



IMAGE QUALITY EVALUATION OF CONE BEAM COMPUTED TOMOGRAPHY (CBCT) IN AN O-ARM FLUOROSCOPY MACHINE USING THE SEDENTEXCT IQ PHANTOM

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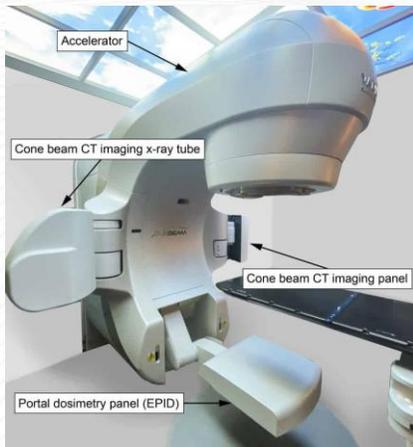
Cone Beam Computed Tomography

Cone Beam Computed Tomography (CBCT) is an advanced imaging modality that provides detailed 3-dimensional images and slices of anatomical structures.

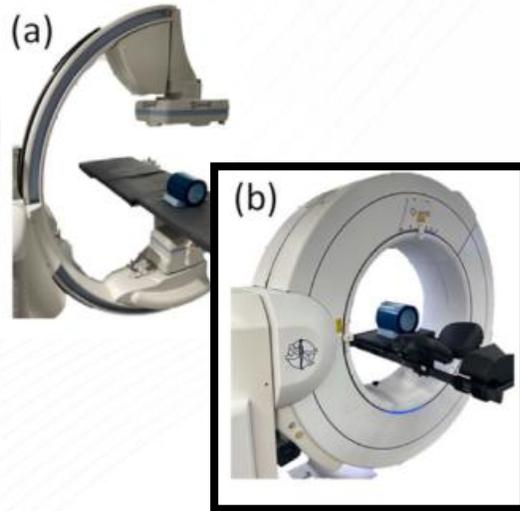
Applications of CBCT



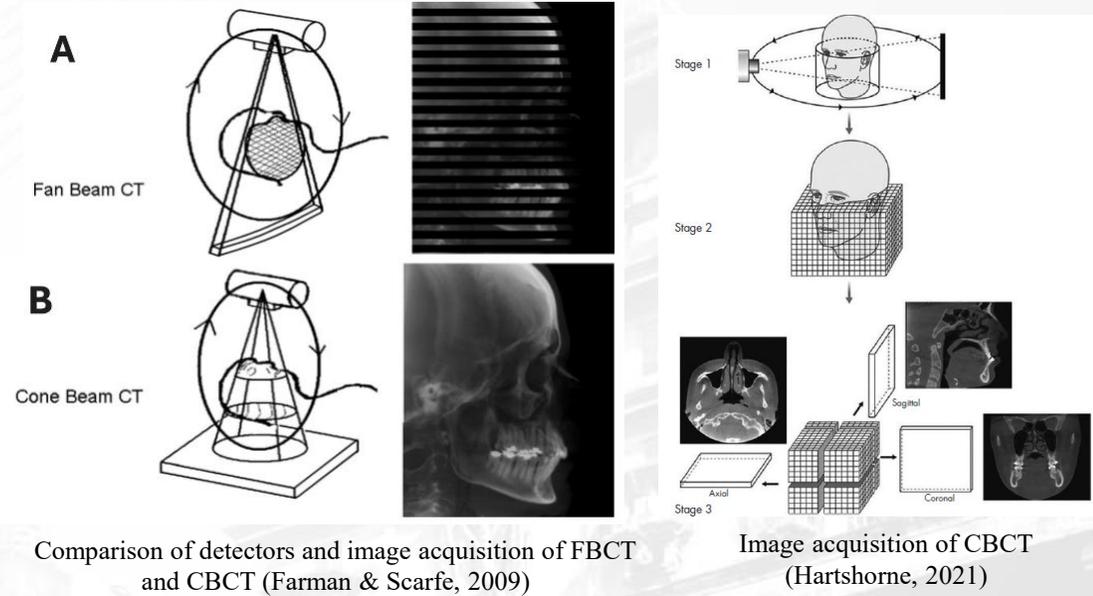
Dental



Radiotherapy



Interventional



Characteristics:

- X-ray tube and flat panel detector
- Cone shaped beam
- Volumetric acquisition
- Single 360° rotation

O-arm Fluoroscopy Machine



SedentexCT IQ Phantom

An image quality phantom designed for CBCT units, specifically for **Dental CBCT** machines.

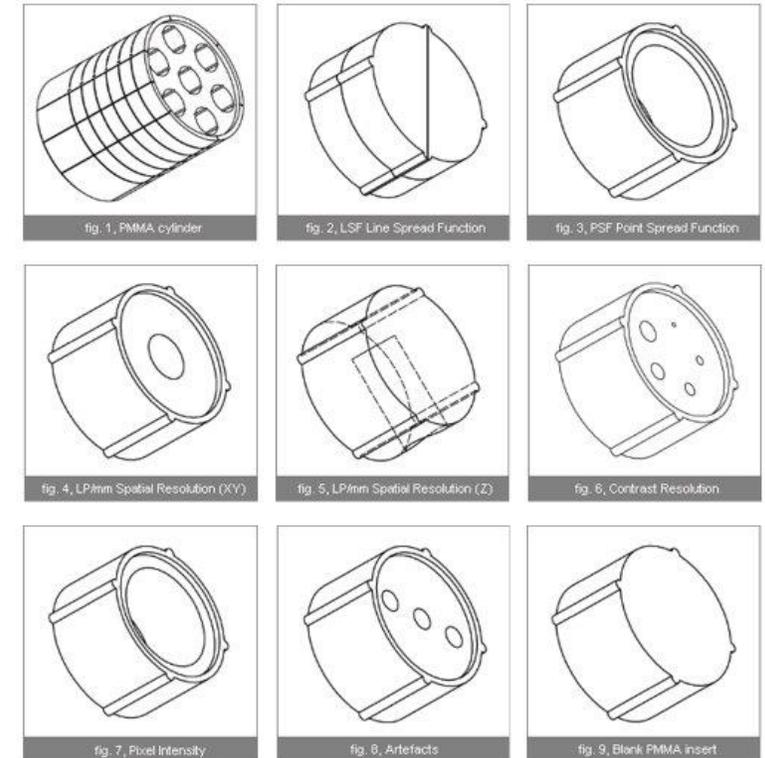
- 160 mm diameter

Applicable Image Quality Tests:

