PRINT ISSN 1119-8362
Electronic ISSN 2659-1502

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 27 (11) 2469-2474 November 2023

Assessment of Correlation between Dimensions of Ball Phantom and Distortion Rate of Panoramic Radiography in Dental Cone Beam Computed Tomography

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ABSTRACT: The objective of this study was to assess correlation between dimensions of ball phantom and distortion rate of panoramic radiography in dental cone beam computed tomography (CBCT) system using appropriate standard methods. The results revealed that only two measurement (2.99%) out of 67 measurements exceeded the recommended threshold value for distortion rate. There was no correlation between the ball diameter and the distortion produced. However, a low positive correlation was observed between the distortion rate and the ratio of the horizontal to the vertical diameter of the ball images. Also, the matlab code, presented results which are closer to the acceptable limit than the Romexis software. Patient positioning should be carefully and correctly considered to prevent and to bring the image distortion rate to its barest minimum for proper diagnosis in dental CBCT. For proper diagnosis and treatment planning, this distortion must be accounted for during clinical applications.

DOI: https://dx.doi.org/10.4314/jasem.v27i11.15

Cite this paper as: RABBA, J. A; ULOKO, F. O; EFENJI, G. I; EGHAGHE, S. O; JAAFAR, H. A; JAFRI, M. Z. M; OSMAN, N. D. (2023). Assessment of Correlation between Dimensions of Ball Phantom and Distortion Rate of Panoramic Radiography in Dental Cone Beam Computed Tomography. *J. Appl. Sci. Environ. Manage.* 27 (11) 2469-2474

Dates: Received: 30 September 2023; Revised: 29 October 2023; Accepted: 07 November 2023 Published: 30 November 2023

Keywords: Cone-beam computed tomography; Distortion rate; Dental imaging; Radiography; digital panoramic

In the field of periodontology, evaluation of the condition of teeth and surrounding alveolar bone relies upon largely on two-dimensional imaging modalities such as conventional and digital radiography. Recently, cone beam computed tomography (CBCT) was once added for head and neck applications. CBCT images display a high accuracy in assessing the furcation involvement (Asmita *et al*., 2014). The goal of radiographic imaging in implant dentistry is to acquire the most practical and comprehensive information that can be used for the various phases of implant treatment (Shahidi *et al.,* 2018). Dental X-Ray panoramic radiograph has been widely utilized in diagnosing and treatment of dentistry diseases, because it includes overall anatomical information of teeth and jaw (Han *et al.*, 2011). A detailed description of the maxillofacial complex is presented in panoramic radiographs and is accessible and unbiased at a low radiation dose, whereas the best radiographic survey is provided. Panoramic radiograph acts as an important diagnostic and screening method for analysis of images. In several dental field, such as orthodontics, oral surgery, prosthodontics and general dentistry, this technique is often used (Suphangul *et al*., 2016). One

