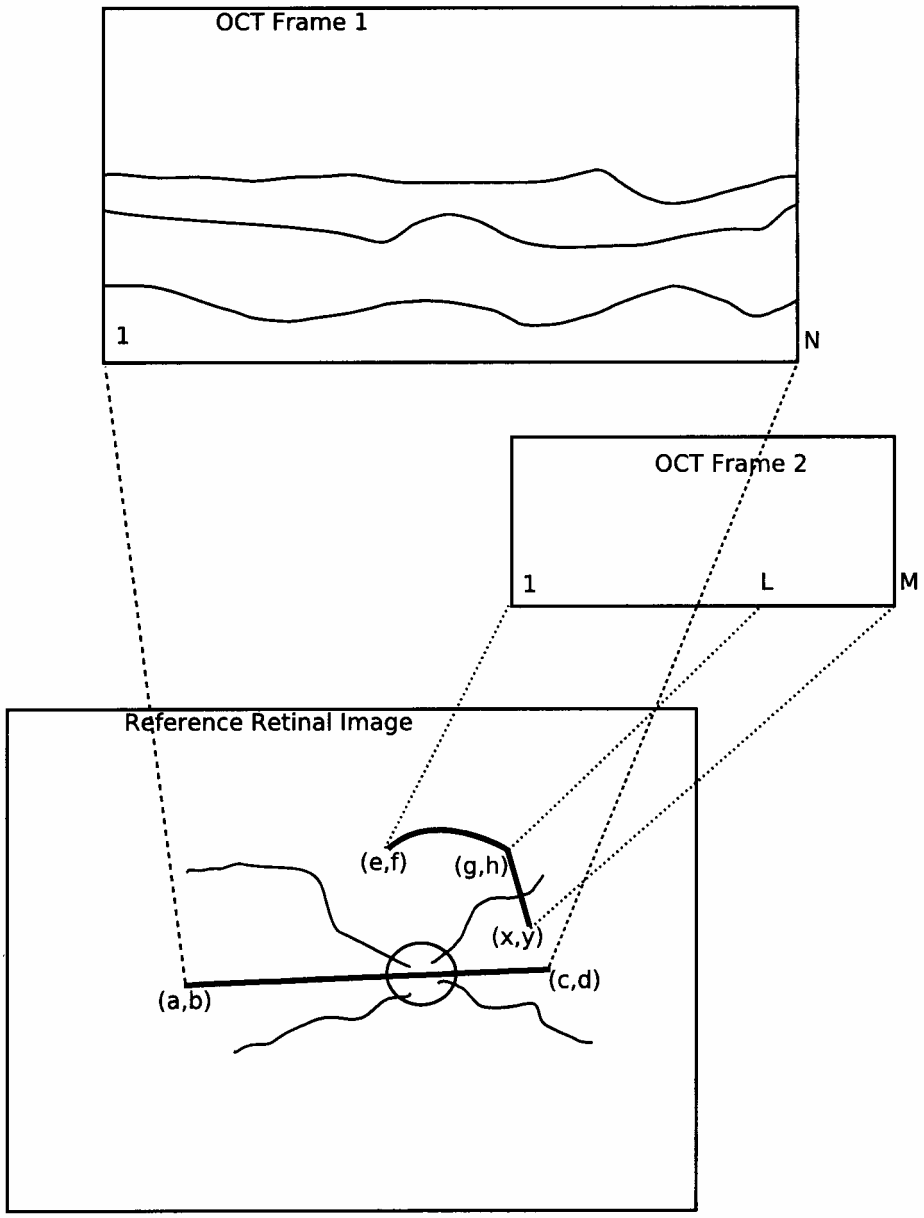

Figure C.8.17.X5-1: Relationship of Longitudinal (nominally perpendicular) OCT Frames to Reference Frame

In the case of ophthalmic tomography (OPT) images with a transverse orientation, the OPT image corresponds to a sub-rectangle of the reference image. See Figure C.8.17.X5-2. The OPT frame is nominally parallel to the reference image. Therefore, each corner of the OPT frame can also correspond to a particular pixel on an associated image. It is assumed that the edges of OPT frame are exactly parallel to the edges of the reference image.