- Noise and Uniformity
- Geometric Distortion
- Spatial Resolution
- Contrast Resolution
- Pixel Intensity
- Beam Hardening Artefacts



[SedentexCT IQ - Leeds Test Objects](#)



Related Studies

Image Quality of a Cone Beam O-arm 3D Imaging System

Jie Zhang^{*}, Victor Weir, Jingying Lin, Hsiang Hsiung, E Russell Ritenour
 Center for Interdisciplinary Medical Imaging Research and Medical Physics Division, Department
 of Radiology, University of Minnesota, Minneapolis, MN, 55455, USA

Used CATPHAN phantom

Received: 6 September 2018 | Revised: 7 December 2018 | Accepted: 22 December 2018
 DOI: 10.1002/acm2.12534

MEDICAL IMAGING

WILEY

Radiation dose and image quality comparison during spine surgery with two different, intraoperative 3D imaging navigation systems

Rami Nachabe¹ | Keith Strauss² | Beth Schueler³ | Mohamad Bydon⁴

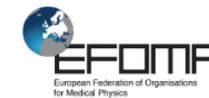
Used ACR CT phantom

European Commission:

- Noise
- Uniformity
- Geometric accuracy
- Contrast resolution
- Spatial resolution
- Image density values

Quality control in cone-beam computed tomography (CBCT)

EFOMP-ESTRO-IAEA protocol



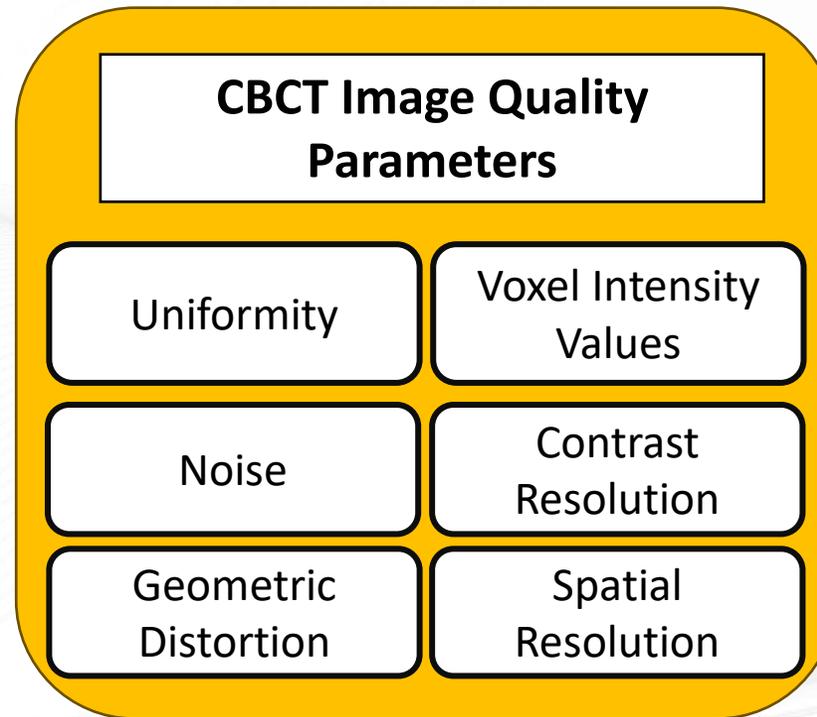
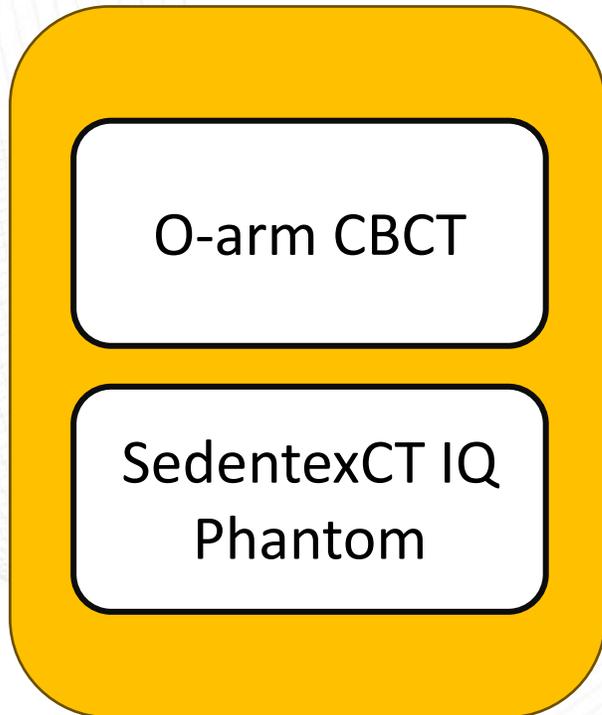
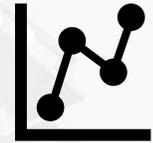
ESTRO



EFOMP
 2nd edition, May 2019

- The current practice in the Philippines for conducting image quality performance test for O-arm fluoroscopy machine is limited to 2D imaging mode.
- No phantoms are specifically designed to evaluate the image quality of interventional CBCT systems (3D imaging mode) (De Las Heras Gala et al., 2019).
- It's like “hitting two birds with one stone”.

METHODOLOGY



METHODOLOGY: SET-UP



Gantry (O-arm)



Patient table and
Laser indicator



Phantom positioning

METHODOLOGY: CBCT System Exposure Factors

Exposure Mode	Kilovoltage (kV)	mA	mAs
Low Dose	120	10	40
Standard Dose	120	25	100
High Dose	120	20	150
Enhanced Cranial	100	80	600