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disadvantage to the use of panoramic radiography is the magnification and distortion that occurs when the patient's jaws are not positioned near the focal trough of the X-ray beam (Devlin and Yuan, 2013). In recent years, maxillofacial cone beam computed tomography (CBCT) has been widely used in dental implanting, assessment of orthodontic treatment, complex alveolar surgery, oral local system reconstruction and treatment of tooth and dental pulp diseases. CBCT is advantageous in high spatial resolution, short scan time and rapid image acquisition (Tang *et al*., 2017). The diagnostic desires for dentomaxillofacial radiography are enhanced dramatically because of the new treatment techniques and image criterion in dentistry. Until now, the patient's radiography desires were transferred from one X-ray machine to a different depending on the diagnostic requirements (Al-Nakik, 2007). In panoramic radiography, image distortion is a known phenomenon and can cause diagnostic inaccuracy when clinically disregarded (Ladeira *et al*., 2012). One of the drawbacks well known in panoramic radiographs is the distortion of radiographic images. This distortion depends on factors such as: patient distance with film, machine type and measured object position within the mandible (Kayal, 2016). Even when properly taken, dental panoramic radiography images are associated with enlargement of the particular object size by about 15–25 %, and distortion happens once horizontal magnification differs from vertical magnification with poor patient positioning. Magnification may additionally be influenced by variation in a patient's jaw shape and size, and even inside a selected jaw, distortion and magnification are greatest within the canine and premolar regions and least in the third molar region (Devlin and Yuan, 2013; Suphangul *et al*., 2016). Furthermore, when the ratio of the horizontal dimension to the vertical dimension of the ball phantom image is not unity, it leads to distortion. Hence, critical attention must be given to assess the distortion rate of dental CBCT and the health risk associated with the ionizing radiation received by patients during CBCT examination (Osman *et al*., 2014). However, inconsistent performance of the dental CBCT unit can lead to beam misalignment and image distortion if the measured distances of the ball phantom images exceed the reference limit (Rabba *et al*., 2020). In rotational panoramic radiography, X-ray tubes to object distance and object-film distance control the degree of vertical magnification. But horizontal magnification has an important further issue, such as the speed of the film in relation to the speed of the X-ray beam at object point. Yeom *et al*, 2018, in a study reported that as the distortion rate threshold decreases, the number of balls which satisfies the threshold decreases proportionally and the layer of the image will be narrower (Yeom *et al*., 2018). This Image layer of panoramic radiography can also be measured by spatial resolution using horizontal and vertical line pair phantoms and by evaluating the ball distortion rates through a ball-type panorama phantom (Yeom *et al.,* 2020). The objective of this study was to assess correlation between dimensions of ball phantom and distortion rate of panoramic radiography in dental cone beam computed tomography (CBCT) system using a ball phantom.

MATERIALS AND METHODS

For panoramic view, the performance parameter testing only involved the evaluation of beam alignment by the analysis of image distortion on the ball phantom images. In this study, a commercial ball phantom was scanned using Planmeca ProMax 3D Mid Dental CBCT unit (Planmeca, Helsinki, Finland) at the Imaging Unit, Universiti Sains Malaysia Medical Centre Bertam (PPUSMB), AMDI USM, Penang. The experimental setup for ball phantom study is shown in Figure 1.

The ball phantom was accurately positioned at the isocenter with the reference of the laser light for phantom scanning. The phantom study was performed to check the X-ray beam and the C-arm gantry alignment of the dental CBCT system and the distortion rate for each of the balls of the ball phantom. This test is performed to ensure the beam and gantry are correctly positioned and well calibrated. This test was done for calibration of the machine and to take measurements at zero position (Al-Nakik, 2007).
The exposure settings used for phantom scanning were based on the default setting in routine clinical procedure (68 kVp, 8 mAs and patient FOV size is M). This study was done retrospectively by the collection of previous phantom image datasets which had been obtained from January 2019 until October 2020 amounting to 67 images which were retrieved from the picture archiving and communication system (PACS) and used for further image analysis.

All the acquired images were viewed on the screen of the workstation computer. Using the Planmeca Romexis viewer software version 3.8.3.R, (a software program that is provided with this machine) on screen, which gave the standard diameter of the ball (6 mm). A random selection of four balls was done and the vertical and horizontal dimensions of these balls were measured using the Romexis measuring tool. Similarly, these measurements were repeated using the MATLAB R2019b software developed in our previous work (Rabba *et al*., 2023), which gave an automatic measurements of both the ball diameter and the distance from the center ball to the middle of the 10^{th} ball (both sides).

