DICOM Correction Proposal

STATUS	Final Text
Date of Last Update	2024/09/13
Person Assigned	Harry Solomon
Submitter Name	Harry Solomon for WG9
Submission Date	2023/08/10

Correction Number CP-2347	
Log Summary: Clarify OPT Frame of Reference Coordinate System	
Name of Standard PS3.3 2024c	
Rationale for Correction: The Ophthalmic Tomography IOD (OPT) uses the Plane Position (Patient) and Plane Orientation (Patient) Functional Groups. These Functional Group definitions assume a Euclidean geometry congruent with the cartesian Patient-based Coordinate System. However, the OPT modalities in fact produce images where the image columns align with the laser beam that passes through and is refracted by the lens of the eye onto the curved retinal surface. Moreover, the columns are not strictly perpendicular to the retina, as the scan beam comes from the lens, not the center of the sphere of the eye. Thus the coordinate system of the images, while approximating the Patient-based Coordinate System, is deformed as columns and frames (slices) are not truly parallel, and the pixel spacing between columns and between frames varies from the anterior to the posterior of the imaged volume. The actual amount of deformation is not quantifiable, as it is affected by the patient-specific and unmeasured characteristics of the lens and size and shape of the eye. [Maximum possible distortions are recorded in the attributes of the Ophthalmic Tomography Parameters Module.] The variability of pixel spacing is not significant for the clinical purposes of OPT imaging, but technically is not conformant to the assumptions of the Plane Position (Patient) and Plane Orientation (Patient) Functional Groups. In order to not break existing implementations, i.e., for OPT to continue to use Plane Position (Patient) and Plane Orientation (Patient), DICOM should clarify that the coordinate system associated with the OPT Frame of Reference is deformed from the Patient-based Coordinate System, and that pixel measures are nominal in that context. Note that the Ophthalmic Photography Image Module includes this note on Pixel Spacing (0028,0030):   *These values are specified as nominal because the physical distance may vary across the field of the images and the lens correction is likely to be imperfect.* The Pixel Spacing (0028,0030) definition for OPT is in the Pixel Measures Functional Group, which does not (yet) include such a disclaimer. Additionally, there is a defined cornea-oriented coordinate system for the Corneal Topography Map IOD, which is currently denoted the Ophthalmic Coordinate System. To avoid confusion, that should be renamed the Corneal Coordinate System as it is not the same as the coordinate system for Ophthalmic Tomography imaging.
Correction Wording:	

Rename Ophthalmic Coordinate System in definitions

3.17 Multi-dimensional Definitions

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~~Ophthalmic~~**Corneal** Coordinate System ~~(OCS)~~   The ~~Ophthalmic~~**Corneal** Coordinate System is used as the Frame of Reference that establishes the spatial relationship relative to the corneal vertex. The corneal vertex is the point located at the intersection of the patient's line of sight (visual axis) and the **outer** corneal surface. See Section C.8.30.3.1.4 for further explanation.

A.52.4.3 Ophthalmic Tomography Image Functional Group Macros

Table A.52.4.3-1 specifies the use of the Functional Group Macros used in the Multi-frame Functional Groups Module for the Ophthalmic Tomography Image IOD.

Table A.52.4.3-1. Ophthalmic Tomography Image Functional Group Macros

Functional 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 (Patient)	C.7.6.16.2.3	C - Required if no Ophthalmic Photography Reference Image is available or if Ophthalmic Volumetric Properties Flag (0022,1622) is YES; May be present otherwise
Plane Orientation (Patient)	C.7.6.16.2.4	C - Required if no Ophthalmic Photography Reference Image is available or if Ophthalmic Volumetric Properties Flag (0022,1622) is YES; May be present otherwise
Referenced Image	C.7.6.16.2.5	C - Required if Ophthalmic Photography Reference Image is 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 Synchronization	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
Ophthalmic Frame Location	C.8.17.10.1	U

A.52.4.3.1 Ophthalmic Tomography Image Functional Group Macro Constraints

The Patient-based Coordinate System of the Plane Position (Patient) and Plane Orientation (Patient) Functional Groups presumes an orthogonal Cartesian right-handed system representing real-world positions and orientations in the patient. The Pixel Measures Functional Group presumes consistent column and row spacing across an image frame. However, the nature of the Ophthalmic Tomography modality and the anatomic structure of the eye as imaged introduce deformations in the OPT images, such that the position and orientation at the first (top left) pixel of a frame cannot be used to accurately compute the position of other pixels of the frame. Therefore, for the Ophthalmic Tomography IOD, the Attribute Values of those Functional Groups are nominal values.

