Comparison between Digital Panoramic Radiography and Cone-Beam Computed Tomography in Measuring Presurgical Dental Implant Vertical Height at Posterior Mandible

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ABSTRACT

Objectives: *This study aims to evaluate the reliability of panoramic radiograph in comparison to cone beam computed tomography for posterior mandibular pre-implant assessment.* **Materials and Methods:** *A retrospective evaluation of the panoramic (PAN) and CBCT images in complete, partially edentulous, and dentate patients was conducted on 66 cases for presurgical dental implant assessment. Assessment of the vertical bone height was conducted by dividing the posterior mandible region into anterior (first premolars to second premolars) and posterior (first molars to second molars) segments. The average mesiodistal crown dimensions from each segment were measured as a midpoint. The reference point to measure the vertical bone height was established from the alveolar crest to the superior border of mandibular canal. Therefore, the measurement will begin at the midpoint of total mesiodistal crown dimension of each segment from the alveolar crest to the superior border of mandibular canal. All measurements were independently performed by two observers thrice on each modality.* **Results:** *A paired comparison between PAN and CBCT images in measuring the presurgical dental implant vertical height from alveolar crest to the superior border of mandibular canal (paired t-tests) showed statistically significant difference in the mean difference of vertical bone height at each region between PAN and CBCT*

(p<0.001). **Conclusion:** *PAN radiograph provides sufficient information for presurgical implant assessment at the posterior mandible in routine cases or during the unavailability of CBCT at the clinic. However, CBCT remains the best imaging modality for presurgical implant assessment as it has a minimal magnification error.*

Keywords: *Cone-Beam Computed Tomography, Dental implant, Panoramic radiograph, Vertical bone height.*

Abbreviations: *UiTM- Universiti Teknologi Mara, PAN- Panoramic, CBCT- Cone Beam Computed Tomography, IAN- Inferior Alveolar Nerve, FOV- Field of View, kV- kilovoltage, mA- milliampere, s-seconds,*

INTRODUCTION

A thorough pre-surgical implant assessment is one of the determinants contributing to a successful dental implant. Evaluation of trabecular bone dimension, quality, surface topography and the relationship of proposed implant site to the anatomic structures such as nerves, blood vessels, adjacent tooth roots, nasal floor and maxillary sinus are part of pre-implant assessment. Utilization of leading imaging diagnostic tools available in the market such as Panoramic (PAN) and Cone Beam Computed Tomography (CBCT) images have been reported to be the most frequent imaging modalities used in treatment planning of implant placement to achieve a long-term treatment success (Özalp et al., 2018).

PAN radiography has been used as a main imaging investigation for implant assessment for quite sometimes. Its main advantage is the ability to display body of the mandible and maxilla, mandibular canal that contains inferior alveolar nerve (IAN) and maxillary sinus in a single image. PAN radiography allows the identification of a suitable implant site, measurement of the residual bone height, determination of the length required and mesiodistal angulation of an implant for presurgical planning (Hu et al., 2012). However, horizontal and vertical plane magnification as well as its incapability of displaying the existing bone width and the precise associations with adjacent anatomical structures limit the usage of PAN radiography in pre-implant assessment.

Limitations from PAN radiography in pre-surgical implant assessment leads to the utilization of CBCT. It is one of the advanced imaging modalities in the dental field that produce a detailed and high quality three-dimensional (3D) images of hard tissue structures. CBCT images enables clinicians in assessing the bone as clear 3D-images of highly contrasted structures can be seen and corrected magnification of the images displayed can be helpful to obtain an accurate measurement (Angelopoulos et al., 2008). It also has lesser radiation dose as compared to conventional computed tomography scan where radiation hazards can be minimized by utilizing CBCT (Kumar et al., 2015). Although CBCT has more advantages in pre-implant assessment, it is not available in most dental clinics where it becomes a question whether PAN radiograph is adequate as pre-operative imaging modalities before proceeding to dental implant treatment.