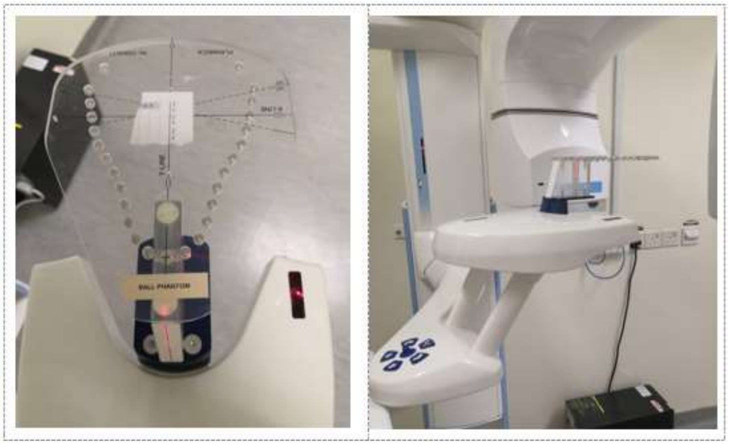

Fig 1 The positioning of the ball phantom during the phantom scanning

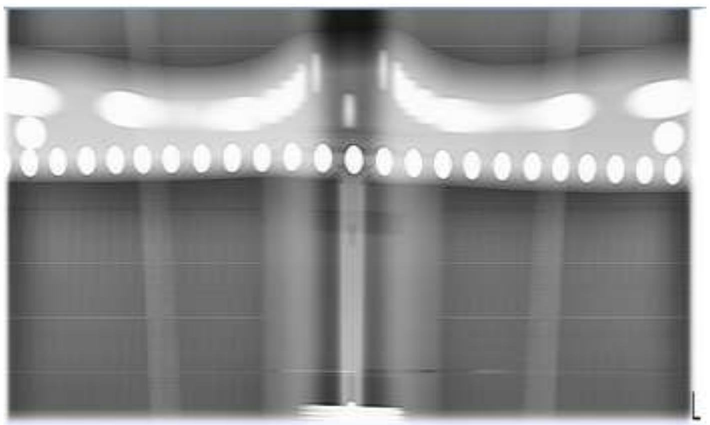

Fig 2. An example of the ball phantom image (panoramic view) with a total of 23 metal balls at zero position

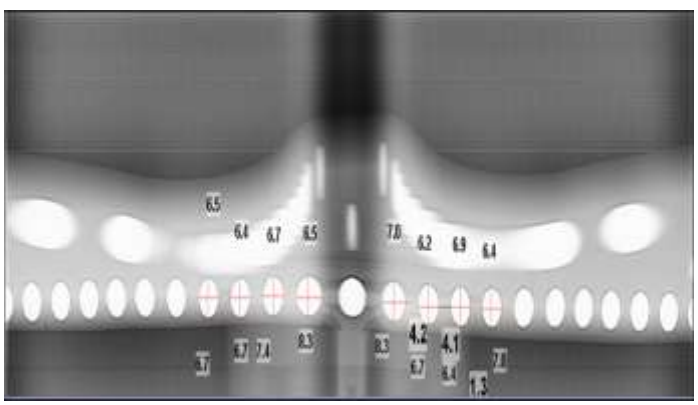

Fig Error! No text of specified style in document.1 Ball phantom showing the dimension of few selected balls

Evaluation of Image Distortion Rate: The beam and gantry alignment were tested by image distortion analysis that was performed through qualitative assessment (subjective analysis) and quantitative assessment (objective analysis) on the ball phantom for panoramic study. For the subjective assessment of the ball phantom image, the phantom image should consist of 23 metal balls that appeared round and symmetrical at zero position (Figure 2). Besides, the observer should ensure that the outer most balls on the left and right sides also appeared symmetrical by qualitative observation.

For the image distortion assessment, one important parameter measured on the ball phantom images using Romexis measuring tool was the measurement of both vertical and horizontal diameter of any four balls (Figure 3).

The actual measured size diameter of the metal ball stated was compared with the reference diameter of the ball which is 6 mm as provided by the manufacturer. The vertical and horizontal diameters will determine the image distortion and evaluate the beam alignment and symmetry.

The magnification (vertical and horizontal) of the ball phantom images also indicates how well the beam of the CBCT unit aligns.