Patient Size	Field of View
S	20 cm

Uniformity

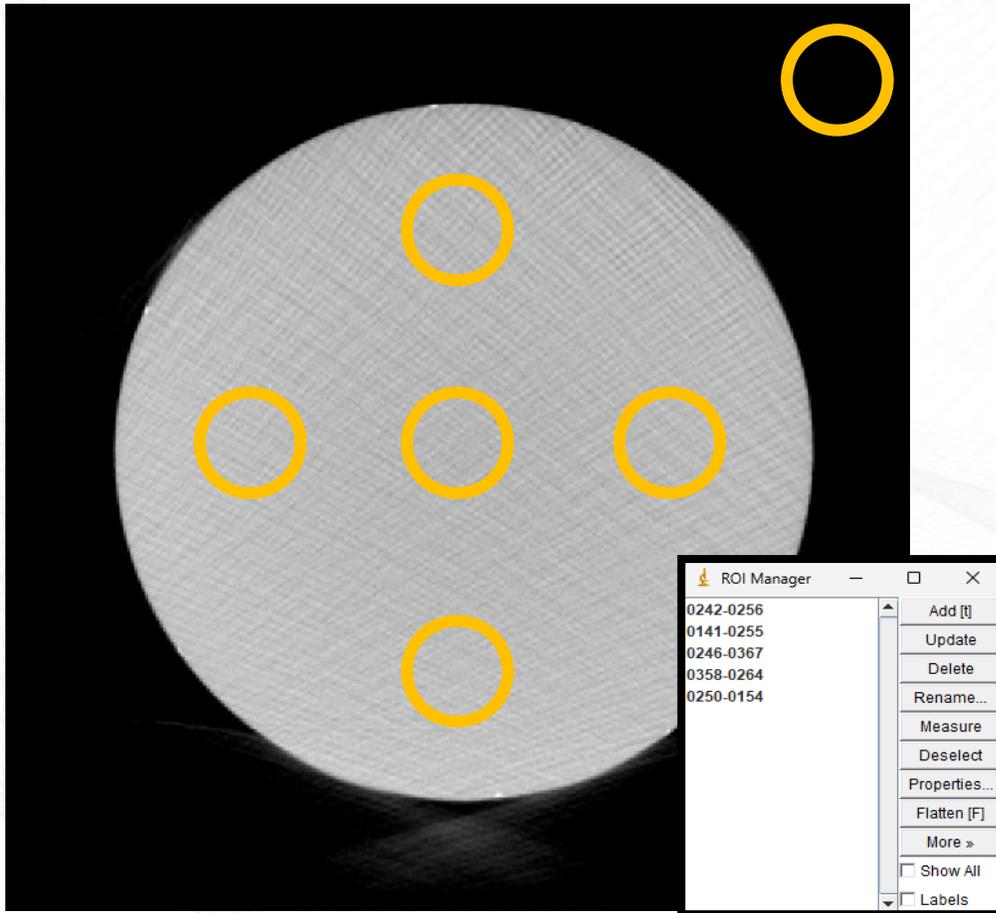


Image J procedure:

- Set the slice thickness to at least 2 cm.
- Place one ROI on the center, four ROIs on the periphery, and one ROI on the air region.

$$U = \frac{\max(MPV_{periphery} - MPV_{center})}{|MPV_{air} - MPV_{water}|} \times 100\%$$

Performance Criteria:

- The Uniformity value should be below 10% of the difference between air and water-like regions

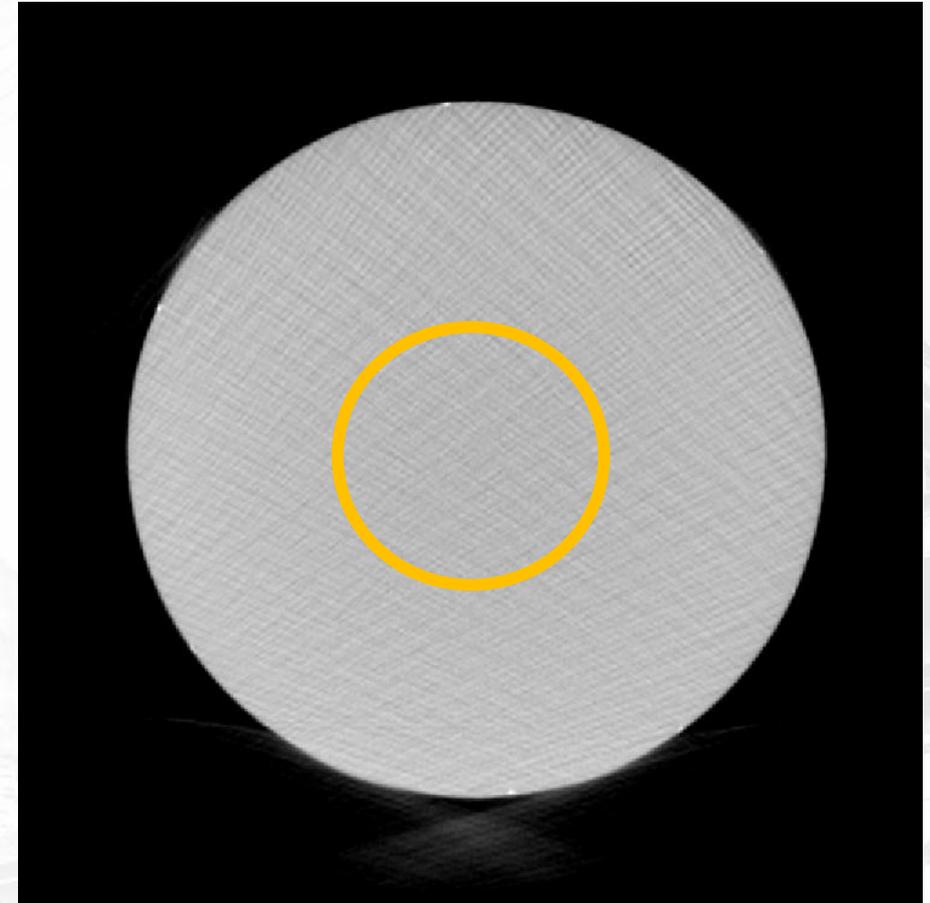
Noise

Image J procedure:

