Original Article

Quality Assessment of Mobile Cone-beam Computerized Tomography Scanner Made in Thailand: A Phantom Study

Nond Rojvachiranonda MD[1], Petcharleeya Suwannapradit MSc[2], Walaiporn Suksancharoen MSc[2], Sukalaya Lerdlum MD[3]

[1] Division of Plastic and Reconstructive Surgery, Department of Surgery, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand

[2] Department of Radiology, King Chulalongkorn Memorial Hospital, Bangkok, Thailand

[3] Department of Radiology, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand

Background: In 2011, the National Science and Technology Development Agency had successfully developed the first local-made mobile cone-beam computed tomography (CBCT) scanner, called MobiiScan. Before a computed tomography (CT) scanner can be used in clinical practice, it must pass a quality assurance process.

Objective: To assess the performance of MobiiScan before it can be further evaluated in human subjects.

Materials and Methods: Images from scanning of an imaging phantom by MobiiScan were compared to a commercial 64-slice (GE Discovery CT750 HD) and a mobile (Neurologica CereTom) CT scanner, which were used as controls. Spatial resolution, uniformity, noise, accuracy of CT number, and geometric accuracy were examined by three investigators.

Results: According to the bone scanning protocol, spatial resolution of the images produced by MobiiScan was comparable to the mobile scanner, but it was less than the 64-slice scanner. In addition, the signal uniformity of MobiiScan was poorer compared to the controls. MobiiScan produced more noise than the mobile and the 64-slice scanners at the 120-kVp mode, but less noise than the 64-slice scanner at the 80-kVp mode. Using the brain protocol, the spatial resolution from the MobiiScan was higher than the mobile scanner, but comparable to the 64-slice scanner. Although the signal uniformity of the MobiiScan was superior compared to the controls, the noise production was more than the controls. At all settings, the MobiiScan gave underrated distances and inaccurate CT numbers. However, it delivered very low radiation doses.

Conclusion: MobiiScan had a good spatial resolution and delivered low radiation dose, which suggested that it could be used for bone examination as intended by the creator. However, its noise production and inaccurate CT numbers suggest that MobiiScan should not be used to diagnose soft tissue problems. It is recommended that the hardware and software should be adjusted to provide a better signal uniformity, lower noise level, accurate CT number, and geometric accuracy.

Keywords: X-ray computed tomography; Cone-beam computed tomography; Craniofacial abnormalities; Radiologic phantom; MobiiScan

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Computed tomography (CT) is the most popular imaging technique used to evaluate the human skeleton in modern medicine, but CT scanners in Thailand are all imported from overseas. As long as CT remains a popular investigation in medical fields, Thailand will continue to lose money in using this medical technology, which tends to evolve endlessly. Local investment on research and development of medical technology seems to be the only way to prevent such financial loss.

In 2011, the National Metal and Materials Technology Center (MTEC) and the National Electronics and Computer Technology Center (NECTEC), under the umbrella of the National Science and Technology Development Agency (NSTDA), were successful in making the first cone-beam CT (CBCT) scanner. It was named DentiiScan and used only for the dental field among sitting patients. The gantry system rotated around the head of a sitting patient at 360 degrees and collected raw projection data from each angle to reconstruct a two-dimensional (2D) and three-dimensional (3D) images with relevant measurements. DentiiScan passed the tests for radiation dose safety, electrical safety, image quality, and accuracy when compared to other dental

Correspondence to:

Rojvachiranonda N.

Princess Sirindhorn Craniofacial Center, Floor 14, Sor Gor Building, King Chulalongkorn, Memorial Hospital, Rama 4 Road, Pathumwan, Bangkok 10330, Thailand.

