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Original Article

Dentistry Section

Comparison of Cone Beam Computed Tomography and Multi Slice Computed Tomography Image Quality of Human Dried Mandible using 10 Anatomical Landmarks

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ABSTRACT

Introduction: Cone Beam Computed Tomography (CBCT) has gained a broad acceptance in dentomaxillofacial imaging. Computed Tomography (CT) is another imaging modality for diagnosis and preoperative assessments of the head and neck region.

Aim: Considering the increased radiation exposure and high cost of CT, this study sought to subjectively assess the image quality of CBCT and Multi Slice CT (MSCT).

Materials and Methods: A dry human mandible was scanned by five CBCT systems (New Tom 3G, Scanora, CRANEX 3D, Promax and Galileos) and one MSCT system. Three independent oral and maxillofacial radiologists reviewed the CBCT and MSCT scans for the quality of 10 landmarks namely mental foramen, trabecular bone, Periodontal Ligament (PDL), dentin, incisive canal, mandibular canal, dental pulp, enamel, lamina dura and cortical bone using a five-point scale.

Results: Significant differences were found between MSCT and CBCT and among the five CBCT systems ($p<0.05$) in visualization of different anatomical structures. A fine structure such as the incisive canal was significantly less visible and more variable among the systems in comparison with other anatomical landmarks such as the mental foramen, mandibular canal, cortical bone, dental pulp, enamel and dentin ($p<0.05$). The Cranex 3D and Promax systems were superior to MSCT and all other CBCT systems in visualizing anatomical structures.

Conclusion: The CBCT image quality was superior to that of MSCT even though some variability existed among different CBCT systems in visualizing fine structures. Considering the low radiation dose and high resolution, CBCT may be beneficial for dentomaxillofacial imaging.

Keywords: Image assessment, Inferior jaw multi slice computed tomography, Vital structure

INTRODUCTION

Intraoral Two Dimensional (2D) and panoramic radiography are extensively used by dental clinicians for dentomaxillofacial imaging [1-3]. However, interpretation of 2D images is hard because of the overlapping and superimposition of different structures. Anatomical landmarks such as the lingual foramen and the incisive canal containing neurovascular bundles can be hardly identified or thoroughly assessed on these images. The mandibular bone and the alveolar ridge width cannot be evaluated on these images either [3-7]. Using, 3D technique has become more popular today [8]. CT has enabled 3D assessment of the craniofacial structures; CT is also available as a diagnostic tool for the head and neck region [9,10] and is ordered prior to some oral surgical procedures [11,12].

It should be noted that CT is not ideal for some diagnostic purposes in dentistry such as evaluation of impacted teeth and periapical lesions. The main disadvantages of CT include high patient radiation dose, limited availability and high cost. CBCT was introduced as an optimal imaging modality due to its sub millimeter resolution, high image quality, short scanning time and decreased patient radiation dose {15 times lower than that of MSCT [13].

Also, CBCT has various applications in oral and maxillofacial surgery for implant placement [14-18], bone and tooth fractures [17,19], assessment of temporomandibular joint [20], orthodontic treatment, cases of cleft lip and palate, impacted teeth, osteosynthetic screw [21], third molar extraction [22] and endodontic procedures (assessment of root canal configuration, root resorption and apical lesions) [21,22]. By using appropriate imaging system to pinpoint vital structures, the risk of damage to them during surgery can be reduced [23]. Previous studies comparing MSCT and CBCT showed diverse quality of these systems in showing the details of anatomical structures in the head and neck region [24]. Most previous reports on CBCT and its image quality were limited to one or two systems [24-26]. It should be noted that new CBCT systems have been recently introduced to the market.

Thus, considering all the above and also since MSCT has been introduced as a superior imaging technique to visualize the details of bony structures, the aim of this study was to evaluate the image quality of different CBCT systems available in the Iranian market compared to a MSCT system.

MATERIALS AND METHODS

This experimental study was performed in five private radiology centers and maxillofacial radiology department of Hamadan Dental Faculty, Iran, which lasted for six months.

In this study, dry human mandible was used. The mandible was placed in a plastic container filled with water to simulate the soft tissue. Then, the mandible was scanned by means of five CBCT systems and one MSCT system [Table/Fig-1].

