Comparative Evaluation of Cone Beam Computed Tomography (CBCT)

Capt Darin Bateman,[1] Col Wen Lien,[2] Col Teresa Reeves,[1] Capt Minju Yi,[2] Dr. Kraig Vandewalle[1]

[1]Air Force Postgraduate Dental School, JBSA-Lackland TX

[1,2]Uniformed Services University of the Health Sciences Postgraduate Dental College

[2]DRCS, Ft. Sam Houston, TX

Introduction: Selecting a CBCT system that meets the needs for a dental facility can often be challenging. This process is complicated further by sparse scientific literature and the lack of standards to compare the various CBCT systems. Similar image enhancement features are often referred to by proprietary names. One feature such as metal artifact reduction is referred to by many different names depending upon the manufacturer and is applied at different times, in some cases before and in other cases after image acquisition. Several companies provide features not available on other systems, such as choosing the number of basis images, arc of rotation, model scanning ability, surface rendering capabilities, and use proprietary nomenclature to refer to similar processes

Objective: To obtain objective variables with which comparisons of the CBCT systems could be performed, a quality assurance (QA) QUART DVT phantom (QUART GmbH, Zorneding, Germany) was utilized, as shown in Figure 2.

Figure 1: Images from analysis using QUART DVT_pro software

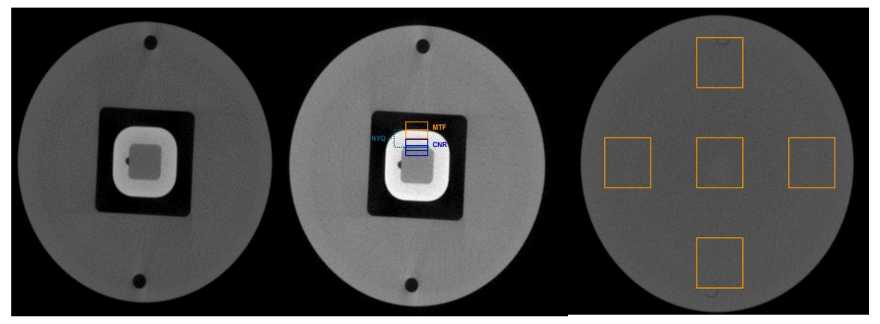

Figure 2: QUART DVT phantom

Materials and Methods: Four CBCT systems were evaluated: Carestream CS 9300, KAVO Kerr i-CAT FLX, Morita Accuitomo 80, and Planmeca ProMax Max. Image quality parameters such as Nyquist Frequency (NF), contrast, noise, contrast-to-noise ratio (CNR), and polymethylmethacrylate (PMMA) homogeneity were assessed. All CBCT volumes were analyzed using QUART DVT_pro software provided with the Quart DVT phantom (Figure 1). Results were compared using one-way ANOVAs and Tukey-Kramer HSD post hoc tests (alpha=0.05).

Table 1: CBCT Device Specifications

CBCT Manufacturer	Model	Detector	FOV (mm)	Voxel (mm)	kVp	mA	s	Focal Spot (mm)	Dose Display	Scan Mode	Arc of Rotation
Carestream	CS9300	CMOS FPD	50 x 50 80 x 80 170 x 135	0.090 0.180 0.300	84 90 90	5 4 4	20.00 8.00 11.30	0.7	DAP	Pulsed	360
KavoKerr	iCAT FLX	aSi	80 x 50 80 x 80 230 x 170	0.120 0.200 0.300	120 120 120	5 5 5	26.90 26.90 17.80	0.5	DAP	Pulsed	360
Planmeca	ProMax 3D Max	a-Si	50 x 55 100 x 55 230 x 260 *	0.100 0.200 0.400	96 96 96	11 11 11	12.00 12.00 18.00	0.6	DAP	Pulsed	360
Morita	3D Accuitomo 80	CMOS FPD	60 x 60 80 x 80 -----	0.125 0.160 -----	90 90 -----	5 5 -----	17.50 17.50 -----	0.5	CTDI	Continuous	360

a-Si = amorphous silicon, CMOS FPD = Complementary Metal-Oxide-Semiconductor Flat Panel Detector, FOV = field of view, kVp = kilovoltage peak, mA = milliampere, s = second, * Stitched volumes, DAP = Dose Area Product, CTDI = Computed Tomography Dose Index

Results: While the Carestream CS 9300 has the highest contrast ($p<0.0001$) for all FOV of the CBCT systems evaluated; it also has the greatest level of noise for the small and large sizes. For the small and medium FOV (less than 10 x 10 cm), Morita Accuitomo 80 has the lowest noise ($p<0.0001$) of the CBCT systems. As shown in Figure 3 below, NF is an exponential function of voxel size, with a small voxel having a high NF and a large voxel having a low NF. A similar relationship exists between noise and FOV, low noise relates to large FOV, whereas high noise relates to small FOV. A linear relationship is observed between FOV and CNR. Statistical analysis shows the statistically same groupings indicated by the letters A, B and C to the right of each evaluated parameter in Table 1.