Phone: +66-2-2564330, **Fax**: +66-2-2565314

Email: Rnond@hotmail.com

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Table 1. Specification of MobiiScan

Model	MobiiScan
Manufacturer	NSTDA
Country	Thailand
CT type	CBCT
Detector type	Amorphous silicon flat panel
Detector size	40×30 cm
Detector pixel pitch	0.194 mm
Tube voltage	90 kVp
Tube current	4 to 9 mA
Exposure time	4.68 to 5.76 seconds
X-ray focal spot	0.5 mm
X-ray beam angle	15 deg
Scan time	12 s (bone protocol)
Field of View	24 cm (D)×19 cm (H) (max), 12 cm (D)×12 cm (H) (minute)
Voxel size	0.3 mm, 0.4 mm, 0.5 mm
Physical dimensions	0.8 m (W)×1.2 m (D)×1.6 m (H)
Weight	350 kg

NSTDA=National Science and Technology Development Agency; CT=computed tomography; CBCT=cone-beam computed tomography

Table 2. Specifications of the two control scanners

Model	GE Discovery CT750 HD	Neurologica CereTom
Manufacturer	GE Healthcare	Neurologica
Country	USA	USA
CT type	MSCT (64-slice)	MSCT (8-slice)
Detector type	Gemstone scintillator	Solid state detector
Detector size	40 mm width, 64 rows, 192 elements per row	408×8 rows
Detector pixel pitch	0.625	0.5
Tube voltage	80, 100, 120, 140 kVp	100, 120, 140 kVp
Tube current	10 to 835 mA	1 to 7 mA
Exposure time	60 s max	Vary
X-ray focal spot	1×0.7 mm per IEC 60336	1×1 mm
X-ray beam angle	56 deg	N/A
Scan time	0.5 s/rot, 1 s/rot	2 s/rot, 4 s/rot, 6 s/rot
Field of view	25, 50 cm	25 cm
Pixel size	0.35 mm	0.49 mm
Slice thickness	1.0, 2.0, 2.5, 5.0 mm	1.25, 2.5, 5.0, 10.0 mm
Reconstruction matrix	512×512 pixels	512×512 pixels
Pitch	0.5625, 0.9375, 1.375 mm	1, 1.5
Gantry dimensions	2.225 m (W)×1.006 m (D) ×1.882 m (H)	1.338 m (W)×0.729 m (D) ×1.531 m (H)
Gantry weight	1,850 kg	408 kg

CT=computed tomography

and medical CT machines[1-8]. The success of this first CBCT scanner and its low dose of radiation have led to another CT scanner development that is mobile and has a wider use in other non-dental field.

In 2011, NSTDA, in cooperation with the Faculty of Medicine, Prince of Songkhla University, had developed a second CBCT scanner, called MobiiScan. The creators of MobiiScan have claimed that they have improved the hardware and software of the machine to provide better bone examination. The flat-panel detector was changed from 20×25 square centimeters to 30×40 square centimeters to give a wider field of view (FOV) and 3D data without distortion and superposition of the anatomical structures. MobiiScan also can be used in the supine position. With these changes, there is a need to assess the quality and evaluate the radiation dose before using it on humans. Hence, the present study compared the quality of the images produced by MobiiScan and the two control CT scanners.

Materials and Methods

The present study was approved by the Institution Review Board of the Faculty of Medicine, Chulalongkorn University (IRB number: 031/59, COE number: 002/2016).

The performance of MobiiScan was compared to two commercial CT scanners (Table 1, 2). A multi-slice scanner, 64-slice CT scanner, the GE Discovery CT750 HD, and an 8-slice mobile CT scanner, the Neurologica CereTom, were used as controls. All three scanners were used to scan a radiological phantom and the quality of the produced images were evaluated by a panel of three specialists in December 2019.

Scanning

The Quality Assurance in Radiology and Medicine (QRM) cone-beam phantom introduced by QRM GmbH[9] was used as the CT scanning object in the present study. Comparison was made between MobiiScan (Table 1) and the controls (Table 2). Because each scanner had its own physical characteristics and preset scanning protocols, it was not possible to get the same protocols from all scanners. Best-matching protocol settings for head and neck were selected for each scanner to scan the QRM cone-beam phantom (Table 3). Each scanning protocol by each scanner was repeated three times.