- CRANEX® 3D (Soredex, Tuusula, Finland)
- New Tom 3G (Quantitative Radiology, Verona, Italy)
- Scanora 3D (Soredex, Tuusula, Finland)
- Promax (Planmeca, Helsinki, Finland)

- Galileos (Sirona, Bensheim, Germany) with multiple Fields of View (FOV)
- MSCT (Siemens, Erlangen, Germany)

Image Assessment: Three oral and maxillofacial radiologists evaluated the scans under the same conditions (flat panel monitor; 1440×900 pixels resolution). In order to assess each system, certain software was used: Sygno, Fast Viewer for MSCT, on Demand 3D for Cranex 3D, Romexis Viewer for Promax, Sirona for Galileos and NNT Viewer for New Tom 3G.

They were asked to distinguish 10 anatomical landmarks namely the mental foramen, the mandibular canal, trabecular bone, cortical bone, dental pulp, dentin, enamel, incisive canal, PDL and lamina dura on the scans and then rank them from one to five based on the quality of the images using a five-point Likert scale [22]. The observers were allowed to observe the images in three planes of coronal, axial and sagittal or in each reconstructed plane. Moreover, they were allowed to adjust the contrast and brightness of the images. In order to prevent bias, each radiologist was blinded to the interpretations of others.

STATISTICAL ANALYSIS

Data were analyzed using non-parametric Kruskal–Wallis test. Post-hoc comparisons of different systems were done by the Kendall's W test. Also, the Friedman's and Kendall's W tests were used to assess the intra-observer agreement. Finally, in order to study the inter-observer agreement for the 10 landmarks, two observations were done in total and the results for each landmark were compared in two states. The Cramer's V was used to compare the assesment by the three radiologists.

Ten landmarks in the mandibular bone were independently observed by three radiologists by means of six different software programs.

In order to rank the quality of images for observation of the landmarks, the five-point Likert scale was used ranging from one (undesirable observation) to five (excellent observation). Each radiologist assessed the landmarks twice. Since, the image quality for observation of the landmarks was reported using a five-point Likert scale, the Kruskal–Wallis and Mann–Whitney U tests (for comparison of average ratings), the Crammer's V, the Kendall's tau coefficient and the Friedman's test were used for calculation of intra and inter observer agreements.

In order to study the differences in image quality among different systems, pairwise comparisons were made using the Mann–Whitney U test.

Finally, to assess the intra observer agreement in different sizes of Field of View (FOV), Wilcoxon signed rank and Friedman's tests were used and the coefficient of agreement was calculated using the Cochran's Q and the Kendall's W tests.

In order to detect the general agreement coefficient of the three radiologists for the 10 landmarks, general reports by each radiologist at two different occasions for the six different systems were analyzed using the Cramer's V.

RESULTS

For precise evaluation of the scans taken by the different CBCT systems (New Tom, Scanora, CRANEX 3D, Promax, and Galileos) and MSCT in our study, three oral and maxillofacial radiologists evaluated the 10 landmarks (mental foramen, mandibular canal, trabecular bone, cortical bone, dental pulp, dentin, enamel, incisive canal, PDL and lamina dura) twice in a dry human mandible scanned by these systems, and scored the image quality from one to five (excellent=1, good=2, average=3, bad=4 and very bad=5).

Significant differences were noted in the quality of observation of lamina dura (p=0.003), mental foramen (p=0.002), incisive canal (0.000) and PDL (p=0.002); but the difference was not significant for other landmarks [Table/Fig-2].

Among six CBCT systems in two observations (in total), CRANEX acquired the highest score in six landmarks and Promax ranked second in three landmarks. Scanora and Galileos acquired the highest score in one landmark and the MSCT and New Tom acquired the lowest score among all [Table/Fig-3].

Pair wise comparisons of different systems showed that image quality of some systems had significant difference [Table/Fig-4].

[Table/Fig-5] explained the amount of the intraobserver agreement for different sizes of FOV for each system.

There was a weak correlation in the radiologists' interpretation for lamina dura (Cramer's V=0.293), which was not significant (p=0.62). Similarly, there was a weak correlation for mental foramen (Cramer's V=0.216) and this correlation was not significant either (p=0.22). The three radiologists had complete agreement in observing the mandibular canal. The three radiologists had complete agreement (100%) in observing the cortical bone as well. There was a strong correlation in the radiologists' interpretation of dental pulp (Cramer's V=0.675), which was significant (p=0.01). There was a strong

	Size of FOV (mm)	mA	kVp
NewTom 3G	6, 9, 12	0.5	110
Scanora 3D	7.5×14.5,7.5×10,6×6	13	90
CRANEX 3D	6×8,6×4	13	90
Promax	8×8	12	84
Galileos	15×15	4	90
MSCT	25×7.6	80	120

[Table/Fig-1]: The factor exposure of CBCT systems.

