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Accuracy of artificial bone defects measurements on two cone beam computed tomography scanners. A comparative study

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ABSTRACT

Introduction: Several CBCT systems are currently on the market variable in their image quality and ability to visualize anatomic structures. Those systems differ from each other in detector design, patient scanning settings, and data reconstruction parameters. Moreover, other scanning and reconstruction factors including scan field of view (FOV), voxel size and the number of basis projections used for reconstruction have significant influence on image quality in CBCT. The aim of this study is to compare two CBCT systems regarding their linear measurements accuracy.
Materials and methods: Eighteen bone defects were created in one dry skull by using a round diamond bur mounted on a high speed hand piece. The defects were fully injected with polyvinyl siloxane impression. The skull was scanned using Planmeca ProMax 3D (Planmeca, Helsinki, Finland) and i-CAT next generation (Imaging Sciences international, Hatfield, PA, USA). Images were uploaded to a third party software (On Demand, Cyber med Inc. South Korea) for applying the measurements. Several measurements of each rubber impression material were done using the measurement tool on the cross sectional images in order to determine the maximum diameter. Then the impression material was removed carefully from the mandible by a dental probe and all the rubber balls were measured with a digital caliber to determine the actual maximum diameter (gold standard). Numerical collected data were explored for normality by checking the data distribution.
Results: The results of the present study showed that the overall measurements by Planmeca showed statistically significantly higher mean measurement than the standard reference while i-CAT measurements showed non-statistically significant difference from the standard reference at all areas and also regarding the overall measurement. Regarding the overall error measurement and error percentage; Planmeca showed statistically significantly higher mean error and error percentage than I-CAT.
Conclusion: CBCT is highly accurate and reproducible in linear measurements in the axial and coronal image planes and in different areas of the maxillofacial region. According to the findings of the present study I-CAT is recommended when the purpose of the CBCT scan is to measure linear distances. This will result in lower patient radiation dose and faster scan time.

1. Introduction and review of literature

The advent of cone beam computed tomography (**CBCT**), with its three dimensional representation of maxillofacial structures, has led to major advances in diagnosis and treatment planning in various areas of dentistry [1,2].

The advantages of this technology are three dimensional (**3D**) images of dento-facial regions with lower cost, more convenient size, easier operation, quicker scans and lower radiation dose compared to medical computed tomography machines. CBCT technology is able to achieve radiation dose levels equivalent to a full-mouth series, and as low as two panoramic radiographs, depending on the setting in use [3–5].

The recent accuracy studies involving CBCT scans have shown not only that 3D measurements are much more accurate than 2D measurements, but also that they are close to reality [6,7]. Another study showed that CBCT has a higher sensitivity and diagnostic accuracy than intraoral digital or conventional radiographs when evaluating the presence of artificially created periapical bone defects [8].

Several CBCT systems are currently on the market variable in their image quality and ability to visualize anatomic structures [9,10].Those

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systems differ from each other in detector design, patient scanning settings, and data reconstruction parameters [11–13]. Moreover, other scanning and reconstruction factors including scan field of view (**FOV**), voxel size and the number of basis projections used for reconstruction have significant influence on image quality in CBCT.

So the aim of this study is to compare two CBCT systems regarding their linear measurements accuracy.

2. Materials and methods

Eighteen bone defects were created in one side of a dry skull by using a round diamond bur mounted on a high speed hand piece. The defects were created in the mandible in order to obtain three defects at the anterior area, three defects at the premolar area and three defects at the molar area. The same was repeated for the maxilla. The defects were injected with polyvinyl siloxane impression material (3 M ESPE Imprint™ II Garant™ Heavy Body, St Paul, USA). The impression material was injected inside the defects as to be flushed with the buccal surface of the bone. Each defect was assigned a number in order to be identified. The skull-mandible assembly was scanned using Planmeca ProMax 3D (Planmeca, Helsinki, Finland) and I-CAT next generation (Imaging Sciences international, Hatfield, PA, USA) Fig. 1(A&B).