Evaluation of the image quality

Images produced by the three scanners were imported into the present study hospital picture

Table 3. Protocol settings of all scanners

Scanning protocol	MobiiScan		Neurologica CereTom		GE Discovery CT750 HD		
	Bone - low kVp	Brain - low kVp	Bone - high kVp	Brain - high kVp	Bone - low kVp	Bone - high kVp	Brain - high kVp
Scan type	Axial	Axial	Axial	Axial	Helical	Helical	Axial
kVp	90	90	120	120	80	120	120
mA	9	9	6	6	200	200	280
Rotation time (second)	12	18	4	4	0.5	0.5	1
Scan time (second)	12	18	72	72	1.5	1.5	1
Exposure time (second)	5.76	11.88	72	72	1.47	1.47	1
Pitch	1	1	1	1	0.531:1	0.531:1	1
Scan FOV (mm)	220	200	250	250	320	320	320
Display FOV (mm)	220	200	250	250	220	220	200
Detector coverage (mm)	188	120	10	10	20	20	20
Slice thickness (mm)	0.4	0.4	1.25	5.0	2.5	2.5	5.0
Filter type	N/A	N/A	Bone	Soft tissue	Bone	Bone	Standard
Pixel size (mm)	0.400	0.400	0.49	0.49	0.625	0.625	1.25

FOV=field of view

archiving and communication system (PACS) so the panel of three investigators could examine the images in an anonymous fashion. For quality assurance, the investigators assessed each image on the same set of medical-grade three-megapixel monitors twice for reproducibility of the performance. Interested parameters were spatial resolution, uniformity, noise, accuracy of CT number, and geometric accuracy[10-12].

Spatial resolution or high-contrast resolution referred to the ability to resolve closely spaced objects on radiological images. In the present study, the investigators chose a set of white lines that lied at the smallest amount of spacing but still separable on a black background and recorded the choice as the maximal line pair (lp/cm) (Figure 1).

A good scanner should be able to accurately provide the CT number with an acceptable range. In the present study, the uniformity, noise, and accuracy of the reconstructed CT numbers by these three scanners were assessed.

Uniformity reflected the consistency of the CT signal in an image of a homogenous material. Ideally, the CT number measurement should not alter with the location of the selected regions of interest (ROI). In the present study, CT numbers were measured across five 400-cm² circular regions of ROI, one at the center and four at the peripheral areas of the phantom (Figure 2). Uniformity was then calculated for the differences in the CT number in the central ROI from those at the periphery.

The noise means there is a deviation of the CT signal in a homogenous phantom. Traditionally, the noise measurement is recorded as the standard deviation within a ROI of a reconstructed image. Therefore, the noise indicated that there was a variation of uniformity. In the present study, the noise was calculated from the standard variation of the signal (CT number) at each ROI, the center and the four peripheral areas of the phantom.

Figure 1. For spatial resolution, the investigator chose the maximal line pair (lp/cm) that was still visible as a set of separable black and white lines.

Typically, the accuracy of the reconstructed CT

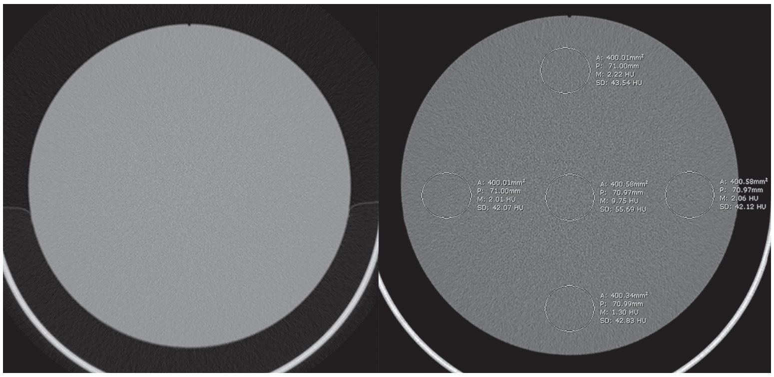

Figure 2. Uniformity was studied by measuring CT numbers on the 400-cm^2 circular ROIs at the center and four peripheral areas of the phantom.