	First Radiologist	Second Radiologist	Third Radiologist	Kruskal–Wallis	
				Chi-square	p-value
Lamina dura	2.76	3.5	3.86	11.65	0.003
Mental foramen	4.47	3.59	4.36	12.36	0.002
Mandibular canal	4.57	4	4.45	5.58	0.061
Cortical bone	4.90	4.90	4.59	5.53	0.063
Dental pulp	4.61	4.68	4.59	1.25	0.535
Dentin	4.52	4.63	4.36	2.29	0.318
Incisive canal	3	1.68	4.36	30.68	0.000
Enamel	4.61	4.45	4.45	0.789	0.674
Periodontal ligament	3.28	3.5	4.18	12.428	0.002
Trabecular bone	4.57	4.40	4.18	2.237	0.327

[Table/Fig-2]: The factor exposure of CBCT systems.

	Galileos	MSCT	Promax	CRANEX 3D	Scanora	New-Tom	Kruskal–Wallis	
							Chi square	p-value
Lamina Dura	3.16	2.00	3.50	4.27	3.77	2.29	20.152	0.001
Mental foramen	3.83	3.16	5.00	4.36	3.94	.4 33	13.893	0.016
Mandible canal	4.16	3.33	4.66	5.00	4.61	3.94	27.357	<0.001
Cortical bone	5.00	4.66	5.00	5.00	4.88	4.50	12.488	0.029
pulp	4.50	3.00	5.00	5.00	4.94	4.55	35.418	<0.001
dentin	4.50	2.00	4.50	5.00	4.94	4.61	33.461	<0.001
Incisive canal	3.00	1.83	3.00	2.72	3.27	2.11	13.435	0.020
enamel	4.66	1.66	5.00	4.81	4.94	4.61	32.480	<0.001
Periodontal ligament	3.33	2.50	3.83	4.45	3.77	3.50	20.078	0.001
Trabecular bone	4.50	3.16	5.00	4.81	4.88	3.77	36.917	<0.001

[Table/Fig-3]: The quality score of 10 landmarks given by three radiologist among different systems.

	Mann-Whitney	p-value
New Tom-Scanora	66.5	0.002
New Tom-CRANEX 3D	13	<0.001
New Tom-Promax	16	0.011
New Tom-MSCT	4	0.001
New Tom- Galileos	43	0.462
Scanora-CRANEX 3D	61	0.086
Scanora-Promax	46.5	0.614
Scanora-MSCT	<0.001	<0.001
Scanora-CRANEX 3D	61	0.086
Scanora-Galileos	43.5	0.482
Promax-CRANEX 3D	22.5	0.286
Promax-Galileos	13.5	0.47
Promax-MSCT	<0.001	0.004

[Table/Fig-4]: Pairwise comparisons to study the differences in image quality among different systems.

correlation in the radiologists' interpretation of dentin (Cramer's V=0.737), which was significant (p=0.003). There was a weak correlation in the radiologists' interpretation for the incisive canal (Cramer's V=0.899), which was not significant (p=0.178). There was a strong correlation in the radiologists' interpretation for the enamel (Cramer's V=0.737), which was significant (p=0.003). There was a weak correlation in the radiologists' interpretation for the PDL (Cramer's V=0.221), which was significant (p=0.204). Also, there was an average correlation in the radiologists' interpretation for the trabecular bone (Cramer's V=0.537), which was not significant (p=0.01).

As a whole, it can be said that the difference was significant for four landmarks namely mental foramen, lamial dura, incisive canal and PDL [Table/Fig-6].

DISCUSSION

The use of three-dimensional imaging systems has improved dento-maxillofacial diagnosis [26]. Optimal image quality of vital structures has many benefits for patient and clinician especially in implant therapy.