During image acquisition, the smallest voxel size available was used (i.e. highest resolution) for this particular field of view (**FOV**) for each CBCT system. Exposure parameters were as follows: For Planmeca Promax 3D, (0.2 mm voxel size, 120kVp, 5 mA, 7sec exposure time, 8 × 8 cm FOV) and for i-CAT next generation, (0.125 mm voxel size, 90kVp, 12 mA, 12sec exposure time).

Images were saved as DICOM (digital imaging and communication in medicine) files and they were uploaded to On Demand software (Cyber med Inc. South Korea) for applying the measurements. Two radiologists with 15 and 17 years of experience performed the measurements twice separated by two weeks interval after agreement on the methodology of measuring the injected rubber material. Both observers viewed the images in a dimmed light room on the same computer monitor 17 inch HD LED (Dell Inc., Berkshire, UK). Sharpness filter was adjusted to (FILTER X1). Obtained images from both scanners were uploaded and several measurements of each rubber impression material was done using the measurement tool on the cross sectional images in order to determine the maximum diameter of the defect. This was accomplished by measuring the rubber balls from different planes and choosing the maximum measurement Fig. 2(A).

After completing measurements on the software, the impression material was removed carefully from the mandible by a dental probe and all the rubber balls were measured with a digital caliber (Mitutoya, Japan) to determine the actual maximum diameter (gold standard) as shown in Fig. 2(B). All data were tabulated and then numerical data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. All measurements showed normal (parametric) distribution while error measurements and error percentage data showed non-normal (non-parametric) distribution. Data were presented as mean, median, standard deviation (**SD**), minimum, maximum and 95% Confidence Interval (95% **CI**) for the mean values.

For parametric data; Paired *t*-test was used to compare between each modality and the standard reference. For non-parametric data; Wilcoxon signed-rank test was used to compare between measurement errors and errors percentage of the two CBCT systems. Intra and inter-observer agreements were assessed using Cronbach's alpha reliability coefficient and Intra-Class Correlation Coefficient (**ICC**). The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM[1] SPSS[2] Statistics Version 20 for Windows.

[1] IBM Corporation, NY, USA.

[2] SPSS, Inc., an IBM Company.

3. Results

Intra-observer agreement for all areas with Cronbach's alpha values ranged from (0.944–0.988) for Planmeca and (0.928–0.986) for i-CAT. Inter-observer agreement for all areas with Cronbach's alpha values ranged from (0.926–0.967) for Planmeca and (0.912–0.973) for i-CAT.

Measurements obtained from Planmeca CBCT system showed statistically significant higher mean measurement than the standard reference at the maxillary anterior and maxillary premolar areas. In all other areas; Planmeca measurements showed non-statistically significant difference from the standard reference. However, the overall measurement (regardless of area) showed statistically significantly higher mean measurement than the standard reference as shown in Table 1. Measurements obtained from i-CAT CBCT system showed non-statistically significant difference from the standard reference at all areas and also regarding the overall measurements as shown in Table 1.

Mean SD values and results of Wilcoxon signed-rank test for comparison between error measurements and error percentage of the two CBCT systems showed that there was no statistically significant difference between measurement errors of the two systems regarding each area. There was also no statistically significant difference between error percentages of the two CBCT systems regarding each area as shown in Table 2. However, regarding the overall error measurement and error percentage; Planmeca showed statistically significantly higher mean error and error percentage than i-CAT as shown in Fig. 3.

4. Discussion

In cases where bone destruction is expected, radiographs are valuable diagnostic tools as an adjunct to clinical examination. Two-dimensional (**2D**) periapical and panoramic radiographs are routinely used for assessment of the amount of bone destruction; which are limited by projection geometry and superimpositions of adjacent anatomical structures [14,15]. These limitations can be avoided by 3D imaging techniques such as cone beam computed tomography [16]. Therefore, the present study aimed to compare between measurement accuracy of artificial bone defects of images acquired by two CBCT systems. Several previous studies compared between different CBCT systems available in the market [17–20]. Authors compared the accuracy of CBCT systems regarding their ability to detect vertical root fractures [17–19], effect of metal artifact [20], reliability of cephalometric landmark identification [21], detection of external root resorption caused by impacted maxillary canines [22–24], visualization of root canals [25], radiation absorbed dose [26]. In the present study, measurements were performed at different areas in both arches; anterior, premolar and molar areas to test the error percentage in different areas of the jaws according to several researches regarding linear measurement accuracy [27–29].