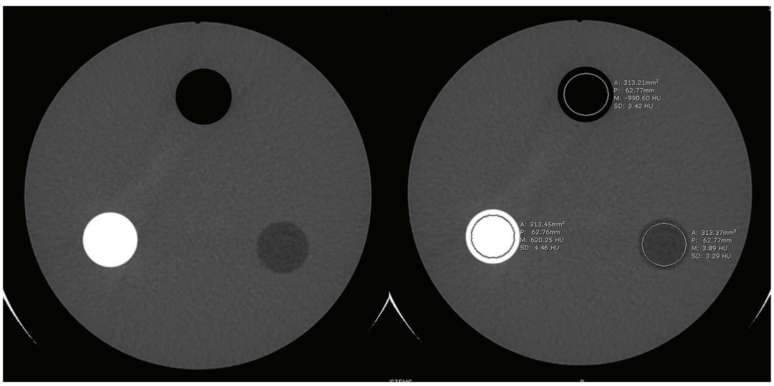

Figure 3. Accuracy of CT number was assessed by measuring CT numbers on 300-cm^2 circular ROIs at center of three objects (air, water and bone) in the phantom.

numbers is assessed by using a readily identifiable object of a known CT number. In the present study, the CT numbers were acquired from 300-cm^2 circular ROIs at the center of the three objects, which were air, water, and bone in the phantom (Figure 3).

Geometric accuracy is usually assessed by determining the accuracy of the measured distances on the images of an object with known geometry. In the present study, the distances between the known locations in the phantom were measured and then compared to the results with known values at 100 mm horizontal length, 120 mm horizontal length, 140 mm horizontal length, 100 mm vertical length, 120 mm vertical length, and 140 mm vertical length (Figure 4). Error was calculated as the difference between the known length (minuend) and the length interpreted by each scanner (subtrahend).

Radiation doses

Radiation doses from the three scanners were measured as computed tomography dose index (CTDI) by using a cylindrical, acrylic phantom with five holes, one center hole and four peripheral holes at 0, 90, 180, and 270 degrees. A cylindrical pencil-shaped air ionization chamber (Radcal Corporation, USA) was used to measure the dose (Figure 5). Measurement was done at all holes to collect absorbed doses to the CT dosimetry phantom and the measured doses were then calculated as a single value.

One third of the measured dose at the center (CTDIc) of the phantom plus two thirds of the average dose of all four peripheral values (CTDIp) became weighted CTDI (CTDIw).

$$\text{CTDIw} = [(1/3)\ \text{CTDIc}] + [(2/3)\ \text{CTDIp}]$$

For the MobiiScan, mobile, and 64-slice CT scanners protocols with axial scanning, CTDIw was equal to Volume CTDI (CTDIvol). For the 64-slice CT scanner with spiral scanning, CTDIvol was calculated from CTDIw divided by pitch which is the travel distance of the CT table in one complete gantry rotation divided by total thickness of all acquired

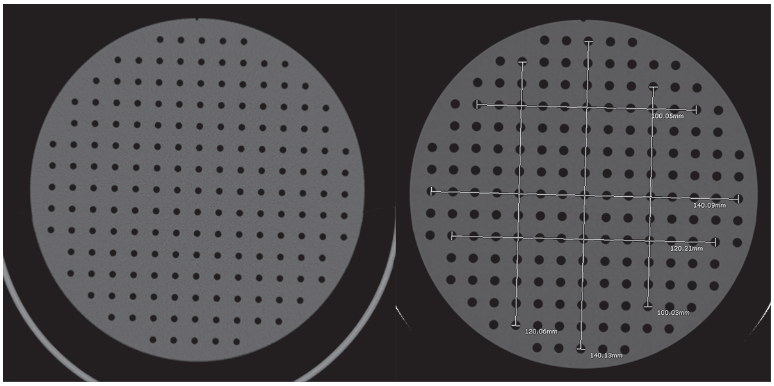

Figure 4. Geometric accuracy was studied by making length measurements on the images, between known locations of the phantom, and comparing the results with the known values for these horizontal and vertical lengths: 100 mm, 120 mm, and 140 mm.