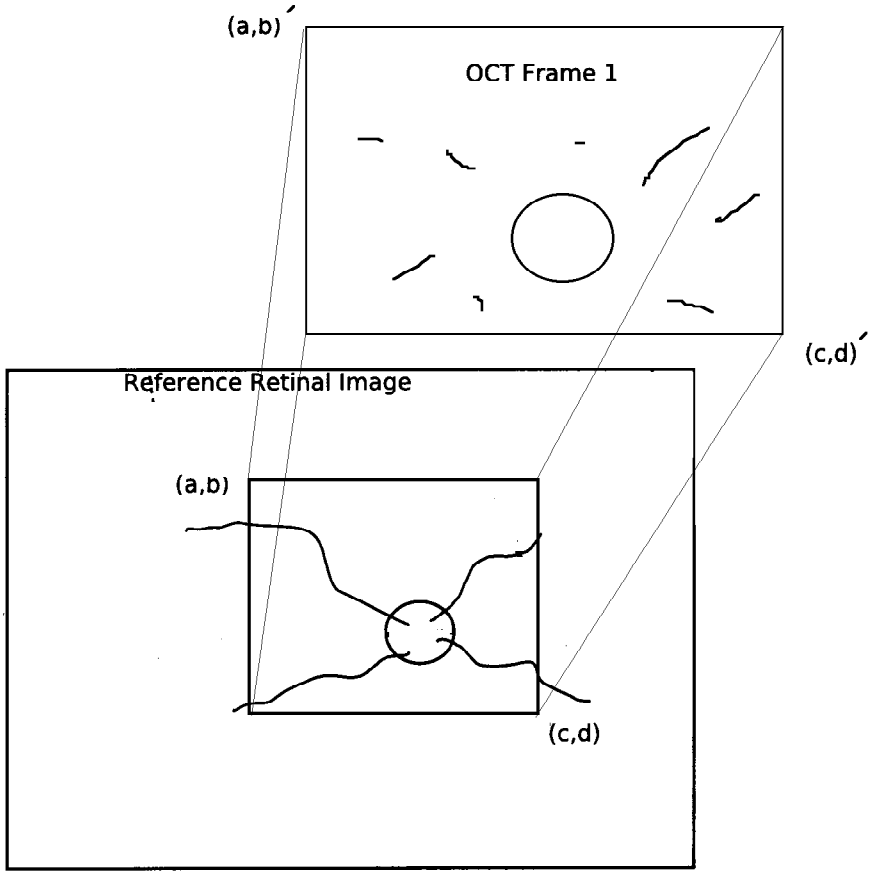

Figure C.8.17.X5-2: Relationship of Transverse (nominally parallel) OCT Frame to Reference Frame

245

Part 4 Additions

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)
…		
Ophthalmic Tomography Image Storage	**1.2.840.10008.5.1.4.1.1.77.1.5.4**	**Ophthalmic Tomography Image**

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)
…		
Ophthalmic Tomography Image Storage	**1.2.840.10008.5.1.4.1.1.77.1.5.4**	**Ophthalmic Tomography Image**

Part 6 Additions

Add to PS3.6 Annex A

UID Value	UID NAME	UID TYPE	Part
…			
1.2.840.10008.5.1.4.1.1.77.1.5.4	**Ophthalmic Tomography Image Storage**	**SOP Class**	**PS 3.4**

Add the following data elements to PS 3.6:

Tag	Name	VR	VM
(0022,0030)	Axial Length of the Eye	FL	1
(0022,0031)	Ophthalmic Frame Location Sequence	SQ	1
(0022,0032)	Reference Coordinates	FL	2-2N
(0022,0035)	Depth Spatial Resolution	FL	1
(0022,0036)	Maximum Depth Distortion	FL	1
(0022,0037)	Along-scan Spatial Resolution	FL	1
(0022,0038)	Maximum Along-scan Distortion	FL	1
(0022,0039)	Ophthalmic Image Orientation	CS	1
(0022,0041)	Depth of Transverse Image	FL	1
(0022,0042)	Mydriatic Agent Concentration Units Sequence	SQ	1
(0022,0048)	Across-scan Spatial Resolution	FL	1
(0022,0049)	Maximum Across-scan Distortion	FL	1
(0022,004E)	Mydriatic Agent Concentration	DS	1
(0022,0055)	Illumination Wave Length	FL	1
(0022,0056)	Illumination Power	FL	1
(0022,0057)	Illumination Bandwidth	FL	1
(0022,0058)	Mydriatic Agent Sequence	SQ	1

Part 16 Additions

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

CID 29 Acquisition Modality

Context ID 29
Acquisition Modality
Type: Extensible Version: 20071016

Coding Scheme Designator	Code Value	Code Meaning
…	..	…..
DCM	OP	Ophthalmic Photography
DCM	**OPT**	**Ophthalmic Tomography**
…	..	…

CID 4203 Ophthalmic Photography Illumination

Context ID 4203
Ophthalmic Photography Illumination
Type: Extensible Version: ~~20040921~~20071016

Coding Scheme Designator	Code Value	Code Meaning
SRT	R-1020E	Dual diffuse direct illumination
SRT	R-1020F	Fine slit beam direct illumination
SRT	R-10211	Broad tangential direct illumination
SRT	R-10213	Indirect sclerotic scatter illumination
SRT	R-10215	Indirect retroillumination from the iris
SRT	R-10217	Indirect retroillumination from the retina
SRT	R-10218	Indirect iris transillumination
DCM	**111625**	**Diffuse direct illumination**

Add the following new Context Groups 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: 20071016

Coding Scheme Designator	Code Value	Code Meaning
SRT	A-00FBE	Optical Coherence Tomography Scanner
SRT	R-FAB5A	Retinal Thickness Analyzer
SRT	A-00E8B	Confocal Scanning Laser Ophthalmoscope
DCM	111626	Scheimpflug Camera

CID 4211 Ophthalmic OCT Anatomic Structure Imaged

Context ID 4211
Ophthalmic OCT Anatomic Structure Imaged
Type: Extensible Version: 20071016