Using the automated measurement algorithm (Matlab), a noise reduction filter was applied to clearly emphasize the boundaries of the selected ball images and the ellipse detection with a universal threshold was applied to detect the boundaries of the balls obtained in circular or elliptical shapes in the image.

The lengths of the long and short axes of the balls were determined using these limits and the ratio of the two lengths (vertical and horizontal diameters) were used as an index indicating the degree of deformation of the ball (ball distortion rate).

Based on this parameter measurement, the distortion rate (DR) for each of the balls was calculated using Equation 1 (Yeom *et al*., 2018, 2020).

$$DR = \left(|1 - \frac{HLBI}{VLBI}|\right) \times 100\% \qquad 1$$

Where DR = distortion rate; HLBI= horizontal length of the obtained ball image; VLBI = vertical length of the obtained ball image

RESULTS AND DISCUSSIONS

The distortion rate produced by each ball is presented in scattered plots. Figure 4 shows a scatter plot of the measured distortion rate.

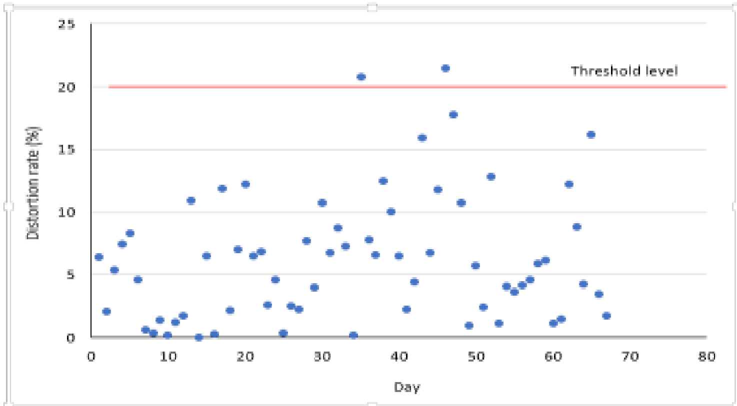

Fig Error! No text of specified style in document. Distortion rate of ball phantom

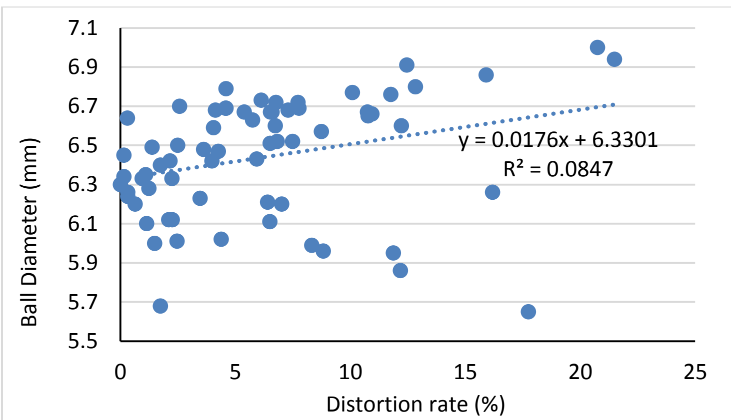

Fig 5 Correlation between measured ball diameter and distortion rate.

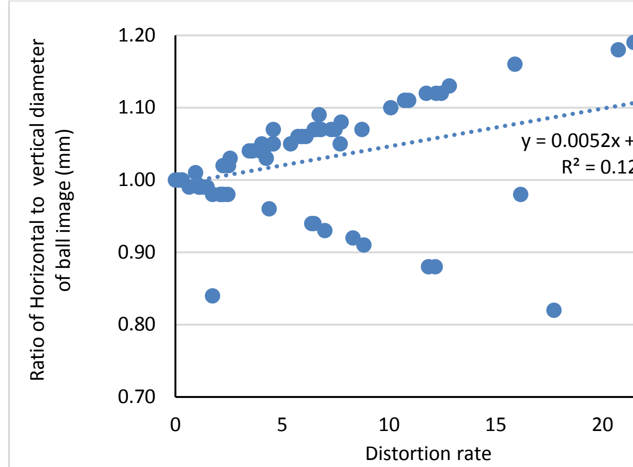

Fig 6 Correlation between the ratio of horizontal to vertical diameter of ball image to distortion rate