The drawbacks that arise from the usage of PAN radiograph and the unavailability of CBCT restricting the oral surgeon from performing an accurate pre-surgical implant assessment. This may give rise to harmful complication such as injury to the vital surrounding structure such as the mandibular canal that contains IAN. Intrusion into the canal especially due to misguided implant placement may results in damage to the nerve as it might be stretched, compressed and partially or totally transected which commonly resulted with paresthesia, hypoesthesia, hyperesthesia, dysesthesia or anesthesia of the teeth, lower lip or surrounding skin and mucosa (Al-Juboori et al., 2016).

Hence, accurate alveolar bone height measurement and a safe margin distance from vital anatomical structures such as mandibular canal are important factors in dental implant placement for pre-

surgical planning phase (Shahidi et al., 2018). These factors need to be considered as previous report of 40% incidence of IAN injuries caused serious complication to the patient (Al-Juboori et al., 2016). Therefore, the objective of this study is to evaluate the reliability of PAN radiograph in comparison to CBCT images for posterior mandibular pre-implant assessment.

MATERIALS AND METHODS

This study was approved (reference number: REC/02/2020 (UG/MR/65)) by the Research Ethics Committee of Universiti Teknologi Mara (UiTM), Selangor, Malaysia. A retrospective review of the PAN and CBCT images of the posterior mandible in patients with fully or partially edentulous and dentate conducted on 66 patients (19 male, 42 female) for pre-surgical dental implant assessment between July 2016 and December 2020 at the Diagnostic Imaging Unit, Faculty of Dentistry, Universiti Teknologi MARA, Sungai Buloh Campus.

Inclusion criteria:

- Patients aged 18 and older.

- PAN radiograph and CBCT that shows fully or partially edentulous and dentate region in posterior mandible from first premolars to second molars.
- Patients with previous or current dental implant(s) in posterior mandibular arch.

- The visibility of mandibular canal and mental foramen.

- CBCT images with Field of View (FOV) of 5x5 cm and above.

Exclusion criteria:

- Images with bony pathologies and abnormalities.

- Blurred vision of PAN radiograph and CBCT.

- Radiographs in which the mental foramen and inferior alveolar canal could not be identified.

PAN images were obtained using the ORTHOPANTOMOGRAM OP300 with acquisition parameters of 66 kV, a current of 7.9 mA, a minimum exposure time of 16.4 s and a radiation dose of 74.9 mGycm2. They were analyzed by using CLINIVIEW Version 10.2.6, by Instrumentarium Dental Software. The CBCT exams were executed using CARESTREAM CS9300c armamentarium with acquisition parameters of 85 kV, a current of 10 mA, a FOV of 10x10 cm and a scanning time of 8.01 s and the images viewed using CS 3D Imaging Version 3.8, a program by Dental Carestream.

The linear measurement was performed by dividing the posterior mandible into two regions: anterior and posterior of every obtained PAN and CBCT image. The anterior region was categorized from the mesial part of first premolar to the distal segment of second premolar while the posterior region was from the mesial part of first molar to distal portion of second molar (Figure 1.0). Then, the mesiodistal coronal dimension from each region was measured as a midpoint. As for fully or partially edentulous patients, the position of the teeth was determined with the location of mental foramen as the midpoint

reference point. If one tooth is permanently missing at any of those regions (Figure 2.0), the midpoint was obtained by dividing the total measurement from one part of the crown of the remaining tooth to the nearest segment of a crown of the tooth adjacent to the missing area. However, if more than two teeth were missing at any anterior or posterior region without presence of teeth distal to the area (Figure 3.0), the measurement will be obtained by using standardized measurement of each region (Table 1.0) which are 14.4 mm and 20.6 mm respectively. The reference point for measuring the vertical bone height was established from the alveolar crest to the superior border of mandibular canal. Therefore, the measurement will begin at the midpoint of total mesiodistal coronal dimension of each region from the alveolar crest to the superior border of mandibular canal. For each patient's PAN and CBCT images, every measurement taken at two different regions was repeated three times and average readings were calculated to obtain a more accurate reading. Once all region's mean readings were determined, the mean difference in measurement between PAN radiograph and CBCT for each patient was then calculated. All measurements were independently performed by two observers (two dental students).