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
SRT	T-AA050	Anterior chamber of eye
SRT	T-AA310	Choroid of eye
SRT	T-AA400	Ciliary body
SRT	T-AA860	Conjunctiva
SRT	T-AA200	Cornea
SRT	T-AA500	Iris
SRT	T-AA700	Lens
SRT	T-AA630	Optic nerve head
SRT	T-AA610	Retina
SRT	T-AA110	Sclera
SRT	T-AA079	Vitreous
SRT	T-AA220	Corneal epithelium
SRT	T-AA260	Corneal endothelium

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
111625	**Diffuse direct illumination**	**A broad or "soft" light supplied from a single source.**	
111626	**Scheimpflug Camera**	**A slit reflected light microscope, which has the ability to form an image of the back scattered light from the eye in a sagittal plane. Scheimpflug cameras are able to achieve a wide depth of focus by employing the "Sheimpflug principle" where the lens and image planes are not parallel with each other. Rotating Sheimplug cameras are able to generate three-dimensional images and calculate measurements of the anterior chamber of the eye.**	
OPT	**Ophthalmic Tomography**	**Tomography of the eye acquired by a modality that is based on light and optical principles. Tomography based on other principles, such as ultrasound, is excluded.**	

Rename section U.1 in PS 3.17

U.1 Opthalmic Photography Use Cases

Add to PS3.17 Annex U

U.3 Ophthalmic Tomography Use Cases (Informative)

Optical tomography uses the backscattering of light to provide cross-sectional images of ocular structures. Visible (or near-visible) light works well for imaging the eye because many important structures are optically transparent (cornea, aqueous humor, lens, vitreous humor, and retina – see Figure U.3-1).

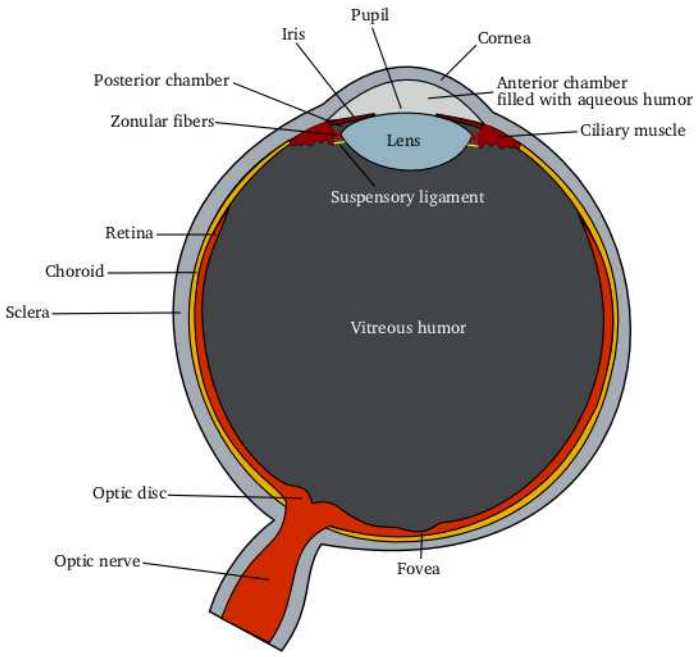

Figure U.3-1 Schematic representation of the human eye.

To provide analogy to ultrasound imaging, the terms A-scan and B-scan are used to describe optical tomography images. In this setting, an A-scan is the image acquired by passing a single beam of light through the structure of interest. An A-scan image represents the optical reflectivity of the imaged tissue along the path of that beam – a one-dimensional view through the structure. A B-scan is then created from a collection of adjacent A-scan images – a two dimensional image. It is also possible to combine multiple B-scans into a 3-dimensional image of the tissue.

When using optical tomography in the eye it is desirable to have information about the anatomic and physiologic state of the eye. Measurements like the patient's refractive error and axial eye length are frequently important for calculating magnification or minification of images. The accommodative state and application of pupil dilating medications are important when imaging the anterior segment of the eye as they each cause shifts in the relative positions of ocular

structures. The use of dilating medications is also relevant when imaging posterior segment structures because a small pupil can account for poor image quality.

U.3.1 Anterior Chamber Tomography

U.3.1.1 Anterior Chamber Exam for Phakic Intraocular Lens surgery planning

Ophthalmic tomography may be used to plan placement of a phakic intraocular lens (IOL). A phakic IOL is a synthetic lens placed in the anterior segment of the eye in someone who still has their natural crystalline lens (i.e. they are "phakic"). This procedure is done to correct the patient's refractive error, typically a high degree of myopia (near-sightedness). The exam will typically be performed on both eyes, and each eye may be examined in a relaxed and accommodated state. Refractive information for each eye is required to interpret the tomographic study.

A study consists of one or more B-scans (see Figure U.3-2) and one or more instances of refractive state information. There may be a reference image of the eye associated with each B-scan that shows the position of the scan on the eye.

U.3.1.2 Anterior Chamber Angle Exam

The anterior chamber angle is defined by the angle between the iris and cornea where they meet the sclera. This anatomic feature is important in people with narrow angles. Since the drainage of aqueous humor occurs in the angle, a significantly narrow angle can impede outflow and result in increased intraocular pressure. Chronically elevated intraocular pressures can result in glaucoma. Ophthalmic tomography represents one way of assessing the anterior chamber angle.