> **Note:**
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> **The deformed Patient-based Coordinate System used in Ophthalmic Tomography might treat the curved retinal surface as if it were a flat coronal plane.**

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A.84.3.2.1 Ophthalmic Optical Coherence Tomography B-scan Volume Analysis IOD Content Constraints

This source for an Ophthalmic Optical Coherence Tomography B-scan Volume Analysis SOP Instance is one or more multi-frame Ophthalmic Tomography SOP Instance(s). The correlation is encoded at the Frame Level and conveyed in the Derivation Image Macro (see Section C.8.17.14.1.7 for examples).

A.84.3.2.1.1 Derivation Image Functional Group

The following constraints to the Derivation Image Macro shall apply:

1. Derivation Image Sequence (0008,9124) shall be Type 1

2. The value for Derivation Code Sequence (0008,9215) shall be (128303, DCM, "OCT B-scan analysis")

3. Source Image Sequence (0008,2112) shall be Type 1 and contain one Item. The referenced SOP Instance shall have the same value for Frame of Reference UID (0020,0052) as this SOP Instance

4. The value for Referenced SOP Class UID (0008,1150) shall be Ophthalmic Tomography Image Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.4")

5. The value for Purpose of Reference Code Sequence (0040,A170) shall be (128250, DCM, "Structural image for imaging processing")

6. The value for Spatial Locations Preserved (0028,135A) shall be YES

A.84.3.2.1.2 Coordinate System

The Coordinate System associated with the Frame of Reference UID may be deformed from the nominal Patient-based Coordinate System (see Section A.52.4.3.1), and thus the Attribute Values of the Plane Position (Patient), Plane Orientation (Patient), and Pixel Measures Functional Groups are nominal values.

Add note to Pixel Measures Macro

C.7.6.16.2.1 Pixel Measures Macro

Table C.7.6.16-2 specifies the Attributes of the Pixel Measures Macro, which is used as a Functional Group Macro.

Table C.7.6.16-2. Pixel Measures Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Pixel Measures Sequence	(0028,9110)	1	Identifies the physical characteristics of the pixels of this frame. Only a single Item shall be included in this Sequence.

Attribute Name	Tag	Type	Attribute Description
>Pixel Spacing	(0028,0030)	1C	Physical distance in the imaging target (patient, specimen, or phantom) between the centers of each pixel, specified by a numeric pair - adjacent row spacing (delimiter) adjacent column spacing in mm. See Section 10.7.1.3 for further explanation of the value order. Note 1. In the case of CT images with an Acquisition Type (0018,9302) of CONSTANT_ANGLE, the pixel spacing is that in a plane normal to the central ray of the diverging X-Ray beam as it passes through the data collection center. 2. In the case of Enhanced RT Image ("1.2.840.10008.5.1.4.1.1.481.23") or Enhanced Continuous RT Image ("1.2.840.10008.5.1.4.1.1.481.24") the pixel spacing is defined on the x/y plane at z = 0 of the Image Receptor Coordinate System. **3. In the case of Ophthalmic Tomography Image ("1.2.840.10008.5.1.4.1.1.77.1.5.4") or Ophthalmic Optical Coherence Tomography B-scan Volume Analysis ("1.2.840.10008.5.1.4.1.1.77.1.5.8") the pixel spacing is specified as nominal because the physical distance may vary across the field of the images.** Required if: • Volumetric Properties (0008,9206) is other than DISTORTED or SAMPLED, and Image Type (0008,0008) Value 3 is not LABEL or OVERVIEW, or • SOP Class UID is Segmentation Storage ("1.2.840.10008.5.1.4.1.1.66.4") and Frame of Reference UID (0020,0052) is present, or • SOP Class UID is Ophthalmic Tomography Image Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.4") and Ophthalmic Volumetric Properties Flag (0022,1622) is YES, or • SOP Class UID is Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.8"), or • SOP Class UID is Enhanced RT Image ("1.2.840.10008.5.1.4.1.1.481.23"), or • SOP Class UID is Enhanced Continuous RT Image ("1.2.840.10008.5.1.4.1.1.481.24"). May be present otherwise.
>Slice Thickness	(0018,0050)	1C	Nominal reconstructed slice thickness (for tomographic imaging) or depth of field (for optical non-tomographic imaging), in mm. See Section C.7.6.16.2.3.1 for further explanation…. Required if: • Volumetric Properties (0008,9206) is VOLUME or SAMPLED, and Image Type (0008,0008) Value 3 is not LABEL or OVERVIEW, or • SOP Class UID is Segmentation Storage ("1.2.840.10008.5.1.4.1.1.66.4") and Frame of Reference UID (0020,0052) is present, or • SOP Class UID is Ophthalmic Tomography Image Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.4") and Ophthalmic Volumetric Properties Flag (0022,1622) is YES, or • SOP Class UID is Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.8"). May be present otherwise, if • SOP Class UID is not Enhanced RT Image ("1.2.840.10008.5.1.4.1.1.481.23"), and • SOP Class UID is not Enhanced Continuous RT Image ("1.2.840.10008.5.1.4.1.1.481.24").