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY). The intraclass correlation coefficient (ICC) was used to determine interobserver reliability by evaluating 10% of the sample size (randomly selected). The correlation between PAN and CBCT images was evaluated using Pearson correlation coefficient to assess the relationship between PAN radiograph and CBCT in measuring vertical bone height at the posterior of mandible. The comparison between PAN and CBCT images in measuring presurgical dental implant vertical height from alveolar crest to the superior border of mandibular canal was tested using the paired t-test. The significance level will be set at $p < 0.05$.

RESULTS

Demographic data

The most frequently observed gender was female ($n = 42$, 64%). Ethnically, Malay patients were found to the of the highest number with 58 patients (88%) out of 66 total samples as presented in Table 2.0.

Measurements in PAN and CBCT

A total of 66 sets of PAN and CBCT images were assessed in this study. In PAN radiographs, the mean vertical bone height from the alveolar crest to the superior border of mandibular canal at right anterior, right posterior, left anterior and left posterior regions were 14.9±2.8 mm, 14.4±2.7 mm, 14.6±2.7 mm, and 14.5±2.7 mm, respectively. Whereas, in CBCT, the mean vertical bone height at right anterior, right posterior, left anterior and left posterior regions were 13.8±2.7 mm, 13.8±2.7 mm, 13.8±2.7 mm, and 13.9±2.7 mm, respectively. All the four regions had significantly lower mean measurement of the vertical bone height in CBCT images as compared to PAN radiographs. All measurement were tabulated in Table 3.0.

Comparison between PAN and CBCT

The alpha level of 0.05 was used for all statistical tests. The results of all the two-tailed paired samples t-tests showed statistically significant difference in measuring mean difference of vertical bone height at each region between PAN and CBCT ($p < 0.001$), indicating the null hypothesis can be rejected. In the right anterior region, there was a mean difference of 1.1 mm (SD=1.5 mm) in measurement between PAN and CBCT. Also, mean difference of 0.6 mm (SD=1.2 mm) was measured in the right posterior region between the two imaging modalities. In both PAN and CBCT, left anterior region had a mean difference of 0.8 mm (SD=1.3 mm) in measurement of the vertical bone height. Left posterior region showed a mean difference of 0.6 mm (SD=1.1 mm) in vertical bone height when comparing between the two radiographic images. Table 4.0 showed the data that has been tabulated.

Comparison between contralateral segment in PAN and CBCT

There was no statistically significant difference when comparing contralateral anterior region with regards to the mean difference of vertical bone height measurement in CBCT and PAN radiographs (p>0.05), as shown in Table 5.0. Results also indicated a no significant difference in measurement of the mean difference of vertical bone height in the available imaging modalities between contralateral posterior region with p values > 0.05. The data was tabulated in Table 6.0.

Correlation between PAN and CBCT

A Pearson correlation coefficient, *r* was computed to assess the relationship between PAN radiograph and CBCT in measuring vertical bone height at posterior of mandible. The result of the correlation was examined based on an alpha value of 0.05. A significant positive correlation was observed in right anterior region between PAN and CBCT ($r = 0.86$, $p < 0.001$) which suggested very-perfect correlation. In right posterior region, there was a positive linear relationship with very-perfect correlation observed between PAN and CBCT ($r = 0.91$, $p < 0.001$). Also, a significant positive linear relationship ($p < 0.001$) was observed in left anterior and left posterior region between PAN and CBCT with r = 0.88 and r = 0.92 respectively, that indicated very-perfect correlation. Table 7.0 presents the results of correlation.

Inter-observer Reliability Test

Agreement between two examiners (one Undergraduate student and one Oral and Maxillofacial Radiologist) in measuring vertical bone height at posterior of mandible using both PAN and CBCT were assessed using intraclass correlation coefficient (ICC). A two-way mixed-effect model based on absolute agreement were assessed in the inter-rater repeatability. 95% confidence intervals (CI) were reported for each ICC. Interpretation was as follows: <0.50, poor; between 0.50 and 0.75, fair, between 0.75 and 0.90 good; above 0.90, excellent. In our study, the ICC for inter-rater reliability ($p < 0.001$) were excellent. Table 8.0 shows the results for the ICC.