B-scans are obtained of the anterior segment including the cornea and iris. Scans may be taken at multiple angles in each eye (see Figure U.3-2). A reference image may be acquired at the time of each B-scan(s). Accommodative and refractive state information are also important for interpretation of the resulting tomographic information.

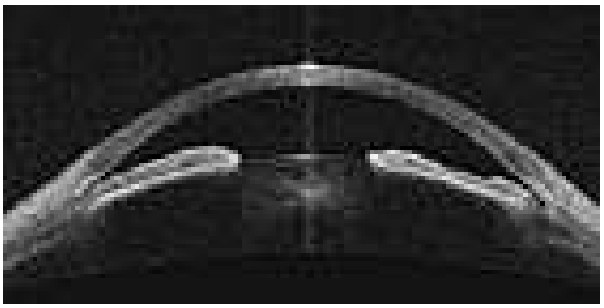

Figure U.3-2 Tomography of the anterior segment showing a cross section through the cornea.

Note in the Figure the ability to characterize the narrow angle between the iris and peripheral cornea.

U.3.1.4 Corneal Exam

As a transparent structure located at the front of the eye, the cornea is ideally suited to optical tomography. There are multiple disease states including glaucoma and corneal edema where the thickness of the cornea is relevant and tomography can provide this information using one or more B-scans taken at different angles relative to an axis through the center of the cornea.

Tomography is also useful for defining the curvature of the cornea. Accurate measurements of the anterior and posterior curvatures are important in diseases like keratoconus (where the cornea "bulges" abnormally) and in the correction of refractive error via surgery or contact lenses. Measurements of corneal curvature can be derived from multiple B-scans taken at different angles through the center of the cornea.

In both cases, a photograph of the imaged structure may be associated with each B-scan image.

U.3.2 Posterior Segment Tomography

U.3.2.1 Retinal Nerve Fiber Layer Exam

The Retinal Nerve Fiber Layer (RNFL) is made up of the axons of the ganglion cells of the retina. These axons exit the eye as the optic nerve carrying visual signals to the brain. RNFL thinning is a sign of glaucoma and other optic nerve diseases.

An ophthalmic tomography study contains one or more circular scans, perhaps at varying distances from the optic nerve. Each circular scan can be "unfolded" and treated as a B-scan used to assess the thickness of the nerve fiber layer (see Figure U.3-3). A fundus image that shows the scan location on the retina may be associated with each B-scan. To detect a loss of retinal nerve fiber cells the exam might be repeated one or multiple times over some period of time. The change in thickness of the nerve fiber tissue or a trend (serial plot of thickness data) might be used to support the diagnosis.

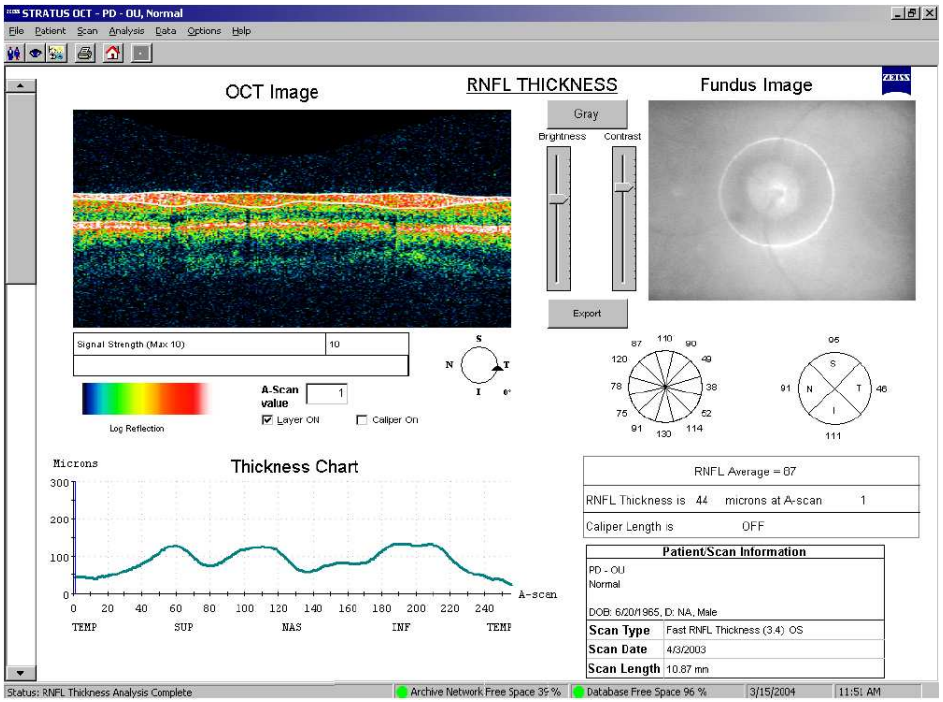

Figure U.3-3 Example tomogram of the retinal nerve fiber layer with a corresponding fundus image.

In the Figure, the pseudo-colored image on the left shows the various layers of the retina in cross section with the nerve fiber layer between the two white lines. The location of the scan is indicated by the bright circle in the photograph on the right.