Attribute Name	Tag	Type	Attribute Description
>Spacing Between Slices	(0018,0088)	1C	Spacing between adjacent slices, in mm. The spacing is measured from the center-to-center of each slice, and if present shall not be negative. Required if Dimension Organization Type (0020,9311) is TILED_FULL and Total Pixel Matrix Focal Planes (0048,0303) is greater than 1. May be present otherwise. Note In the case of Whole Slide Images, Spacing Between Slices (0018,0088) describes the spacing of focal planes separately encoded, and is distinct from Distance Between Focal Planes (0048,0014), which describes in what manner different focal planes were combined into a single encoded plane (focus stacking).

Add note to Plane Position (Patient) Macro

C.7.6.16.2.3 Plane Position (Patient) Macro

Table C.7.6.16-4 specifies the Attributes of the Plane Position (Patient) Macro, which is used as a Functional Group Macro.

Table C.7.6.16-4. Plane Position (Patient) Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Plane Position Sequence	(0020,9113)	1	Identifies the position of the plane of this frame. Only a single Item shall be included in this Sequence.
>Image Position (Patient)	(0020,0032)	1C	The x, y, and z coordinates of the upper left hand corner (center of the first voxel transmitted) of the frame, in mm. See Section C.7.6.2.1.1 and Section C.7.6.16.2.3.1 for further explanation. Note 1. In the case of CT images with an Acquisition Type (0018,9302) of CONSTANT_ANGLE the image plane is defined to pass through the data collection center and be normal to the central ray of the diverging X-Ray beam. 2. **In the case of Ophthalmic Tomography Image ("1.2.840.10008.5.1.4.1.1.77.1.5.4") or Ophthalmic Optical Coherence Tomography B-scan Volume Analysis ("1.2.840.10008.5.1.4.1.1.77.1.5.8") the coordinate values are specified as nominal because the imaged volume may be deformed from the Patient-based Coordinate System due to the imaging optical path interaction with the anatomy of the eye.** Required if: • Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and Volumetric Properties (0008,9206) of this frame is other than DISTORTED, or • SOP Class UID is Segmentation Storage ("1.2.840.10008.5.1.4.1.1.66.4") and Frame of Reference UID (0020,0052) is present, or • SOP Class UID is Ophthalmic Tomography Image Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.4") and Ophthalmic Volumetric Properties Flag (0022,1622) is YES, or • SOP Class UID is Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.8").

Attribute Name	Tag	Type	Attribute Description
			May be present otherwise.

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<table>
<tr><td>Add note to Plane Orientation (Patient) Macro</td></tr>
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C.7.6.16.2.4 Plane Orientation (Patient) Macro

Table C.7.6.16-5 specifies the Attributes of the Plane Orientation (Patient) Macro, which is used as a Functional Group Macro.

Table C.7.6.16-5. Plane Orientation (Patient) Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Plane Orientation Sequence	(0020,9116)	1	Identifies orientation of the plane of this frame. Only a single Item shall be included in this Sequence.
>Image Orientation (Patient)	(0020,0037)	1C	The direction cosines of the first row and the first column with respect to the patient. See Section C.7.6.2.1.1 and Section C.7.6.16.2.3.1 for further explanation. **Note** **In the case of Ophthalmic Tomography Image ("1.2.840.10008.5.1.4.1.1.77.1.5.4") or Ophthalmic Optical Coherence Tomography B-scan Volume Analysis ("1.2.840.10008.5.1.4.1.1.77.1.5.8") the image orientation is specified as nominal because the coordinate system may be deformed from the Patient-based Coordinate System, and orientation values may vary across the field of the images.** Required if: • Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and Volumetric Properties (0008,9206) of this frame is other than DISTORTED, or • SOP Class UID is Segmentation Storage ("1.2.840.10008.5.1.4.1.1.66.4") and Frame of Reference UID (0020,0052) is present, or • SOP Class UID is Ophthalmic Tomography Image Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.4") and Ophthalmic Volumetric Properties Flag (0022,1622) is YES, or • SOP Class UID is Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.8"), or • SOP Class UID is Enhanced RT Image ("1.2.840.10008.5.1.4.1.1.481.23"), or • SOP Class UID is Enhanced Continuous RT Image ("1.2.840.10008.5.1.4.1.1.481.24"). May be present otherwise.