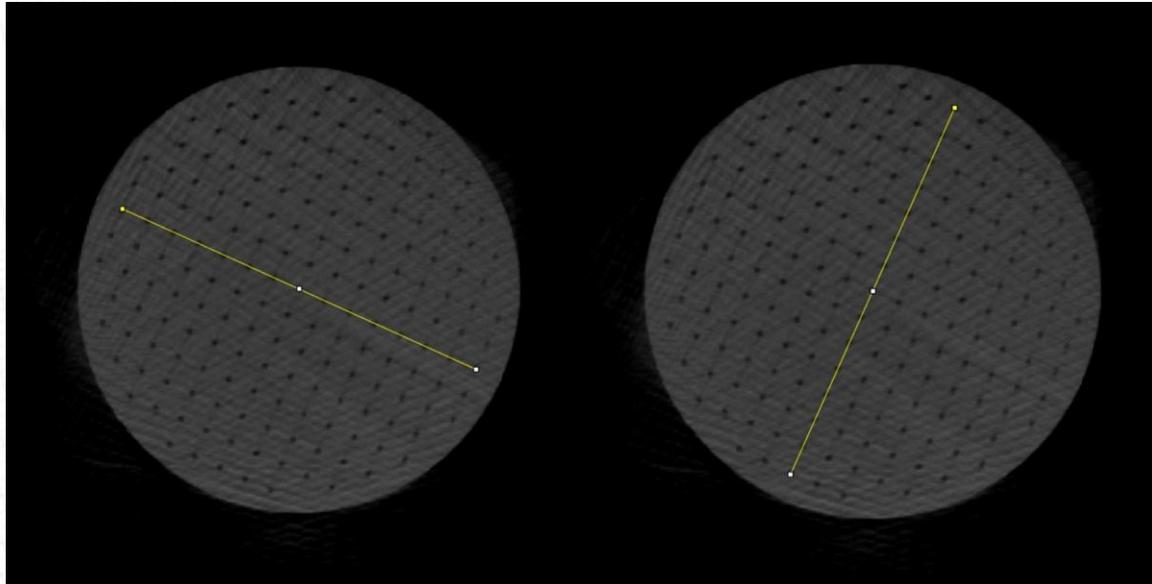
- Set the slice thickness to at least 2 cm.
- Measure standard deviation on five different slices of the uniform section of the phantom.

Performance Criteria:

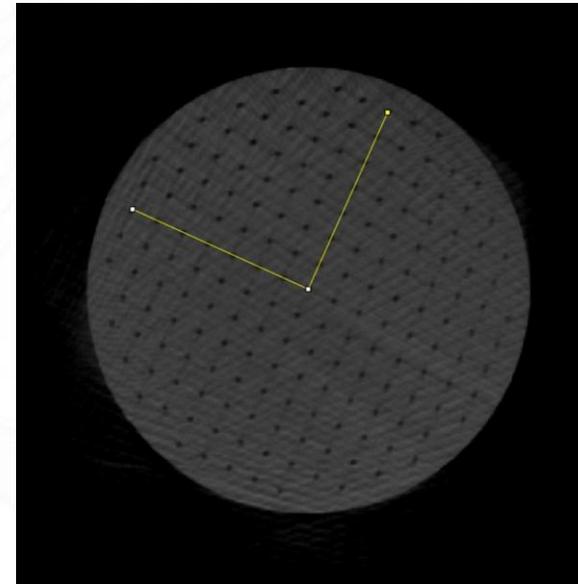
- The image noise measurement should be within 20% of baseline measurement.



Geometric Distortion



Distance Measurement



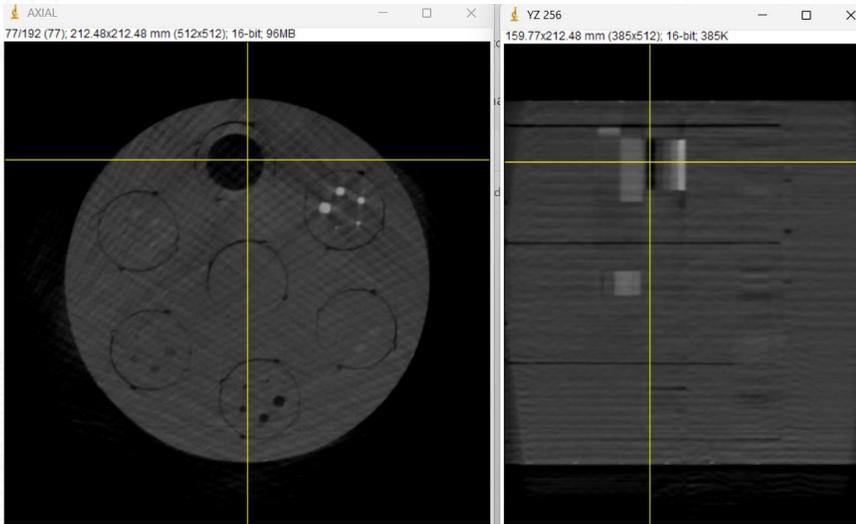
Angle Measurement

End-to-end distance: 140 mm

Performance Criteria:

- Geometric Accuracy should be within ± 2 mm from actual distance.

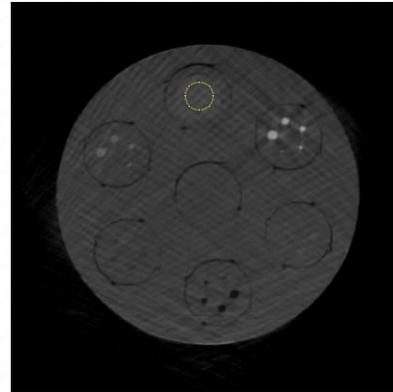
Voxel Intensity Values



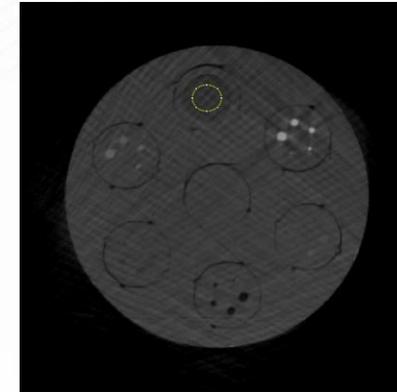
Orthogonal View (ImageJ)

Performance Criteria:

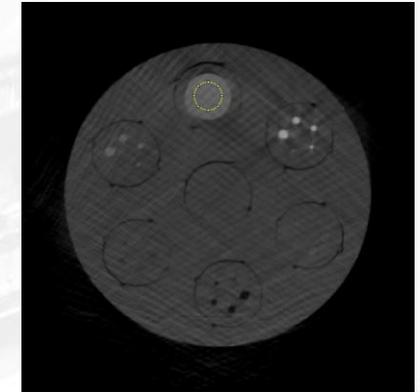
- Measured MPV for each material should not vary by more than 25% of the difference between air and water-like regions from its baseline values.