Figure 3: Analysis comparing different image quality factors

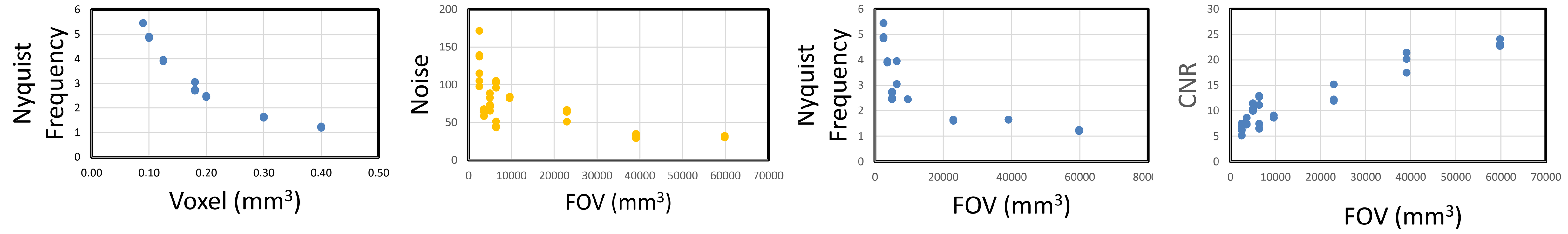

Table 2: Compiled Data based on size of FOV

FOV Size*	Model	Homogeneity	SD		Contrast	SD		Noise	SD		CNR	SD		NF	SD	
Small	ProMax 3D Max	23.12	4.50	B	734.91	26.20	B	105.86	8.60	B	6.98	0.70	A	4.88	0.029	B
	CS9300	16.28	0.40	B	893.36	27.70	A	149.40	19.10	A	6.05	0.80	A	5.45	0.000	A
	iCAT FLX	25.22	0.50	B	688.89	21.50	B	101.20	4.60	B	6.82	0.50	A	3.95	0.000	C
	3D Accuitomo 80	59.86	8.40	A	489.60	13.10	C	63.37	4.70	C	7.76	0.70	A	3.92	0.000	C
Medium	ProMax 3D Max	27.00	1.60	B	734.75	12.80	B	68.95	3.20	B	10.68	0.70	AB	2.47	0.029	C
	CS9300	31.26	0.80	A	849.87	25.80	A	81.45	7.70	A	10.48	0.80	AB	2.73	0.029	B
	iCAT FLX	17.31	0.30	C	730.10	13.50	B	83.11	1.10	A	8.79	0.30	B	2.45	0.000	C
	3D Accuitomo 80	18.17	0.30	C	567.33	6.90	C	46.53	4.10	C	12.25	1.00	A	3.05	0.000	A
Large	ProMax 3D Max	62.36	12.30	A	724.70	20.70	B	31.07	1.20	B	23.34	0.70	A	1.23	0.029	B
	CS9300	73.37	1.20	A	782.98	10.20	A	60.50	8.30	A	13.11	1.80	B	1.63	0.029	A
	iCAT FLX	36.86	0.90	B	627.70	22.90	C	32.08	2.80	B	19.68	2.00	A	1.65	0.000	A
	3D Accuitomo 80	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

*Small FOV: 5x5 to 8x8 cm, Medium FOV: 5x10 to 16x6 cm, Large FOV: 17x13.5 to 23x26 cm (FOV expressed as diameter x height)
For each FOV size, when comparing variables the same letters are not significantly different ($p > 0.05$)

Conclusion: Overall, no single CBCT system excelled on all QA parameters evaluated. Based on the CBCT systems in this study, the best contrast system also has the highest noise level. Selection of a CBCT system should be task dependent. For example, high contrast may be more desirable for endodontic evaluation, but low noise is preferential for 3D model fabrication and consistency in homogeneity may be more desirable when assessing bone quality. Due to the linear relationship between FOV and CNR, selecting an adjustable FOV CBCT device is important to ensure sufficient detail in the region of interest.