U.3.2.2 Macular Exam

The macula is located roughly in the center of the retina, temporal to the optic nerve. It is a small and highly sensitive part of the retina responsible for detailed central vision. Many common ophthalmic diseases affect the macula, frequently impacting the thickness of different layers in the macula. A series of scans through the macula can be used to assess those layers (see Figure U.3-4).

A study may contain a series of B-scans. A fundus image showing the scan location(s) on the retina may be associated with one or more B-scans. In the Figure, the corresponding fundus photograph is in the upper left.

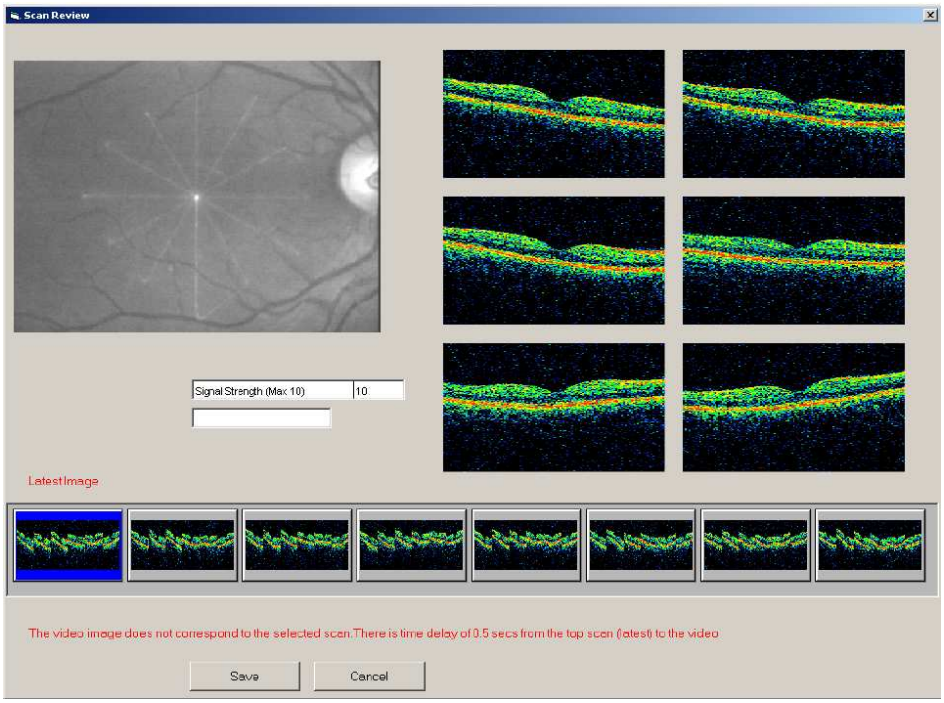

Figure U.3-4 Example of a macular scan showing a series of B-scans collected at six different angles

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U.3.2.3 Angiographic Exams

Some color retinal imaging studies are done to determine vascular caliber of retinal vessels which can vary throughout the cardiac cycle. Images are captured while connected to an ECG machine or a cardiac pulse monitor allowing image acquisition to be synchronized to the cardiac cycle.

Angiography is a procedure which requires a dye to be injected into the patient for the purpose of enhancing the imaging of vascular structures in the eye. A standard step in this procedure is imaging the eye at specified intervals to detect the pooling of small amounts of dye and/or blood in the retina. For a doctor or technician to properly interpret angiography images it is important to know how much time had elapsed between the dye being injected in the patient (time 0) and the image frame being taken. It is known that such dyes can have an affect on OPT tomographic images as well (and it may be possible to use such dyes to enhance vascular structure in the OPT images), therefore time synchronization will be applied to the creation of the OPT images as well as any associated OP images

The angiographic acquisition is instantiated as a multiframe OPT Image. The variable time increments between frames of the image are captured in the Frame Time Vector of the OPT Multi-frame Module. For multiple sets of images, e.g. sets of retinal scan images, the Slice Location Vector will be used in addition to the Frame Time Vector. For 5 sets of 6 scans there will be 30 frames in the multi-frame image. The first 6 values in the Frame Time Vector will give the time from injection to the first set of scans, the second 6 will contain the time interval for the second set of 6 scans, and so on, for a total of 5 time intervals.

Another example of an angiographic study with related sets of images is a sequence of SLO/OCT/"ICG filtered" image triples (or SLO/OCT image pairs) that are time-stamped relative to a user-defined event. This user-defined event usually corresponds to the inject time of ICG (indocyanine green) into the patients blood stream. The resultant images form an angiography study where the patient's blood flow can be observed with the "ICG filtered" images and can be

correlated with the pathologies observed in the SLO and OCT images which are spatially related to the ICG image with a pixel-to-pixel correspondence on the X-Y plane.

U.3.2.4 3D Reconstruction Exam

The prognosis of some pathologies can be aided by a 3D visualization of the affected areas of the eye. For example, in certain cases the density of cystic formations or the amount of drusen present can be hard to ascertain from a series of unrelated two-dimensional longitudinal images of the eye. However, some OCT machines are capable of taking a sequence of spatially related two-dimensional images in a suitably short period of time. These images can either be oriented longitudinally (perpendicular to the retina) or transversally (near-parallel to the retina). Once such a sequence has been captured, it then becomes possible for the examined volume of data to be reconstructed for an interactive 3D inspection by a user of the system (see Figure U.3-5). It is also possible for measurements, including volumes, to be calculated based on the 3D data set.