To precisely test the accuracy of CBCT measurements, an accurate standard reference must be implemented as the lack of an accurate standard reference will generate bias in the results. Thus for the standard reference to be valid, it should be recorded using a tool which provides measurements with sub-millimeter accuracy as that recorded with a digital caliper [30,31]. On the other hand, other authors used different tools with sub-millimeter accuracy as the standard reference, Mengel et al. [32] used in their study a reflecting stereomicroscope with measuring ocular tool which had been examined for dental research purposes, and it was proved to be accurate with a high precession [33]. Ferrare et al. [34] used micro-CT in their study, but being another imaging modality, it has its own error and deviation from the real measurements, as when examined by Kim et al. [35], they found an error of 0.22 ± 0.635 mm.

In the present result, there was very good intra-observer agreement for all areas with Cronbach's alpha values ranged from 0.944 to 0.988 for Planmeca Promax 3D and 0.928 to 0.986 for i-CAT next generation and there was very good inter-observer agreement for all areas with

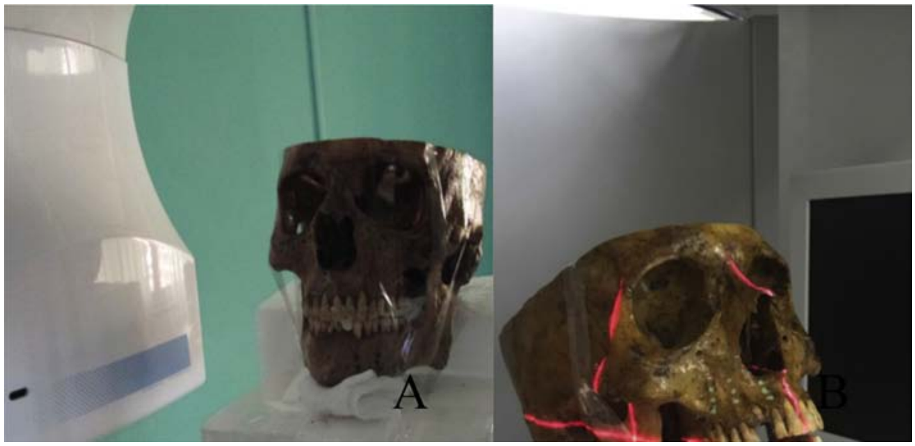

Fig. 1. Photo showing positioning of the skull-mandible assembly on the Planmeca CBCT machine **(A)** and i-CAT CBCT machine **(B)**.

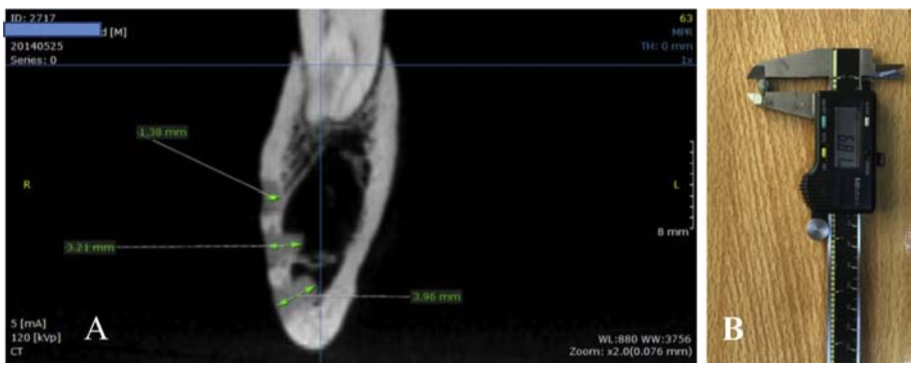

Fig. 2. A. Cross sectional image showing the measurements of the rubber's maximum diameter using On Demand software, **B**. Measurement of the rubber's maximum diameter using the digital caliber.

Table 1
Mean, standard deviation (SD) values and results of paired *t*-test for comparison between each CBCT system and the standard reference.