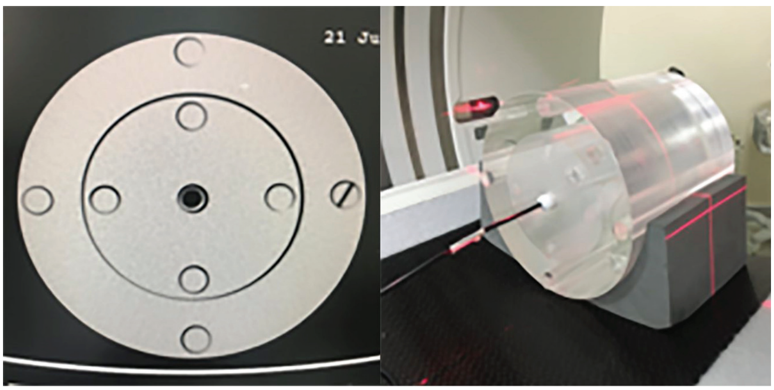

Figure 5. Positioning of the phantom and ionization chamber to measure the CTDI.

slices[13].

Because the scanning settings of the CT scanners had different tube voltages and currents that could not be modified, the CTDIw of all scanning were compared as ratios after dividing by the tube currents (mA).

Statistical analysis

The performance data were collected as continuous variables and were presented as the mean, standard deviations, intraclass correlation coefficient (ICC) and 95% confident interval (CI). All statistical analyses were done by using the Stata statistical software (StataCorp LLC, USA).

Results

The QRM cone-beam phantom was scanned by the three scanners using the two types of scanning settings, bone and brain protocols (Table 4, 5). There were 21 images including six by the MobiiScan, six by the Mobile scanner and nine by the 64-slice CT scanner.

Reproducibility and reliability of the investigators' performance, as the quality insurance, were excellent at ICC of 0.999.

Spatial resolution

When the bone scanning protocol was used, the spatial resolution from MobiiScan was similar to the mobile scanner (ICC 0.714, 95% CI –2.000 to 0.9920) while the 64-slice CT scanner gave a much better result (ICC 0.143, 95% CI 0.000 to 0.865). When using the brain protocol, MobiiScan gave higher spatial resolution than the mobile scanner (ICC 0.000, 95% CI –0.950 to 0.950) but was similar to the 64-slice CT scanner (ICC 0.857, 95% CI –0.107 to 0.996). However, spatial resolutions from all CT scanners were found to be higher than the suspension level of the International Atomic Energy Agency (IAEA)(11) and the International Electrotechnical Commissions (IEC) (2004a) (greater than 0.5 line pair per millimeter).

Table 4. Results from scanning using the bone protocols

Bone protocol	MobiiScan		Neurologica Ceretom		GE Discovery CT750 HD			
	Bone - 90 kVp		Bone - 120 kVp		Bone - 120 kVp		Bone - 80 kVp	
	Mean	STD	Mean	STD	Mean	STD	Mean	STD
Spatial resolution (line pairs/cm)	8.17	0.41	8.17	0.75	9.17	0.75	9.17	0.75
Uniformity								
Mean at center	–11.55	1.03	23.41	0.17	35.53	0.56	10.51	0.39
Mean of peripheral ROIs	–2.03	1.53	17.49	1.61	31.15	0.7	2.13	1.09
Mean of all ROIs	–6.79		20.45		33.34		6.32	
Deviation from center (%)	–9.52	1.89	5.92	1.64	4.38	0.95	8.38	1.02
Noise (average)	38.24	0.71	25.61	1.26	26.46	0.75	45.61	1.79
CT number								
Average air (normal: –1,000 HU)	–823.09	1.6	–980.81	28.4	–994.35	0.47	–994.21	1.93
Average bone	581.66	1.25	620.13	0.23	622.02	0.08	859.12	0.45
Average water (normal: 0 HU)	5.95	3.18	2.06	1.21	3.36	0.07	0.95	0.99
Geometric accuracy								
Error at 140 mm in horizontal	0.11	0.08	–1.09	0.1	–0.2	0.15	–0.09	0.09
Error at 120 mm in horizontal	0	0.17	–0.14	0.08	–0.16	0.15	–0.15	0.14
Error at 100 mm in horizontal	0.05	0.07	–0.12	0.1	–0.25	0.2	–0.1	0.09
Error at 140 mm in vertical	0.15	0.17	–0.07	0.1	–0.11	0.08	–0.08	0.09
Error at 120 mm in vertical	0.06	0.12	–0.02	0.18	–0.16	0.11	–0.02	0.05
Error at 100 mm in vertical	0.13	0.1	–0.08	0.13	–0.07	0.09	–0.08	0.06
Average error	0.08		–0.09		–0.16		–0.09	