A reference image is often combined with the OCT data to provide a means of registering the 3D OCT data-set with a location on the surface of the retina (see Figures U.3-6 and U.3-7).

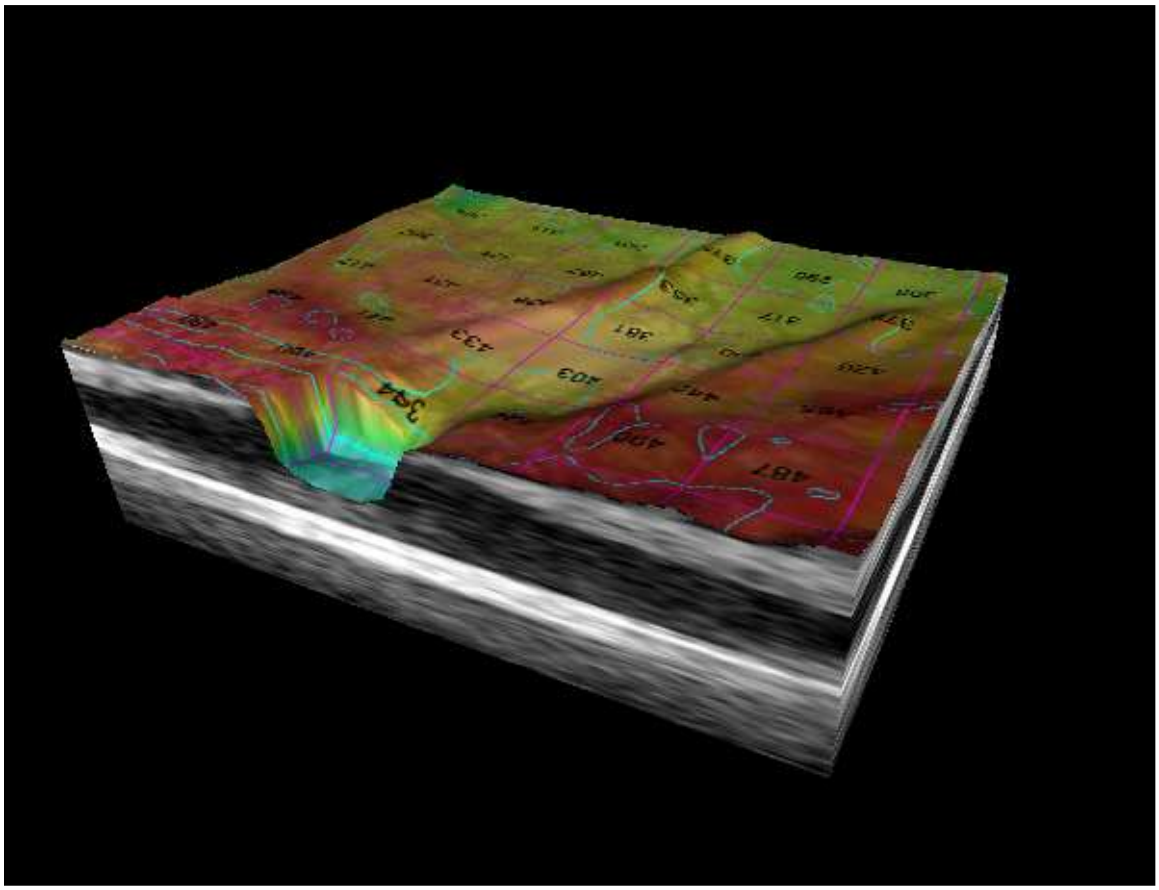

Figure U.3-5 Example 3D reconstruction

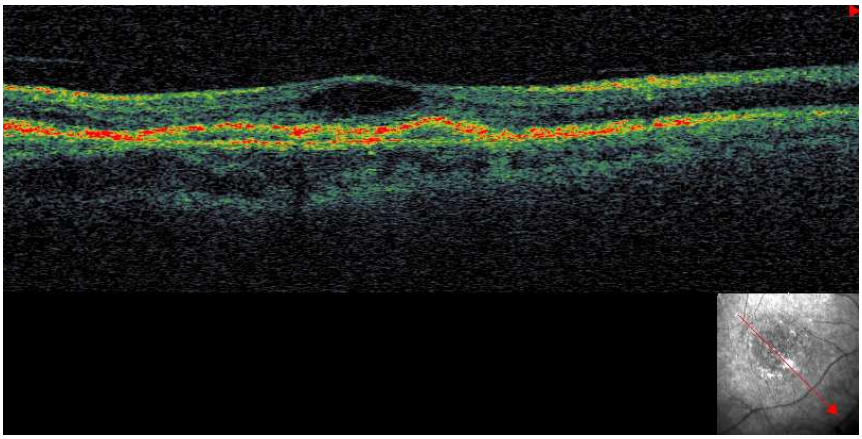

Figure U.3-6 Longitudinal OCT Image with Reference Image (inset)