Area	Planmeca		Standard reference		Error		P-value
	Mean	SD	Mean	SD	Mean	SD	
Maxillary anterior	3.1	0.3	2.9	0.3	0.2	0.01	0.001*
Maxillary premolar	2.6	0.7	2.4	0.7	0.2	0.1	0.032*
Maxillary molar	3.1	0.5	2.8	0.7	0.3	0.2	0.142
Mandibular anterior	3.0	0.3	2.8	0.4	0.2	0.2	0.201
Mandibular premolar	2.2	0.2	2.3	0.2	−0.1	0.2	0.443
Mandibular molar	2.4	0.2	2.3	0.1	0.1	0.1	0.371
Overall	2.7	0.5	2.6	0.4	0.1	0.2	0.004*
	iCAT		Standard reference		Error		
Maxillary anterior	2.6	0.5	2.9	0.3	−0.3	0.2	0.138
Maxillary premolar	2.3	0.6	2.4	0.7	−0.1	0.3	0.678
Maxillary molar	2.8	0.7	2.8	0.7	0.01	0.1	0.784
Mandibular anterior	2.6	0.5	2.8	0.4	−0.2	0.2	0.413
Mandibular premolar	2.4	0.3	2.3	0.2	0.1	0.1	0.424
Mandibular molar	2.3	0.1	2.3	0.1	−0.08	0.1	0.420
Overall	2.5	0.5	2.6	0.4	−0.1	0.2	0.108

*: Significant at P ≤ 0.05.

Table 2
Mean standard deviation (SD) values and results of Wilcoxon signed-rank test for comparison between error measurements and error percentage of both CBCT systems.

	Area	Planmeca		iCAT		P-value
		Mean	SD	Mean	SD	
Error (mm)	Maxillary anterior	0.2	0.01	−0.3	0.2	0.109
	Maxillary premolar	0.2	0.1	−0.1	0.3	0.285
	Maxillary molar	0.3	0.2	0.01	0.1	0.109
	Mandibular anterior	0.2	0.2	−0.2	0.2	0.109
	Mandibular premolar	−0.1	0.2	0.1	0.1	0.285
	Mandibular molar	0.1	0.1	−0.08	0.1	0.285
	Overall	0.1	0.2	−0.1	0.2	0.011*
Error (%)	Maxillary anterior	7.6	1.0	−10.6	8.0	0.109
	Maxillary premolar	7.9	2.4	−2.4	15.2	0.285
	Maxillary molar	11.1	9.1	0.2	2.7	0.109
	Mandibular anterior	8.2	8.2	−5.6	9.7	0.109
	Mandibular premolar	−4.5	8.4	3.4	6.2	0.593
	Mandibular molar	4.1	6.3	−3.3	5.8	0.285
	Overall	5.7	7.6	−3.1	8.7	0.012*

*: Significant at P ≤ 0.05.

Cronbach's alpha values ranged from 0.926 to 0.967 for Planmeca Promax 3D and 0.912 to 0.973 for i-CAT next generation. These results proved that CBCT linear measurements are highly reproducible. This was in agreement with the results of Kamburoglu et al. [18], who found the inter-observer reliability to be 0.995 to 1 and intra-observer reliability to be 0.992 to 1. Also Oz et al. [36] found high inter-observer reliability of the CBCT measurements in the craniofacial area.

The results of the present study revealed that Planmeca Promax 3D showed statistically significantly higher mean error and error percentage than i-CAT next generation. The difference could be related to the kVp difference between the two systems as i-CAT next generation acquires the image using 120 kVp in contrast to 90 kVp used by Planmeca Promax 3D imaging sytem. Also the superiority of i-CAT next