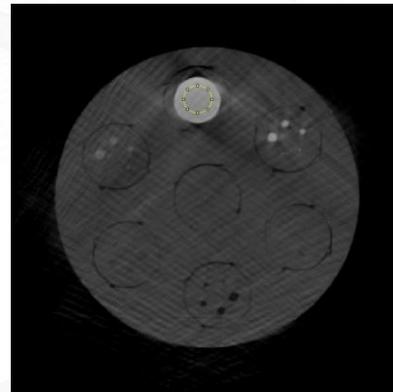
Delrin



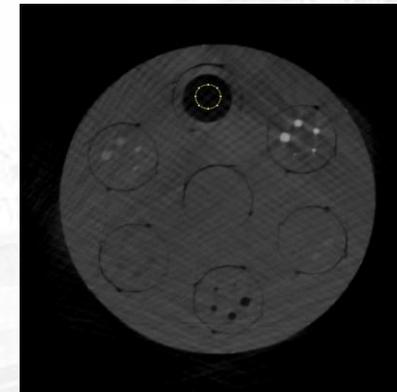
LDPE



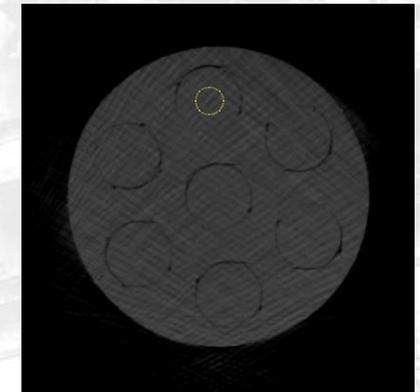
Teflon



Aluminum

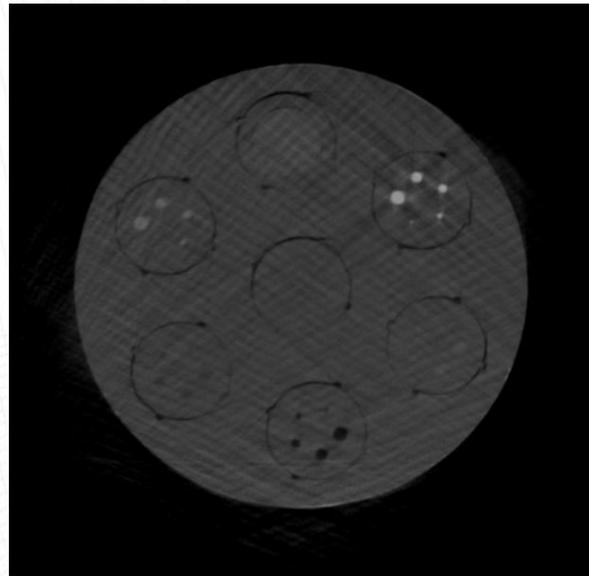


Air

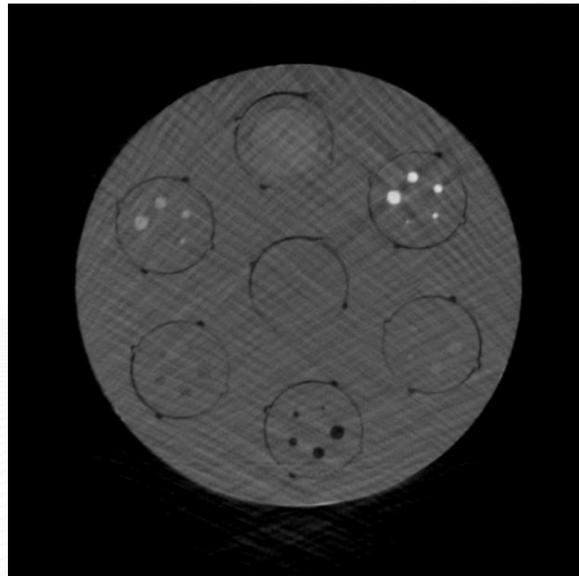


PMMA

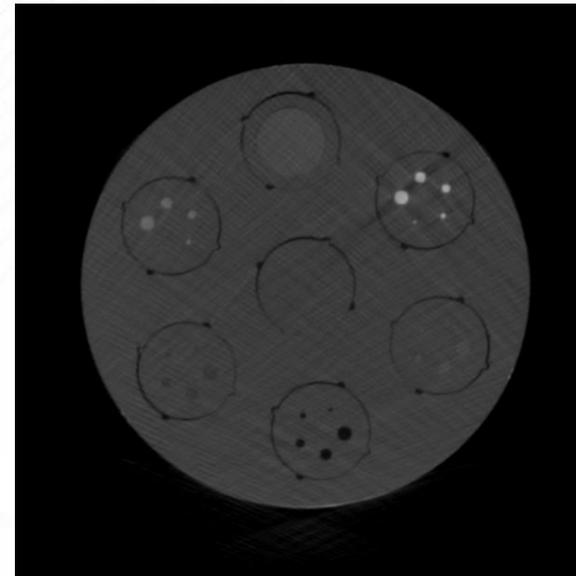
Contrast Resolution



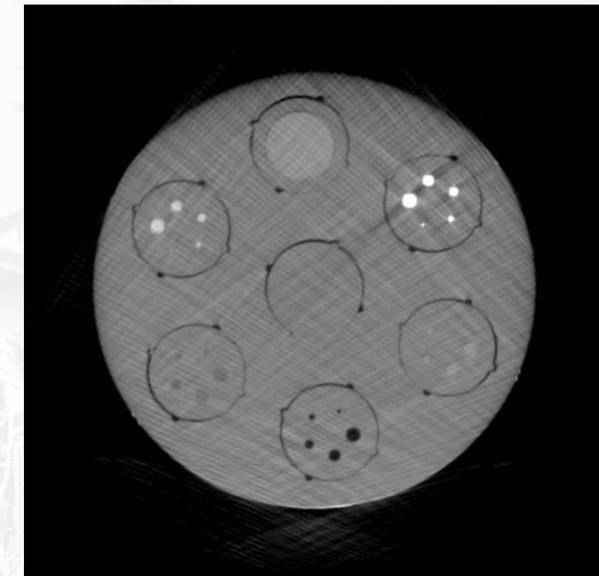
Low Dose



Standard Dose



High Dose



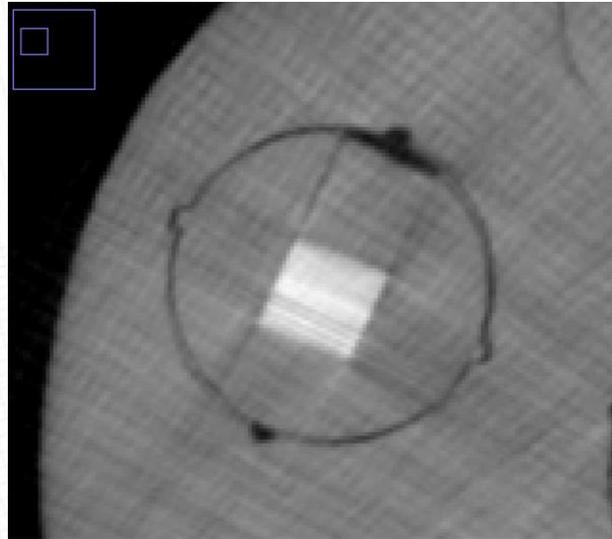
Enhanced Cranial

Performance Criteria:

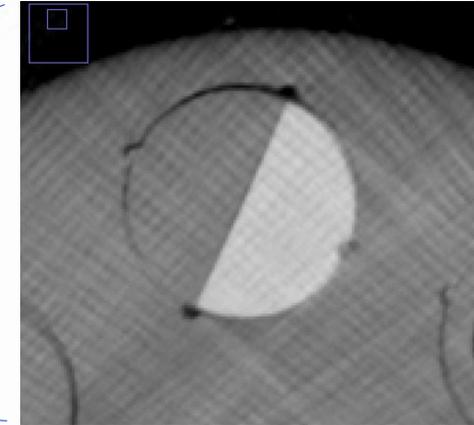
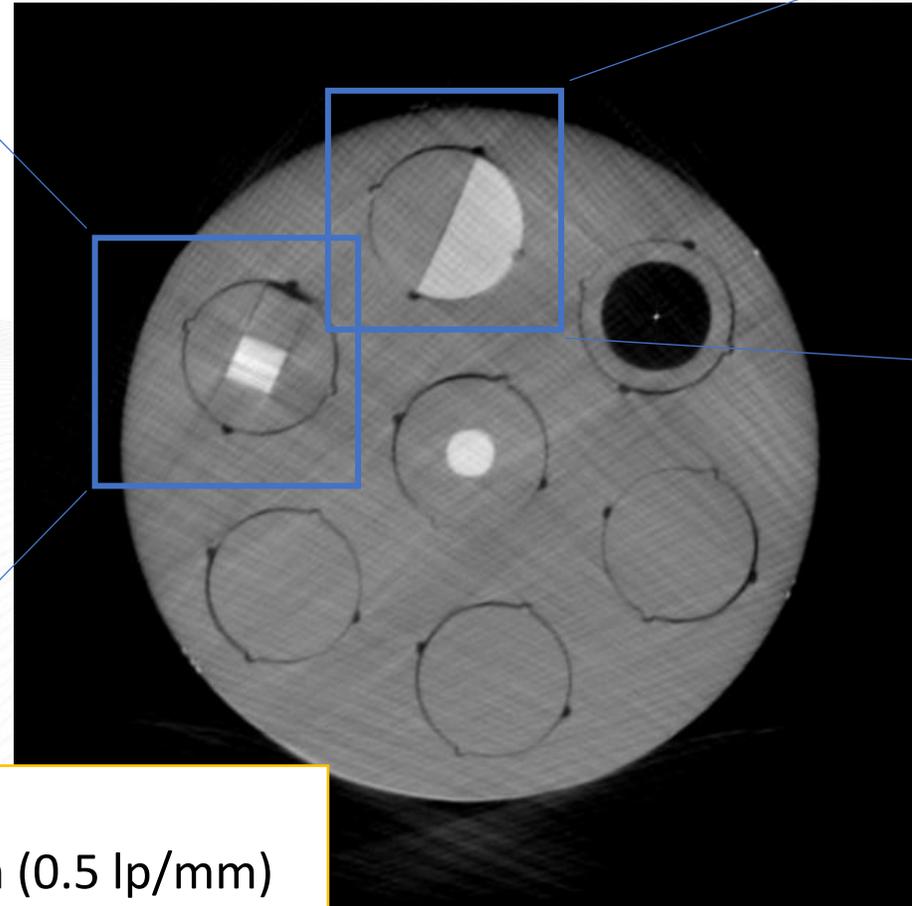
- Contrast to Noise Ratio (CNR) of different materials should be less than 40% of its baseline value.

$$CNR = \frac{MPV_{material} - MPV_{background}}{SD_{background}}$$

Spatial Resolution



Line pair per mm



Slanted Edge MTF

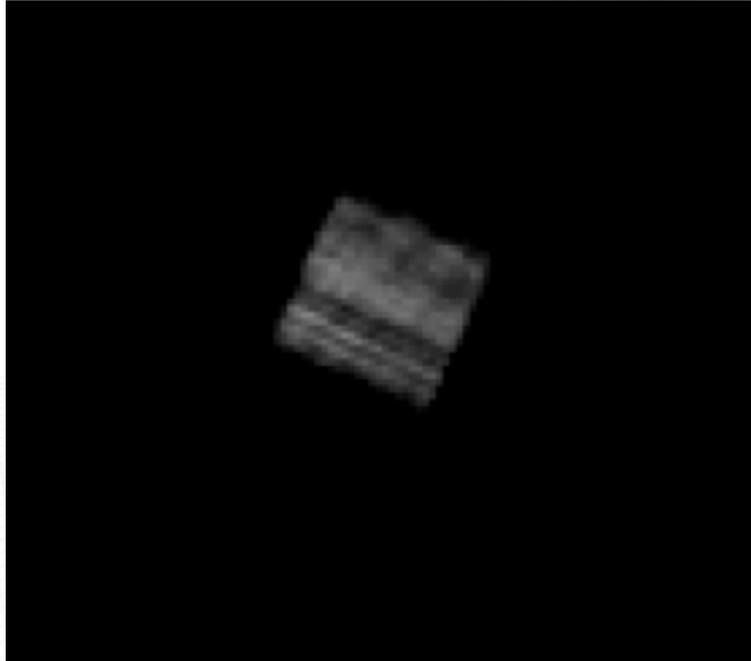
Performance Criteria:

- Spatial Resolution values should be within 20% of the baseline values.

