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Diagnostic accuracy of cone-beam computed tomography with modified grayscale range for detection of buccal cortical plate defects adjacent to dental implants

Soophia Yaghoobi[1], Zahra Dalili Kajan[2], Negar Khosravifard[2], Ali Khalighi Sigaroudi[3], Reza Modanlou Jouybari[3]

[1]Department of Maxillofacial Radiology, School of Dentistry, Guilan University of Medical Sciences, [2]Department of Maxillofacial Radiology, Dental Sciences Research Center, School of Dentistry, Guilan University of Medical Sciences, [3]Department of Maxillofacial Surgery, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran

ABSTRACT

Background: This study assessed the diagnostic accuracy of cone-beam computed tomography (CBCT) with a modified grayscale range for the detection of buccal cortical plate defects adjacent to dental implants.
Materials and Methods: In this *in vitro* experimental study, titanium implants were inserted in 168 fresh bovine bone blocks with 1–1.5 mm of buccal cortical plate thickness. The blocks were randomly divided into four groups ($n = 42$). No defect was created in the control blocks. In the three experimental groups, cortical plate defects were randomly created in the cervical, middle, or apical third by a round bur with a 2-mm diameter ($n = 42$). All blocks underwent CBCT with and without change in the grayscale range. Two observers evaluated all images regarding the presence/absence of defects. Kappa test is used for the agreement of the observers. The diagnostic accuracy of the two modalities was compared by calculating the area under the receiver operating characteristic curve (AUC) ($P \leq 0.05$). The sensitivity and specificity values were also compared.
Results: The AUC was not significantly different between the two modalities with and without altered grayscale range (0.754 vs. 0.762, respectively, $P = 0.716$). The diagnostic sensitivity of CBCT with and without change in the grayscale range was 51% and 52%, respectively, with a specificity of 100% for both. The diagnostic accuracy of CBCT with and without altered grayscale range had no significant difference for apical and middle third defects ($P > 0.05$) and was significantly higher than that for the cervical third defects ($P < 0.05$).
Conclusion: Changing the grayscale range does not improve the diagnostic accuracy of CBCT for the detection of buccal cortical plate defects adjacent to dental implants.

Key Words: Computer-assisted, cone-beam computed tomography, dental implants, diagnosis, radiographic image interpretation

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Address for correspondence: Dr. Zahra Dalili Kajan, Department of Maxillofacial Radiology, School of Dentistry, Guilan University of Medical Sciences, End of Professor Samii Blvd, Rasht, Iran.
E-mail: zahradalili@yahoo.com

INTRODUCTION

Dental implants are commonly used for the replacement of lost teeth to restore favorable esthetics

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and optimal function. However, dental implants and their adjacent anatomical structures require constant monitoring and long-term follow-ups to ensure optimal clinical service and peri-implant tissue health.[1]

The presence of adequate bone volume at the site is a key factor in the long-term success of dental implants.[2] According to the literature, a minimum of 1 mm of bone width in the buccal and lingual cortical plates around dental implants is imperative to ensure their complete bone coverage and osseointegration, and guarantee their long-term success.[3,4] Nonetheless, suboptimal anatomical conditions or some technical errors may result in the placement of dental implants in too close vicinity to the buccal or lingual cortical plate. The presence of a thin buccal or lingual cortical plate around dental implants is a challenging situation.[5] In such cases, it would be difficult for dental clinicians to ensure complete bone coverage of dental implants. The absence of adequate bone thickness covering the dental implant surface would increase the risk of defects such as fenestration and dehiscence.[5] Therefore, an efficient, reliable imaging modality is required to accurately assess the cortical bone plate thickness and possible defects around dental implants. Early detection of defects and their time management would decrease the risk of implant failure.

Conventionally, periapical (PA) radiography is used to assess osseointegration after implant placement and to ensure the absence of peri-implant radiolucencies. Dave *et al*.[6] reported a higher success rate of PA radiography than cone-beam computed tomography (CBCT) for the detection of narrow peri-implant bone defects. Furthermore, Raes *et al*.[7] showed that PA radiography had an excellent performance in the assessment of interproximal bone around dental implants. Nonetheless, PA radiography falls short of evaluating buccal and lingual cortical bone plates due to its two-dimensional nature and the resultant superimposition of structures. Thus, defects in buccal and lingual cortical plates often remain undetected on PA radiographs and require a more advanced imaging modality such as CBCT for detection.[7]