ROIs=regions of interest; CT=computed tomography; STD=standard deviation

Uniformity

When the bone scanning mode was used, MobiiScan produced poorer uniformity than both the mobile (ICC 0.013, 95% CI –0.003 to 0.379) and the 64-slice CT scanners in the 120-kVp mode (ICC 0.012, 95% CI –0.004 to 0.395). In the brain scanning mode, it produced better uniformity than the mobile (ICC 0.026, 95% CI –0.042 to 0.734) and the 64-slice CT scanners (ICC 0.054, 95% CI –0.089 to 0.851) but with lower CT numbers from all regions of the phantom. When the brain protocol was used, all the CT numbers from MobiiScan, except the ones from the center of the phantom using brain protocol, were in negative range.

Noise

When scanning with the bone protocols, MobiiScan produced more noise than both the mobile (25.61±1.26) (ICC –0.004, 95% CI –0.004) and the 64-slice CT scanners at the 120-kVp modes (26.46±0.75) (ICC –0.001, 95% CI –0.002 to 0.044), but less noise (38.24±0.71) than the 64-slice CT scanner when the mode was 80-kVp (45.6±1.79) (ICC –0.015, 95% CI –0.016).

When scanning with the brain protocol, MobiiScan produced average noise at higher value (26.63±12.49) than the controls (lower than 4) (ICC 0.000, 95% CI 0.000 to 0.004 for the mobile scanner, and ICC 0.000, 95% CI –0.000 to 0.006 for the 64-slice CT scanner).

Accuracy of the CT number

The CT numbers displayed by MobiiScan were always less accurate than the controls. MobiiScan produced too high CT numbers for air and water in both bone and brain protocols. In the bone protocol, MobiiScan produced the lowest mean CT number for the bone object (ICC 0.000, 95% CI –0.008 to 0.235) for the mobile scanner, and ICC 0.000, 95% CI –0.000 to 0.001 for the 64-slice CT scanner).

Standard deviations of the CT numbers by MobiiScan were also the highest for air, water, and bone, except for scanning air object in the phantom by bone protocol.

Geometric accuracy

Average measurements of the distances at 100, 120, and 140 mm on horizontal and vertical planes

Table 5. Results from scanning using the brain protocols

Brain Protocol	MobiiScan		Neurologica Ceretom		GE Discovery CT750 HD	
	Brain - low kVp		Brain - high kVp		Brain - high kVp	
	Mean	STD	Mean	STD	Mean	STD
Spatial resolution (line pairs/cm)	7.17	0.98	6	0	6.5	0.55
Uniformity						
Mean at center	2	10.79	23.73	0.37	41.86	0.13
Mean of peripheral ROIs	–3.76	2	18.35	1.07	33.51	1.36
Mean of all ROIs	–2.88		21.04		37.68	
Deviation from center (%)	1.76	12.29	5.37	1.2	8.36	1.3
Noise (average)	26.63	12.49	2.41	0.08	3.26	0.15
CT number						
Average air (normal: –1,000 HU)	–849.37	28.52	–995.65	0.86	–990.07	4.74
Average bone	616.02	37.54	623.24	1.36	618.79	1.71
Average water (normal: 0 HU)	16.19	13.49	2.53	0.18	3.64	0.23
Geometric accuracy						
Error at 140 mm in horizontal	0.12	0.15	–0.14	0.12	–0.08	0.1
Error at 120 mm in horizontal	0.13	0.24	–0.03	0.09	–0.05	0.06
Error at 100 mm in horizontal	0.11	0.08	–0.02	0.2	–0.03	0.11
Error at 140 mm in vertical	0.26	0.17	–0.16	0.13	–0.2	0.27
Error at 120 mm in vertical	0.16	0.18	–0.04	0.13	–0.06	0.06
Error at 100 mm in vertical	0.18	0.14	–0.11	0.04	–0.12	0.13
Average error	0.16		–0.12		–0.09	