DISCUSSIONS

Dental implant placement required proper treatment plan by taking into account the clinical and radiographic evaluation. Pre-implant assessment may require either PAN radiograph or CBCT images to assess the availability of vertical bone height at the maxilla and mandible. CBCT is considered the imaging modality of choice for pre-surgical implant assessment due to its reliability, measurement accuracy, bone density evaluation and reproducibility of three-dimensional images. PAN radiograph is widely used by dental practitioner compare with CBCT where its only available at main dental facilities most commonly located around urban area. This study was carried out to compare the reliability of PAN radiographs in comparison to CBCT images in measuring the presurgical dental implant vertical height at the posterior of mandible.

Sixty-six sets of PAN radiographs and CBCT images of 66 samples were evaluated which comprised of 42 females (63.6%), 19 males (28.8%) and 5 missing gender (7.6%) with the majority of them was Malay (88%). Evaluation of PAN radiographs and CBCT images were independently observed by two examiners; one examiner is currently a Fourth-Year Undergraduate dental student and another examiner is an Oral and Maxillofacial Radiologist in the faculty. Excellent agreement was achieved by both examiners in measuring the vertical bone height in accordance with the intraclass correlation coefficient (ICC).

Our study demonstrated a positive linear relationship between PAN and CBCT in measuring the vertical bone height at the posterior of mandible. The present study shows an increased in the vertical bone height measurement on PAN at anterior and posterior mandibular segment. At the right anterior region, PAN presented a mean difference of 1.1 mm from CBCT and approximately 0.6 mm at the right posterior

region. The left anterior and posterior region of posterior mandible shows 0.8 mm and 0.6 mm mean difference in vertical bone height respectively when PAN is compared with CBCT image. Additionally, the present study found minimal difference between PAN and CBCT images during the quantifying of vertical bone height from the alveolar crest up to the superior border of mandibular canal.

According to Ozalp et al. (2018), there was a range of 0.36 mm to 0.76 mm in average difference between PAN and CBCT images. The study also suggested that the use of CBCT is more accurate during planning although less than 1.0 mm average difference between PAN radiograph and CBCT is measured (Özalp et al., 2018). Comparison of the contralateral segment of the posterior mandible resulted in no significant difference in mean difference of measurement between PAN radiograph and CBCT respectively. This may indicate reliability of both PAN and CBCT images in evaluating the respective contralateral segment of the mandible.

A study by Jasim Al-Juboori et al. (2013) stated that the most prevalent location of mental foramen among the Malaysian population was in between the apex of first and second premolars. In our study, to reduce the errors produced when determining the location of mental foramen which will eventually affect the vertical bone height measurement concerning the mandibular canal, a horizontal line is drawn connecting the mental foramen at the right and left side of mandible. The fact that the location of mental foramen may varied from apex of first premolars to first molars (Jasim Al-Juboori et al., 2013), the vertical measurement of the anterior region was performed from the alveolar crest until the digital caliper reaches the horizontal line in both PAN and CBCT.

A good prognosis dental implant should not interfere with the mandibular canal where inferior alveolar nerve runs through. According to Vazquez et al. (2008), a safety margin of at least 2.0mm between the tip of dental implant and the superior border of canal in PAN radiographs is adequate to determine an adequate alveolar bone height prior to posterior mandibular implant insertion. Similarly, a study conducted by Gerlach et al. (2010) suggested when using CBCT-based data for pre-implant surgery assessment, a safety zone of 1.7 mm should be taken into consideration. Correlating those studies to ours, once surgeons obtain the vertical bone height measurement from alveolar crest to superior border of mandibular canal, measurement should be deducted by 2.0 mm in PAN radiographs and 1.7 mm in CBCT to avoid any injury to the nerve.

CONCLUSION

It was concluded based on the results obtained that PAN images could provide sufficient information for presurgical implant assessment at the posterior of mandible in routine cases or during the unavailability of CBCT at the clinic. However, CBCT remains as the best imaging modalities for pre-surgical implant assessment as it has a minimal magnification error.

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