The graph shows that the observed distortion rate ranged from 0-21.5 %. However, 2.99 % of the measurements (two measurements) exceeded the threshold value of 20 %. This shows that there was a slight shift in the alignment of the X-ray beam of the CBCT device as measured distortion rate exceeded the recommended threshold level, while 97.01 % of the measurements were within the recommended threshold level. Figure 5, which is also a scattered plot, revealed that there was no correlation between the dimension of the ball images and the rate of distortion produced in the ball image. However, a low positive correlation was observed between the distortion rate and the ratio of the horizontal to the vertical dimension of the ball image (Figure 6). The rate of distortion produced was observed to be dependent on the ratio of the horizontal to vertical dimensions of the ball phantom image. The closer the ratio of the horizontal to vertical dimension of the ball is to unity (1), the lesser the distortion produce, and the more uniform was the image and vice versa.

*Comparison Between Manual And Automated Measurement For Image Distortion***:** The deviation in the measurements using the two software (Romexis and MATLAB) were calculated, this is to validate the result gotten from the Romexis software. An independent -sample t-test was used to check the accuracy of the result obtained on all the measurements performed on the ball phantom images using both MATLAB and Romexis software. Figure 7 shows a presentation of the result obtained from the t-test. The values for the measured diameter of the metal balls (mean ± SD) for the automated and Romexis calculation were 5.928 ± 0.229 mm and 6.339 ± 0.218 mm, respectively. The findings from the independent sample t-test revealed a t (19) =5.46, p = 3.08343E-6. A significant difference was observed between the two measurements, with MATLAB measurements having lower ball diameter and closer to the reference value than the Romexis software. Furthermore, 4.4 % of the total measurement were found to be above the acceptable limit with Matlab and Romexis having 1.2 % and 3.2 % respectively showing that the automated algorithm (Matlab) presented a more acceptable result.

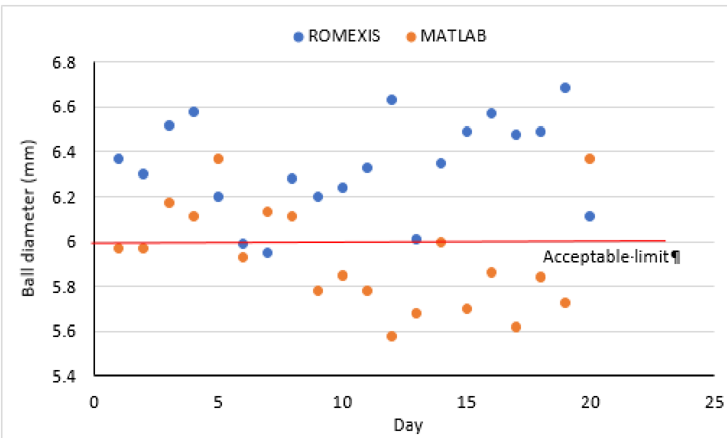

Fig 7. Variation in the measured ball diameter for different software (Romexis and MATLAB).

Conclusion: In conclusion, the CBCT unit at AMDI USM, Penang have been well calibrated as most of the measurements (97.01%) were within the acceptable threshold values (≤20%) and balls in the phantom were within the sharpness zone. Also, the matlab code, presented results which are closer to the acceptable limit than the Romexis software. Hence, automatic measurements of images should be considered during image analysis in dental imaging. Patient positioning should be carefully and correctly considered to prevent and to bring the image distortion rate to its barest minimum for proper diagnosis in dental CBCT.

Acknowledgments: The authors wish to acknowledge the kind support of tertiary education trust fund (TETFund) Nigeria through a scholarship grant provided to Rabba JA. Authors would also like to thank all staff at Imaging Unit of AMDI, USM, Penang, Malaysia for their help and support throughout this work.