ROIs=regions of interest; CT=computed tomography; STD=standard deviation

Table 6. Radiation dose indexes by various CT scanners and protocols

	MobiiScan		Neurologica Ceretom		GE Discovery CT750 HD		
	Bone	Brain	Bone	Brain	Bone - 120 kVp	Bone - 80 kVp	Brain
CTDIw ratio (mGy/mAs)	0.00065	0.00104	0.02802	0.02798	0.00154	0.00055	0.00180

CTDI=weighted computed tomography dose index

by MobiiScan were shorter than the actual distances, while those by the controls were slightly longer in the bone protocols. The errors by MobiiScan were, however, the smallest at an average of 0.08 mm (Table 4) with statistical significances in all measurements except between MobiiScan and the mobile scanner in measuring the vertical 120-mm distance (ICC 0.639, 95% CI –0.568 to 0.989).

In the brain protocols, the average measurements by MobiiScan were still shorter than the actual distances and the controls gave slightly longer-than-actual distances. The errors by MobiiScan were, however, the highest at an average of 0.16 mm (Table 5) with statistical significances in all measurements.

Radiation dose

Radiation dose from MobiiScan was the lowest among the brain protocols. Radiation dose from the 64-slice CT scanner (80 kVp) was the lowest among the bone protocols (Table 6). The highest radiation dose indexes were from mobile scanner for both brain and bone scanning protocols. CTDIw ratios produced by the mobile scanner were 43.1 times higher than MobiiScan in the bone protocols the 64-slice CT scanner was only 1.7 times higher than MobiiScan in the brain protocol. the 64-slice CT scanner in 120-kVp bone protocol produced 2.4 times higher radiation dose than MobiiScan in the bone protocols. However, MobiiScan produced 1.2 times higher radiation dose than the 64-slice CT scanner in 80-kVp bone protocols.

Comparing between the two types of scanning protocols by each scanner, both MobiiScan and the 64-slice CT scanner produced lower radiation doses in the bone protocols than the brain protocols. The mobile scanner produced 1.0-time higher radiation doses in the bone protocol. Bone scanning protocol by MobiiScan produced 0.6-time less radiation dose than the brain protocol. Bone scanning protocol at 120-kVp by the 64-slice CT scanner produced 0.9-time less radiation dose than the brain protocol. Bone scanning protocol at 80-kVp by the 64-slice CT scanner produced 0.3-time less radiation dose than the brain protocol.

Discussion

All CT scanners used in Thailand were imported from overseas except for DentiiScan and MobiiScan, which were developed by the National Science and Technology Development Agency (NSTDA) of Thailand. DentiiScan was the first local cone-beam CT (CBCT) scanner designed for dentistry in 2011[4]. DentiiScan can provide accurate 2D and 3D images together with relevant measurements from a sitting patient. DentiiScan was evaluated for radiation dose safety, electrical safety, image quality, and accuracy[1,3]. The success of this first CT scanner led to another CT scanner development to provide wider use in non-dental field.

This second generation of Thailand-made CT scanner is called MobiiScan. It is a mobile unit that allows examination in supine position. According to NSTDA, MobiiScan is based on the DentiiScan with changes in its hardware and software. It is designed to give a wider field of view (FOV) by changing the flat-panel detector from 20×25 square centimeters to 30×40 square centimeters. The machine has a software that can provide 3D complete data without distortion and superposition of anatomic structures. With these changes, reassessment of the scanner quality by a third party is mandatory before extensive clinical use.

In the present study, the authors tried to match the scanning protocols of the three scanners so that acquired images could be compared for quality. It was, however, impossible as all scanners came with different settings of mA and kVp. Specifically, the kVp adjustment of the two control scanners could be done in steps such as 80, 100, 120, and 140 kVp while the kVp setting of MobiiScan was fixed at 90 kVp. With the unmatched protocols among them, comparison of CT numbers was not truly possible. However, the present study revealed important findings that are useful for those who want to adopt this local-made scanner for use and for the manufacturer to improve the machine into the next generation.