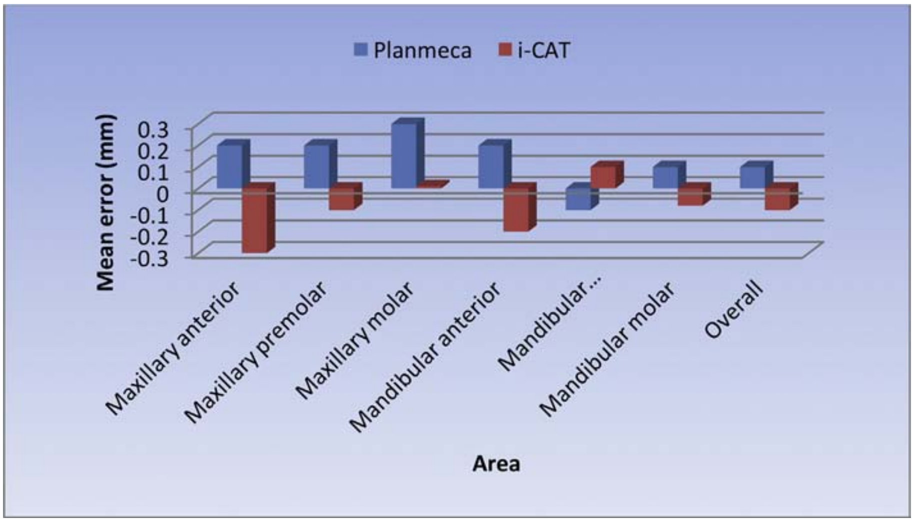

Fig. 3. Bar chart representing mean measurement errors of the two CBCT systems.

generation can be attributed to the inherent smaller voxel size 0.125 mm compared to 0.2 mm used by Planmeca Promax 3D [17]. This could result in better image viewing allowing the observer to accurately determine the object's borders.

Our results were consistent with other authors who investigated the reliability of linear measurements of CBCT imaging systems, as Pactas et al. [37] and Fatemitabar et al. [38] who compared KaVo 3D (KaVo Dental GmbH, Biberach, Germany) and Planmeca respectively with multidetector CT, Dalessandri et al. [39] who compared three CBCT systems; Newtom 3G (Quantitative Radiology, Verona, Italy), Kodak 9500 (Trophy Radiologie, Croissy-Beaubourg, France) and Planmeca Promax 3D. Also Pinsky et al. [40] who investigated I-CAT next generation system. Finally Stratemann et al. [41] who compared Hitachi MercuRay (Hitachi Medico Technology, Tokyo, Japan) with real measurements from digital caliper.

5. Conclusion and recommendations

CBCT is highly accurate and reproducible in linear measurements in the axial and coronal image planes and in different areas of the maxillofacial region. According to the findings of the present study i-CAT is recommended when the purpose of the CBCT scan is to measure linear distances. This will result in lower patient radiation dose and faster scan time.

When comparing 2 different machines, we have a lot of exposure parameters and it would be better in future studies if you choose 0.2 voxel size in both machines to eliminate the resolution parameter and test the machines properly.