Performance Criteria:

- Spatial Resolution ≥ 5 lp/cm (0.5 lp/mm)

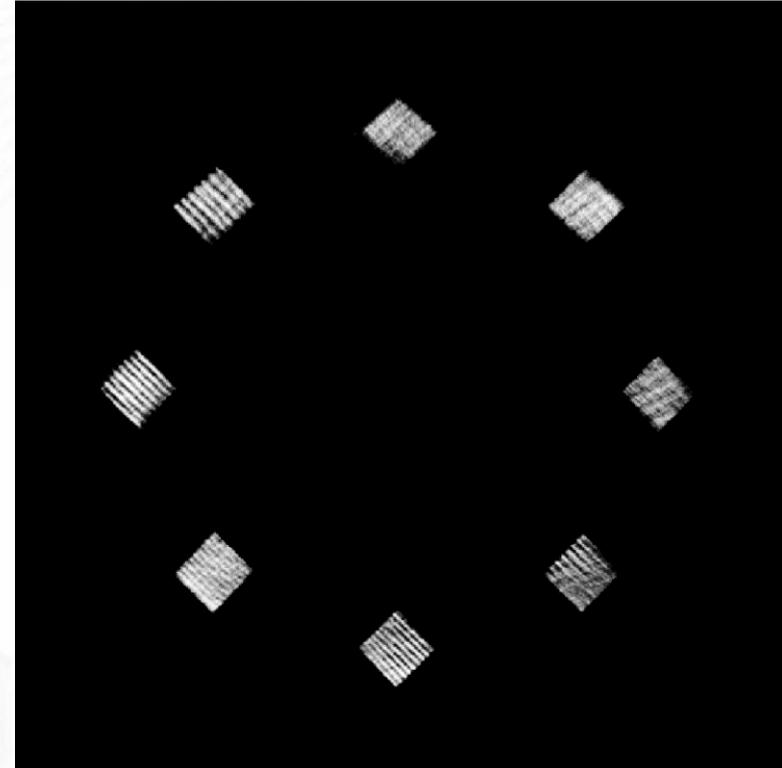
RESULTS (Spatial Resolution)



SedentexCT Phantom

The minimum resolution available for the SedentexCT IQ phantom is **10 lp/cm (or 1 lp/mm)**

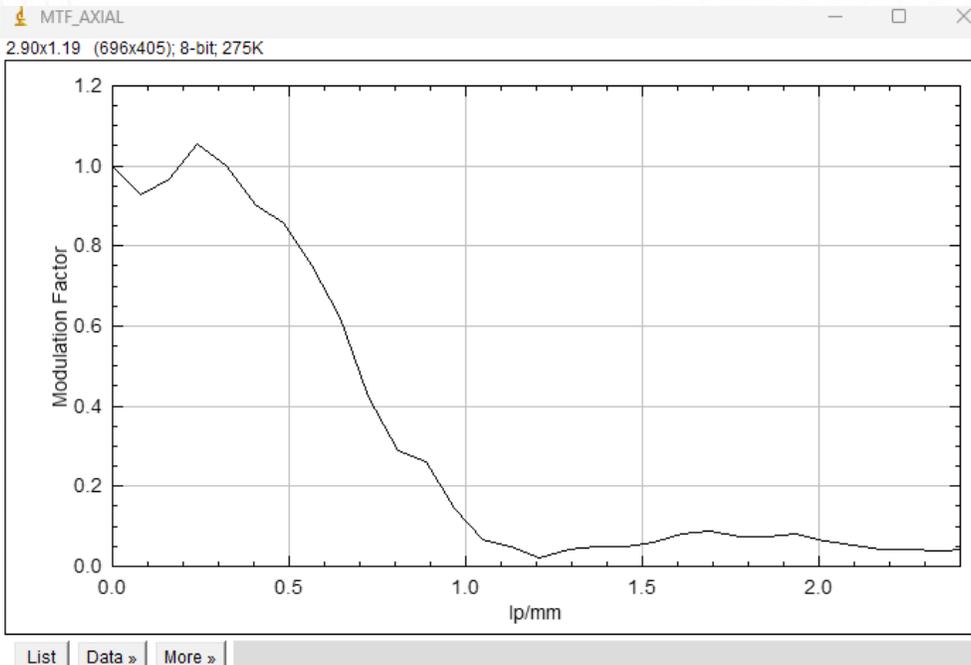
- LP/mm - alternating Aluminium/polymer (XY)
(1.0, 1.7, 2.0, 2.5, 2.8, 4.0 and 5.0 LP/mm) (fig. 4)



ACR CT Phantom

The observed spatial resolution was about **6-7 lp/cm**

RESULTS (Spatial Resolution)



Standard Dose

	lp/mm
MTF 50%	0.65
MTF 10%	0.97

Result

Baseline Values

Summary of Results

Test	Recorded	Results
Uniformity	1%	Pass
Image Noise	SD = 63.907	Baseline
Geometric Distortion	140.142 mm & 140.027 mm	Pass
Voxel Intensity Values	PMMA = 316.854	Baseline
Contrast Resolution		For Reference/Baseline
Spatial Resolution	0.6 – 0.7 lp/mm MTF10% = 0.97 lp/mm	Baseline

Limitation (Spatial Resolution):

- The minimum resolution available for the SedentexCT IQ phantom is 10 lp/cm (or 1 lp/mm)
- MTF evaluation is applicable.

Salamat
Cảm ơn
THANK YOU

RESULTS (Uniformity)

Standard Dose

	Center	Top	Right	Bottom	Left
MPV	287.179	298.221	301.819	320.980	321.232
Average	305.886				
Difference to Average	15.346	7.665	18.707	15.094	4.067
Max Uniformity	1%				

Air region	-1024.000
Water-like region	287.179
Limit*	131.12
Result	Pass

*10% of the difference between water-like and air regions

RESULTS (Noise)

Exposure Mode	Standard Dose (SD)
Slice 1	62.944
Slice 2	65.764
Slice 3	64.596
Slice 4	63.189
Slice 5	63.044
Average SD	63.907

Result	Baseline Values
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RESULTS (Geometric Distortion)

Exposure Mode	Standard Dose
Vertical Distance (mm)	140.142
Horizontal Distance (mm)	140.027
Angle (deg)	90.00
Result	Pass

RESULTS (Voxel Intensity Values)

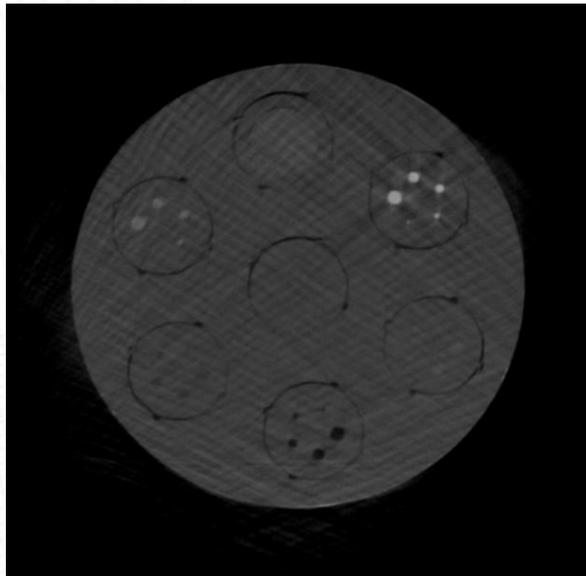
Material	Standard Dose (MPV)
Air	-885.505
LDPE	85.436
Delrin	527.228
PMMA	316.854
Teflon	1145.513
Aluminum	2176.601