REFERENCES

Abramovitch, K; Rice, DD (2014). Basic principles of cone beam computed tomography. *Dental Clinics. North America*, *58*(3), 463–484.

Al-Nakik, LH (2007). Linear image distortion of different patients ' head position using Dimax direct digital panoramic x-ray system . *J Bagh Coll Dentistry*, *19*(1), 65–68.

Asmita, GV; Bains, VK; Singh, GP; Jhingran, R (2014). Clinical and cone beam computed tomography comparison of NovaBone dental putty and perioglas in the treatment of mandibular class II furcations. *Indian J. Dental Res. 25*(2), 166–173.

Devlin, H; Yuan, J (2013). Object position and image magnification in dental panoramic radiography: a theoretical analysis. *Dentomaxillofacial Radiology*, *42*, 29951683

Diane, JF; Regina, CRV (2020). Cone-beam computed tomography applications in dentistry. *Dentalcare.Com*, 91–105.

Han, B; Chen, L; Cai, Z; Pu, F L D; Li, S; Fan, Y (2011). An automatic method of synthesizing panoramic radiograph by unwrapping dental CT image. *Proceedings 2011 International Conference on Mechatronic Science, Electric Engineering and Computer, MEC 2011*, 1094–1096.

Kayal, R (2016). Distortion of digital panoramic radiographs used for implant site assessment. *J. Orthodontic Sci*. *5*(4), 117.

Ladeira, D B S; Cruz, A D; Almeida, S M; Boscolo, F N (2012). Influence of the intergonial distance on image distortion in panoramic radiographs. *Dentomaxillofacial Radiology*, *41*(5), 417–421.

Osman, N D; Salikin, M S; Saripan, M I; Aziz, M Z A; Daud, N M

(2014). Metal artefact correction algorithm based-on DSAT technique for CT images. *IECBES 2014, Conference Proceedings - 2014 IEEE Conference on Biomedical Engineering and Sciences: "Miri, Where Engineering in Medicine and Biology and Humanity Meet," December*, 324–327. https://doi.org/10.1109/IECBES.2014.7047513

Rabba, JA; Jaafar, HA; Jafri, M Z M; Suhaimi, FM; Osman, ND (2020). Beam alignment and image distortion assessment of dental cone beam computed tomography (CBCT) system. *J. Physics: Conf. Series*,.*1497*(1).

Rabba, JA; Suhaimi, FM; Jafri, M Z M; Jaafar, HA; Osman, ND (2023). Radiography Automated measurement for image distortion analysis in 2D panoramic imaging of dental CBCT system : A phantom study. *Radiograph. 29*(3), 533–538

Shahidi, S; Zamiri, B; Abolvardi, M; Akhlaghian, M; Paknahad, M (2018). Comparison of Dental Panoramic Radiography and CBCT for Measuring Vertical Bone Height in Different Horizontal Locations of Posterior Mandibular Alveolar Process. *J. Dentistry (Shiraz, Iran)*, *19*(2), 83–91.

Suphangul, S; Rattanabanlang, A; Amornsettachai, P (2016). *Dimension distortion of digital panoramic radiograph on posterior mandibular regions*. *November*, 279–286.

Tang, Z; Liu, X; Chen, K (2017). Comparison of digital panoramic radiography versus cone beam computerized tomography for measuring alveolar bone. *Head. Face Med. 13*(1), 2–8

Yeom, H G; Kim, J E; Huh, K H; Yi, W J; Heo, M S; Lee, S S; Choi, S C (2018). Development of a new ball-type phantom for evaluation of the image layer of panoramic radiography. *Imaging Sci. Dentistry*, *48*(4), 255–259

Yeom, HG; Kim, JE; Huh, KH; Yi, WJ; Heo, MS; Lee, SS; Choi, SC (2020). Correlation between spatial resolution and ball distortion rate of panoramic radiography. *BMC Med. Imaging*, *20*(1), 1–8.