References

[1] Scarfe William C, Levin Martin D, Gane David, Farman Allan G. Use of cone beam computed tomography in endodontics. Int J Dent 2009:567–634.
[2] Ball RL, Barbizam JV, Cohenca N. Intra-operative endodontic applications of cone-beam computed tomography. J Endod 2013;39(4):548–57.
[3] Mah JK, Danforth RA, Bumann A, Hatcher D. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96(4):508–13.
[4] Palomo JM, Rao PS, Hans MG. Influence of CBCT exposure conditions on radiation dose. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105(6):773–82.
[5] Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. Dentomaxillofacial Radiol 2006;35(4):219–26.
[6] Hilgers ML, Scarfe WC, Scheetz JP, Farman AG. Accuracy of linear temporomandibular joint measurements with cone beam computed tomography and digital cephalometric radiography. Am J Orthod Dentofacial Orthop 2005;128(6):803–11.
[7] Lascala CA, Panella J, Marques MM. Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-NewTom). Dentomaxillofacial Radiol 2004;33(5):291–4.
[8] Stavropoulos A, Wenzel A. Accuracy of cone beam dental CT, intraoral digital and conventional film radiography for the detection of periapical lesions. An exvivo study in pig jaws. Clin Oral Invest 2007;11(1):101–6.
[9] Kobayashi K, Shimoda S, Nakagawa Y, Yamamoto A. Accuracy in measurement of distance using limited cone-beam computerized tomography. Int J Oral Maxillofac Implants 2004;19(2):228–31.
[10] Araki K, Maki K, Seki K, Sakamaki K, Harata Y, Sakaino R, Okano T, Seo K. Characteristics of a newly developed dentomaxillofacial X-ray cone beam CT scanner (CB MercuRay): system configuration and physical properties. Dentomaxillofacial Radiol 2004;33(1):51–9.
[11] Loubele M, Maes F, Jacobs R, van Steenberghe D, White SC, Suetens P. Comparative study of image quality for MSCT and CBCT scanners for dentomaxillofacial radiology applications. Radiat Protect Dosim 2008;129(1–3):222–6.
[12] Kwong JC, Palomo JM, Landers MA, Figueroa A, Hans MG. Image quality produced by different cone-beam computed tomography settings. Am J Orthod Dentofacial Orthop 2008;133(2):317–27.
[13] Bryant JA, Drage NA, Richmond S. Study of the scan uniformity from an i-CAT cone beam computed tomography dental imaging system. Dentomaxillofacial Radiol 2008;37(7):365–74.
[14] Langlois Caroline O, Sampaio Maria C, Silva Alexandre ER, Costa Nilza P, Rockenbach Maria IB. Accuracy of linear measurements before and after digitizing periapical and panoramic radiography images. Braz Dent J 2011;22(5):404–9.
[15] Hoseini Zarch SH, Bagherpour A, Javadian Langaroodi A, Ahmadian Yazdi A, Safaei A. Evaluation of the accuracy of panoramic radiography in linear measurements of the jaws. Iran J Radiol 2011 Sep;8(2):97–102.
[16] Pour Goodarzi, Daryoush, Romoozi Elham, Shayesteh Yadollah Soleimani. Accuracy of cone beam computed tomography for detection of bone loss. J Dent 2015;12.7:513–23.
[17] Elsaltani M.H., Farid M.M., Eldin ashmawy MS. Detection of simulated vertical root fractures: which cone-beam computed tomographic system is the most accurate?. J Endod;42:972–977.
[18] Kamburoglu K, Onder B, Murat S. Radiographic detection of artificially created horizontal root fracture using different cone beam CT units with small fields of view. Dentomaxillofacial Radiol 2014;42:20120261.
[19] Hassan B, Metska ME, Ozok AR, van der Stelt P, Wesselink PR. Detection of vertical root fractures in endodontically treated teeth by a cone beam computed tomography scan. J Endod 2009;35:719–22.
[20] Safi Y, Aghdasi MM, Ezoddini-Ardakani F, Beiraghi S, Vasegh Z. Effect of metal artifacts on detection of vertical root fractures using two cone beam computed tomography systems. Iran Endod J 2015;10(3):193–8.
[21] Katkar 1 RA, Kummet C, Dawson D, Moreno Uribe L, Allareddy V, Finkelstein M, Ruprecht A. Comparison of observer reliability of three-dimensional cephalometric landmark identification on subject images from Galileos and i-CAT cone beam CT. Dentomaxillofacial Radiol 2013;42(9):20130059.
[22] Alqerban A, Jacobs R, Fieuws S, Nackaerts O, SEDENTEXCT Project Consortium. Willems G. Comparison of 6 cone-beam computed tomography systems for image quality and detection of simulated canine impaction-induced external root resorption in maxillary lateral incisors. Am J Orthod Dentofacial Orthop 2011 Sep;140(3):e129–39.
[23] Alqerban A, Jacobs R, Fieuws S, Willems G. Comparison of two cone beam computed tomographic systems versus panoramic imaging for localization of impacted maxillary canines and detection of root resorption. Eur J Orthod 2011 Feb;33(1):93–102.
[24] Alqerban A, Jacobs R, Souza PC, Willems G. In-vitro comparison of 2 cone-beam computed tomography systems and panoramic imaging for detecting simulated canine impaction-induced external root resorption in maxillary lateral incisors. Am J Orthod Dentofacial Orthop 2009 Dec;136(6):764. e1-11.