Limit*	335.21
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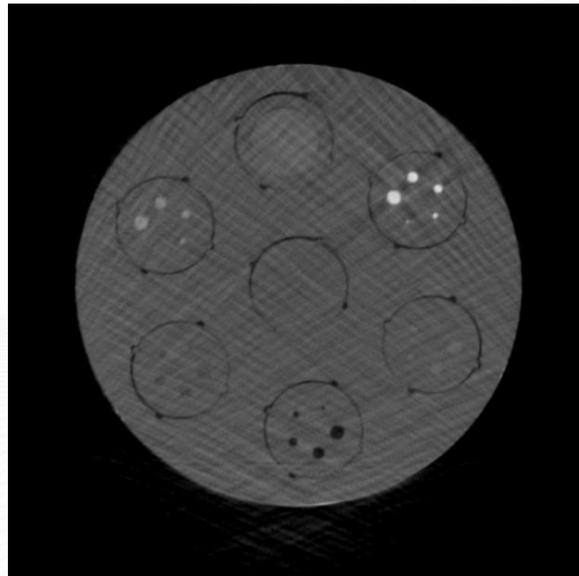
*25% of the difference between water-like and air regions

Result	Baseline Values
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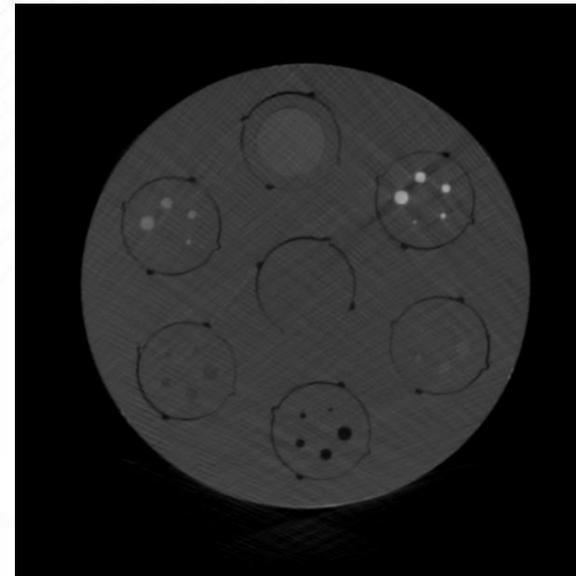
Contrast Resolution



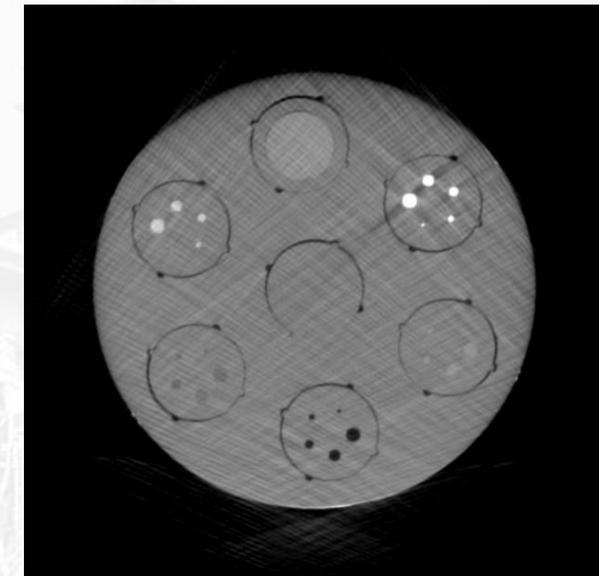
Low Dose



Standard Dose



High Dose



Enhanced Cranial

Performance Criteria:

- Contrast to Noise Ratio (CNR) of different materials should be less than 40% of its baseline value.

$$CNR = \frac{MPV_{material} - MPV_{background}}{SD_{background}}$$

RESULTS (Contrast Resolution)

Qualitative evaluation

Material	Standard Dose
Air	5
LDPE	3
Delrin	4
Teflon	4
Aluminum	5

Performance Criteria: No available criteria from EFOMP-ESTRO-IAEA protocol

Result	For reference
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Quantitative evaluation: Contrast to noise ratio (CNR)

Material	Standard Dose
Air	8.143
LDPE	2.394
Delrin	4.551
Teflon	11.774
Aluminum	28.755

Result	Baseline Values
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REFERENCES

- Hartshorne, J. (2021). Essential guidelines for using cone beam computed tomography (CBCT) in implant dentistry. *International dentistry – African edition*.
https://www.moderndentistrymedia.com/jun_jul2018/hartshorne_part1.pdf
- Schneider, C., Rasband, W. & Eliceiri, K. (2012). NIH Image to ImageJ: 25 years of image analysis. *Nat Methods* 9, 671–675 <https://doi.org/10.1038/nmeth.2089>
- Watanabe, Yoichi & Constantinou, C. (2006). Phantom Materials in Radiology. [10.1002/0471732877.emd201](https://doi.org/10.1002/0471732877.emd201).
- Zhang, J., Weir, V., Lin, J., Hsiung, H., & Ritenour, E. R. (2009). Image quality of a cone beam O-arm 3D imaging system. *Proceedings of SPIE, the International Society for Optical Engineering/Proceedings of SPIE*.
<https://doi.org/10.1117/12.812027>
- Nachabe, R., Strauss, K., Schueler, B., & Bydon, M. (2019). Radiation dose and image quality comparison during spine surgery with two different, intraoperative 3D imaging navigation systems. *Journal of Applied Clinical Medical Physics*, 20(2), 136–145. <https://doi.org/10.1002/acm2.12534>
- De Las Heras Gala, H., Torresin, A., Dasu, A., Rampado, O., Delis, H., Girón, I. H., Theodorakou, C., Andersson, J., Holroyd, J., Nilsson, M., Edyvean, S., Gershan, V., Hadid-Beurrier, L., Hoog, C., Delpon, G., Kolster, I. S., Peterlin, P., Roca, J. G., Caprile, P., & Zervides, C. (2017). Quality control in cone-beam computed tomography (CBCT) EFOMP-ESTRO-IAEA protocol (summary report). *Physica Medica*, 39, 67–72. <https://doi.org/10.1016/j.ejmp.2017.05.069>