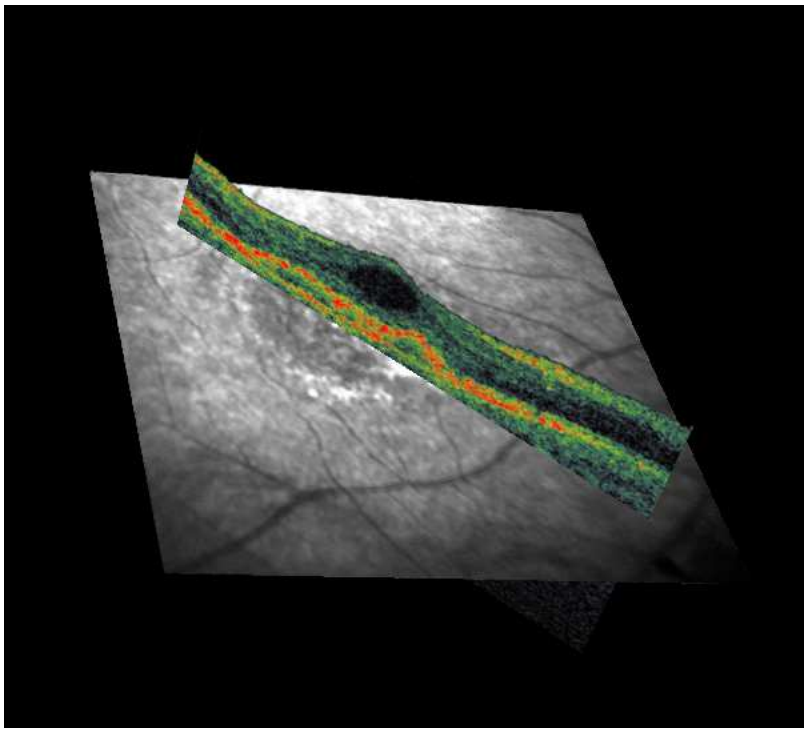

Figure U.3-7 Superimposition of Longitudinal Image on Reference Image

U.3.2.5 Transverse Imaging

While the majority of ophthalmic tomography imaging consists of sets of longitudinal images (also known as B scans or line scans), transverse images (also known as coronal or “en face” images) can also provide useful information in determining the full extent of the volume affected by pathology.

Longitudinal images are oriented in a manner that is perpendicular to the structure being examined, while transverse images are oriented in an “en face” or near parallel fashion through the structure being examined.

Transverse images can be obtained from a directly as a single scan (as shown in Figures U.3-8 and U.3-9) or they can also be reconstructed from a 3D dataset (as shown in Figures U.3-10 and U.3-11). A sequence of transverse images can also be combined to form a 3D dataset.

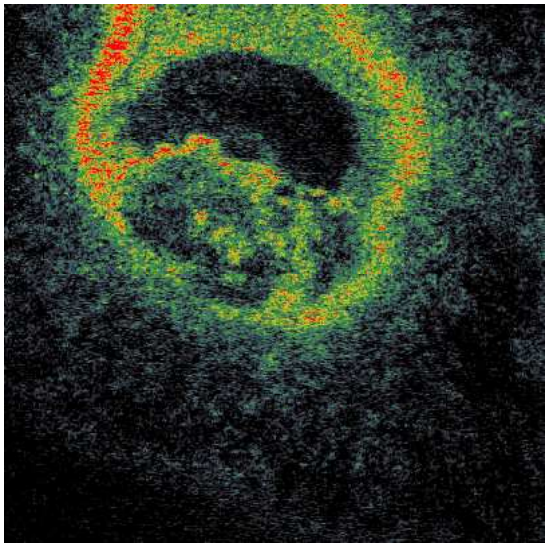

Figure U.3-8 Transverse OCT Image

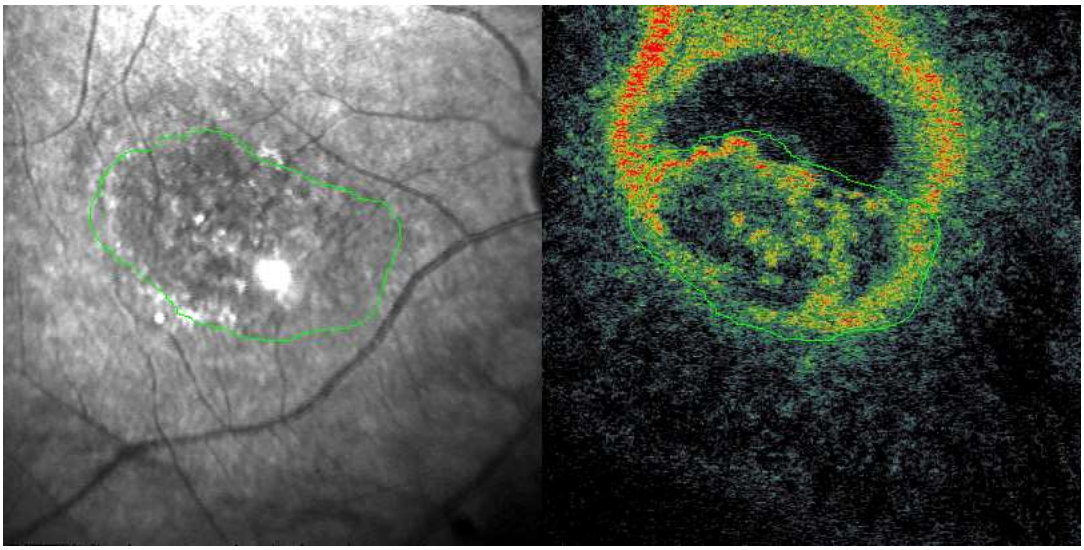

Figure U.3-9 Correlation between a Transverse OCT Image and a Reference Image Obtained Simultaneously