[25] Strobel Sabrina, Lenhart Evelyn, Woelber Johan P, Fleiner Jonathan, Hannig Christian, Wrbas Karl-Thomas. Comparison of two cone-beam computed tomography systems in the visualization of endodontic structures. Swiss Dental Journal 2017;127:221–9.
[26] Ludlow JB, Timothy R, Walker C, Hunter R, Benavides E, Samuelson DB, Scheske MJ. Effective dose of dental CBCT—a meta analysis of published data and additional data for nine CBCT units. Dentomaxillofacial Radiol 2015 Jan;44(1):20140197.
[27] Abdinian Mehrdad, Baninajarian Homa. The accuracy of linear and angular measurements in the different regions of the jaw in cone-beam computed tomography views. Denatl Hypotheses Journal 2017;8(4):100–3.
[28] Ganguly Rumpa, Ramesh Aruna, Pagni Sarah. The accuracy of linear measurements of maxillary and mandibular edentulous sites in cone-beam computed tomography images with different fields of view and voxel sizes under simulated clinical conditions. Imaging Sci Dent 2016 Jun;46(2):93–101.
[29] Maroua Ahmad L, Ajaj Mowaffak, Hajeer Mohammad Y. The accuracy and reproducibility of linear measurements made on CBCT-derived digital models. J Contemp Dent Pract 2016;17(4):294–9.
[30] Halperin-Sternfeld M, Machtei EE, Horwitz J. Diagnostic accuracy of cone beam computed tomography for dimensional linear measurements in the mandible. Int J Oral Maxillofac Implants 2014 May-Jun;29(3):593–9.
[31] Ganguly Rumpa, Ramesh Aruna, Pagni Sarah. The accuracy of linear measurements of maxillary and mandibular edentulous sites in cone-beam computed tomography images with different fields of view and voxel sizes under simulated clinical conditions. Imaging Sci Dent 2016 Jun;46(2):93–101.
[32] Mengel R, Candir M, Shiratori K, Flores-de-Jacoby L. Digital volume tomography in the diagnosis of periodontal defects: an in vitro study on native pig and human mandibles. J Periodontol 2005;76:665–73.
[33] MacLarnon AM. Applications of the reflex instruments in quantitative morphology. Folia Primatol 1989;53:33–49.
[34] Ferrare N, Leite AF, Caracas HC, de Azevedo RB, de Melo NS, de Souza Figueiredo PT. Cone-beam computed tomography and microtomography for alveolar bone measurements. Surg Radiol Anat 2013 Aug;35(6):495–502.
[35] Kim I, Paik KS, Lee SP. Quantitative evaluation of the accuracy of micro-computed tomography in tooth measurement. Clin Anat 2007;20:27–34.
[36] Oz U, Orhan K, Abe N. Comparison of linear and angular measurements using two-dimensional conventional methods and three-dimensional cone beam CT images reconstructed from a volumetric rendering program in vivo. Dentomaxillofacial Radiol 2011;40:492–500.
[37] Patcas R, Markic G, Müller L, Ullrich O, Peltomäki T, Kellenberger CJ, Karlo CA. Accuracy of linear intraoral measurements using cone beam CT and multidetector CT: a tale of two CTs. Dentomaxillofacial Radiol 2012 Dec;41(8):637–44.
[38] Fatemitabar SA, Nikgoo A. Multichannel computed tomography versus cone-beam computed tomography: linear accuracy of in vitro measurements of the maxilla for implant placement. Int J Oral Maxillofac Implants 2010;25:499–505.
[39] Dalessandri D, Bracco P, Paganelli C, Hernandez Soler V, Martin C. Ex vivo measurement reliability using two different cbct scanners for orthodontic purposes. Int J Med Robot 2012 Jun;8(2):230–42.
[40] Pinsky HM, Dyda S, Pinsky RW, Misch KA, Sarment DP. Accuracy of three-dimensional measurements using cone-beam CT. Dentomaxillofacial Radiol 2006 Nov;35(6):410–6.
[41] Stratemann SA, Huang JC, Maki K, Miller AJ, Hatcher DC. Comparison of cone beam computed tomography imaging with physical measures. Dentomaxillofacial Radiol 2008 Feb;37(2):80–93.