C.8.17.7 Ophthalmic Tomography Image Module

Table C.8.17.7-1 specifies the Attributes of the Ophthalmic Tomography Image Module, which describe an Image produced by Ophthalmic Tomography imaging modalities.

Table C.8.17.7-1. Ophthalmic Tomography Image Module Attributes

Attribute Name	Tag	Type	Attribute Description
Ophthalmic Volumetric Properties Flag	(0022,1622)	1C	Whether this SOP Instance is suitable for OCT volumetric processing. **See Section C.8.17.7.1 for further explanation.** Required if this SOP Instance is suitable for OCT volumetric processing. May be present otherwise. Enumerated Values: **YES** **NO**
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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 preventing the use of concatenations.

C.8.17.7.1 Ophthalmic Volumetric Properties and Frame of Reference

The Attribute Ophthalmic Volumetric Properties Flag (0022,1622) is YES when the Ophthalmic Tomography Image Storage SOP Instance encodes volumetric spatial information (e.g. Frame of Reference, Pixel Measures, Plane Orientation, Plane Position, etc.). For example, ophthalmic tomography volumetric information is required when implementations encode Ssurface Segmentation SOP Instance(s) (e.g., surface segmentation is applied to the structural OCT volume to delineate the anatomical boundaries) and/or an Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Storage SOP Instance (e.g., angiographic (blood flow) volume information) based upon the volumetric Ophthalmic Tomography Image Storage SOP Instance.

The coordinate system of the Ophthalmic Tomography Image is typically deformed from the nominal Patient-based Coordinate System. The Frame of Reference UID (0020,0052) identifies volumetric space as represented by the voxels of the SOP Instance, including any such deformations. The values of the Attributes of the Pixel Measures, Plane Position (Patient), and Plane Orientation (Patient) Functional Groups are nominal, and should not be assumed to be usable for computing real-world locations in the patient.

Note:

The coordinate system used in an Ophthalmic Tomography Image Storage SOP Instance may treat the curved retinal surface as if it were a flat coronal plane, and the column, row, and slice spacing may vary across the imaged volume.

C.7.4.1.1.2 Position Reference Indicator

The Position Reference Indicator (0020,1040) specifies the part of the imaging target that was used as a reference point associated with a specific Frame of Reference UID. The Position Reference Indicator may or may not coincide with the origin of the fixed Frame of Reference related to the Frame of Reference UID.

For a Patient-related Frame of Reference, this is an anatomical reference point such as the iliac crest, orbital-medial, sternal notch, symphysis pubis, xiphoid, lower costal margin, or external auditory meatus, or a fiducial marker placed on the patient. The Patient-Based Coordinate System is described in Section C.7.6.2.1.1.

For a slide-related Frame of Reference, this is the slide corner as specified in Section 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 Section C.8.12.2.1.

For a~~n Ophthalmic~~**Corneal** Coordinate System, the Frame of Reference is based upon the corneal vertex. The corneal vertex is 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 ~~Ophthalmic~~**Corneal** Coordinate System is described in Section C.8.30.3.1.4.

The Position Reference Indicator shall be used only for annotation purposes and is not intended to be used as a mathematical spatial reference.

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C.8.17.12.1.2 Two Dimensional to Three Dimensional Map Data

Two Dimensional to Three Dimensional Map Data (0022,1531) is used to convey a sparsely sampled map of 2D image pixels (with sub pixel resolution) to 3D coordinates.

The origin of the 3D points shall be the ~~Ophthalmic~~**Corneal** Coordinate System which is based upon the corneal vertex (i.e., the x, y and z coordinates of 0.0, 0.0, 0.0, in mm). See Section C.8.30.3.1.4.

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C.8.30.3.1.4 Corneal Vertex Location

The Corneal Vertex Location (0046,0202) establishes the reference point for the corneal vertex, the origin of the ~~Ophthalmic~~**Corneal** Coordinate System. The ~~Ophthalmic~~**Corneal** Coordinate System 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 Frame of Reference. The corneal vertex is the point located at the intersection of the patient's line of sight (visual axis) and the **outer** corneal surface. It is represented by the corneal light reflex when the cornea is illuminated coaxially with fixation.

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Figure C.8.30.3.1-6. Schematic of the ~~Ophthalmic~~Corneal Coordinate System of the 3-Dimensional Representation used in Wide Field Measurements