In the present study, CRANEX 3D had the best image quality in the assessment of 10 landmarks and then stood Promax, Scanora, Galileos and New Tom 3G respectively. MSCT had the lowest image quality. Since New Tom and MSCT have higher kVp than other systems [Table/Fig-1], it can be concluded that high kV and, in turn, higher scattered radiation in these devices result in higher noise of the images which makes the visualization of fine structures difficult. In practice, the choice of CBCT system depends on whatever you need from imaging. In major maxillofacial surgery or orthodontic treatment plan we need Large Field Of View (FOV), so New Tom has the selection criteria but in other treatment planning such as implant therapy the CBCT systems with lower kVp and small FOV seem to be a better option for detecting fine details in vital structures and bone status.

In a study by Liang X et al., it was found that the image quality of CBCT was comparable or even higher than that of MSCT and there were some differences among CBCT systems [27]; in the current study, we concluded that the image quality of CBCT was higher than that of MSCT.

Liang X et al., claimed that bone trabecula and Periodontal Ligament (PDL) were less observable and variable among different systems [27]. In our study, the incisive canal had the poorest quality of observation and PDL did not have a good quality of observation either. This difference may stem from the differences in CBCT systems, which were used in the current study and the study by Liang X et al., as well as the method of image quality evaluation.

Kamburoglu K et al., [28] used landmarks for evaluation of image

	Friedman and Kendall's Mean		Observer 3
	Observer 1	Observer 2	
Lamina dura	1.88	3.98	4.2
Mental foramen	6.69	4.25	5.89
Mandibular canal	6.67	5.3	6.3
Cortical bone	7.69	8	6.57
Dental pulp	6.95	7.5	6.8
Dentin	6.64	7.36	5.93
Incisive canal	2.19	1.43	2.5
Enamel	7	6.82	6.36
Periodontal ligament	2.74	3.7	5.36
Trabecular bone	6.55	6.66	5.09

[Table/Fig-5]: The intraobserver agreement coefficient for different sizes of FOV for each system (2 to 3 FOV sizes).
Chi-square=72.433, Chi-square=123.54, Chi-square=139.31, p<0.001, p<0.001, p<0.001

		Radiologist 1	Radiologist 2	Radiologist 3	Agreement coefficient
Lamina dura	Good	13	18	20	0.293
	Bad	8	4	2	
Mental foramen	Good	19	19	22	0.216
	Bad	2	3	0	
Mandibular canal	Good	21	21	21	1
	Bad	0	0	0	
Cortical bone	Good	22	22	22	1
	Bad	0	0	0	
Dental pulp	Good	21	21	22	0.675
	Bad	0	1	0	
Dentin	Good	19	20	20	0.737
	Bad	2	2	2	
Incisive canal	Good	17	20	17	0.889
	Bad	4	1	5	
Enamel	Good	19	20	20	0.737
	Bad	2	2	2	
Periodontal ligament	Good	20	18	21	0.221
	Bad	1	4	1	
Trabecular bone	Good	21	20	21	0.537
	Bad	0	2	1	

[Table/Fig-6]: General agreement coefficient of the three radiologists regarding the image quality of the 10 landmarks.

quality of CBCT and reported different results from the present study. However, regarding the same landmarks (trabecular bone and mandibular canal), both studies concluded that the image quality of these two landmarks in different systems was significantly different.

The study by Hashimoto K et al., was similar to our study and they reported results similar to ours, indicative of higher accuracy of CBCT (3DX) than that of MSCT [22].

Loubele M et al., showed that image quality was better significantly in CBCT than MSCT with respect to lamina dura and PDL observation [29]. They used a dry maxilla for image quality evaluation. Although the systems and the jaw, used in their study were different from the present study but the results were similar.

Lofthag HS et al., evaluated image quality of Accuitomo CBCT in three FOV [30]. Seven radiologists assessed the images. Intra-observer agreement was good and interobserver agreement was moderate. In the present study, interobserver agreement in three landmarks wasn't good.

Lamina dura was given the least score by the first radiologist and there was a weak agreement among the three radiologists with regard to this landmark as well as mental foramen.

Interestingly, with regard to the mandibular canal and cortical bone, all three radiologists completely agreed (100%) that the image quality of these landmarks was good. The first and third observers gave a low score to the incisive canal, which indicates low image quality of this landmark.

LIMITATION

However, limitation of this study was the invitro nature of the study and also we didn't assess image quality of maxilla. Further studies should be carried out for in-vivo evaluation of image quality with other CBCT systems.

CONCLUSION

The present study concluded that CBCT systems had better image quality and lower noise than MSCT. Among CBCT systems selection of the best device depends on the target landmark that is going to be evaluated.

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