Figures U.3-8 through U.3-10 are all images of the same pathology in the same eye, but the two different orientations provide complementary information about the size and shape of the pathology being examined. For example, when examining macular holes, determining the amount of surrounding cystic formation is important aid in the following treatment. Determining the extent of such cystic formation is much more easily ascertained using transverse images rather than longitudinal images. Transverse images are also very useful in locating micro-pathologies such as covered macular holes, which may be overlooked using conventional longitudinal imaging.

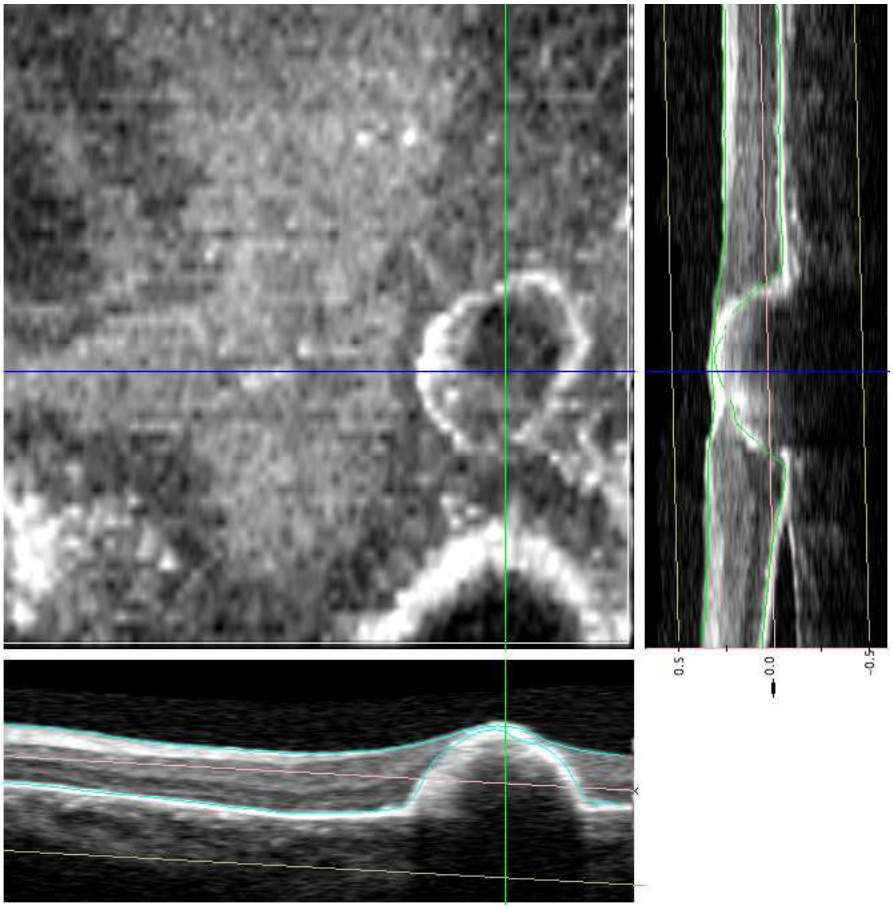

Figure U.3-9 Correspondence between Reconstructed Transverse and Longitudinal OCT Images

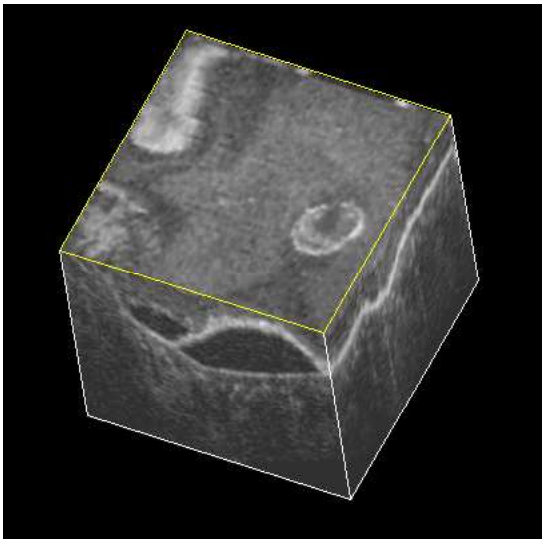

Figure U.3-10 Reconstructed Transverse and Side Longitudinal Images

In Figure U3.9, the blue green and pink lines show the correspondence of the three images. In Figure U3.10, the Transverse image is highlighted in yellow.