In the bone scanning mode, MobiiScan performed well in geometric accuracy and high contrast (spatial) resolution, but poorly in terms of uniformity and noise. Although MobiiScan yielded the smallest errors in geometric accuracy, all measurements tended to be slightly shorter than the actual lengths. Its high contrast resolution was comparable to the mobile scanner, but radiodensity of the images was not consistent. Compared with the two controls with high kVp settings, the uniformity across all ROIs were much less and had more noise at each ROI. On the other hand, uniformity results were similar to the 64-slice CT scanner in the low kVp setting, but with less noise. It is important to note that CT numbers produced by MobiiScan were significantly less accurate than the controls.

In the brain scanning mode, MobiiScan could image high-contrast objects better than the mobile scanner, with significantly better uniformity across all ROIs than both controls. But again, the images contained very low CT numbers, much lower than the controls. This inaccuracy makes MobiiScan unsuitable to examine soft tissue, including the white and grey matter of the human brain. The images by MobiiScan also had 8.2 to 11.1 times more noise than the controls when measuring signal variation at different locations at each ROI. Moreover, MobiiScan yielded the largest errors in geometric accuracy, with shorter measurements than the actual lengths.

Noise is an inherent problem for CBCT scanners. Cone-beam machines have larger detector panel design that tends to register more scattered photons than other types of CT scanners[14]. As the energy rises, scattering increases and causes noise in adjacent pixels of the detector. Developers of CBCT scanners must address this problem in a specific way. MobiiScan is manufactured with low kVp setting but still produces more noise than the controls at a higher kVp setting in the bone scanning mode. It also produced much more noise than the controls in the brain scanning mode. MobiiScan outperformed the 64-slice CT scanner only when used at low kVp setting in the bone protocols.

Apart from the inferior uniformity and noise, MobiiScan produced less accurate CT number. For energy-independent substances like air and water, MobiiScan could not get close to the calibration points at 0 and –1,000 HU, respectively. Additionally, standard deviations of the CT numbers by MobiiScan in the brain mode had much higher values. It is known that the accuracy of the CT number plots has been a problem due to lack of standard photon energy and attenuation mechanism[14]. Radiologists often see significant variations in the CT number among different bones in the same image, among different scanners and among different patients. Moreover, CT numbers expressed as Hounsfield unit (HU) obtained from CBCT can vary much from MSCT. Although this fundamental issue can explain the discrepancy of CT numbers between MobiiScan and the two controls, the inaccurate CT numbers for air and water seem to be another unrelated matter. Both uniformity and noise are parameters related to CT number and the attenuation coefficient of the substance. The software inside the MobiiScan is not properly set to produce adequate CT number accuracy.

In addition to the software problem, there are hardware issues worth mentioning. The machine is designed with a small aperture opening that allows only the patient's head and upper neck to enter. The rest of the body cannot be examined. The scanning rotation time of MobiiScan at 12 seconds in bone protocols and 18 seconds in brain protocols was longer than the 64-slice CT scanner, which is less than 5 seconds, but much shorter than the mobile scanner, which is 72 seconds. This may be a limiting factor in children and non-cooperative patients who cannot keep their heads still until the scanning is completed. Considering the radiation dose delivered to the phantom, MobiiScan gave the lowest indexes. However, CTDIvol is not shown on its console when compared to ordinary CT scanners as required by the International Electrotechnical Commissions (IEC) standard 60601-2-44[13].

Conclusion

The images produced by MobiiScan had acceptable quality in terms of spatial resolution and geometric accuracy but not for uniformity and the noise were far inferior to the controls, which are both MSCT scanner in mobile and standard formats. MobiiScan also had low accuracy of CT number and users should be aware of the underrated measurements. Even though MobiiScan passed the radiation test and produced low dose of radiation, it is still questionable if it could be used in clinical practice. MobiiScan can be used for bone study, but the authors suggest further testing in human cadavers. Furthermore, improvement in both the hardware and software is required.

What is already known on this topic?

Mobile CT scanner is being widely used in the medical practice, and MobiiScan is the first locally made machine in Thailand. However, it has never been evaluated for its quality.

What this study adds?

This study is the first report that demonstrates the performance of MobiiScan by examining the standard radiological parameters.

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Conflicts of interest

All authors have no conflict of interest.

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