Despite the excellent resolution of CBCT in revealing the hard tissue details, it has shortcomings, such as inherent artifacts and metal artifacts around metal restorations or dental implants, such as the beam hardening artifacts.[8,9] Razavi *et al*.[8] showed that metal artifacts due to dental implants decreased the diagnostic accuracy of CBCT for measurement of buccal cortical plate thickness (especially in plates thinner than 0.8 mm). Kamburoglu *et al*.[10] pointed to the adverse effects of CBCT metal artifacts caused by dental implants on the detection of marginal defects around dental implants and reported that the application of the metal artifact reduction (MAR) algorithm could not improve its diagnostic accuracy. Furthermore, Leung *et al*.[9] reported the inferior diagnostic accuracy of CBCT for the detection of fenestration and dehiscence in buccal cortical plates adjacent to natural teeth, compared with direct observation. CBCT could not detect plates thinner than 0.6 mm and resulted in a high percentage of false positive results. Therefore, researchers are searching for strategies to improve the efficacy and diagnostic accuracy of CBCT for a more precise assessment of details and detection of defects.[5,10,11]

Computed tomography (CT) scanners are usually built with a 12-bit depth, which means that they have 4096 or 212 gray scale levels. Computer monitors usually display 256–1024 grayscale levels. The human eye can differentiate approximately 32 gray levels under the same lightness condition. Thus, 6-to 8-bit images often suffice to display CT images. Software programs for the visualization of CT images often allow the observers to narrow down the grayscale range; this post processing is referred to as "windowing." By adjusting the window width and window level, the observers can change the contrast and brightness of the displayed images. Window width determines the range of CT numbers displayed in the grayscale range. Window level refers to the midpoint of the displayed range of CT numbers.[12] Considering the reduction in image quality and difficult assessment of details due to the effect of artifacts, postprocessing of images by altering the grayscale range may improve the diagnostic quality of CBCT images and enhance the detection of bone defects around dental implants.[13]

Although several studies have evaluated the efficacy of CBCT for the detection of bone defects,[8-10,14-17] studies on strategies to improve the diagnostic accuracy of CBCT for the detection of bone defects around dental implants[5,10,11] and teeth[8,14] are limited. Therefore, considering the adverse effects of CBCT artifacts, especially in cases with thin cortical bone plates, or small size of defects, this study aimed to assess the diagnostic accuracy of CBCT with a modified grayscale range for the detection of buccal cortical plate defects adjacent to dental implants.

MATERIALS AND METHODS

The protocol of this *in vitro* experimental study was approved by the Ethics Committee of Guilan University of Medical Sciences (IR.GUMS.REC.1400.230). The sample size was calculated to be 42 in each group according to a previous study 14 assuming alpha = 0.05, power of 80%, and area under the receiver operating characteristic curve (AUC) to be 0.661 for CBCT using MedCalc version 19.0.5 software (MedCalc Software, Ostend, Belgium).

Preparation of specimens

This study was conducted on 168 bovine bone blocks measuring 10 mm in thickness and 15 mm in length that were cut out from fresh cow ribs (to simulate the alveolar bone). The sample size was calculated based on Eskandarloo *et al*.[14] The attached soft tissue was removed. The desired buccal cortical plate thickness was 1–1.5 mm. In blocks with thicker cortical plates, the buccal cortical plate was uniformly trimmed by a postgraduate student (resident of oral and maxillofacial radiology) to reach 1–1.5 mm thickness. The bone blocks were then randomly divided into four groups (n = 42). No defect was created in the control blocks. In the remaining three experimental groups, a round bur with a 2-mm diameter was used to artificially create defects in the buccal cortical plate at the cervical (n = 42), middle (n = 42), or apical (n = 42) third. Eight implants were placed in 8 bone blocks in each round, and the respective defect was created in each block. The blocks were then mounted in a simulated dental arch by using putty impression material (Henry Schein, USA) such that four random blocks (experimental and control) were mounted in each quadrant. The dental arch was made of red dental wax (Cavex Set Up Wax). In CBCT images, putty material has a lesser density than the cortex. In order to randomize the blocks in the wax arches, a permuted block technique was used on each side. SAS software version 9 (SAS Institute, North Carolina) was used to perform this randomization.

After imaging of each arch, eight new blocks were inserted in a new arch for the next round. This was repeated for 21 arches until all 168 blocks with dental implants were radiographed.

Dental implants (4.5 mm × 12 mm) (Dentium System, SuperLine, South Korea) were placed in the blocks by an experienced oral and maxillofacial surgeon using the respective drills operating at 1200 rpm × 800 rpm and 25–35 N/cm torque according to the standard sequence as instructed by the manufacturer. The implants were placed in contact with the buccal cortical plate. Considering the fact that dental implants were mainly placed in the cancellous part of the bone blocks, approximately 1.5 mm of cortical bone was present buccal to the implant surface. Hence, in some cases, we lost the samples because this was not achieved as a limitation of this research. A round bur with a 2-mm diameter was used to artificially create defects in the cortical bone plate. For this purpose, the respective area was first marked on the buccal surface of the block after measurement by a ruler, and then a round bur was positioned at the marked area. Its penetration depth was such that the implant threads were exposed at the site but were not damaged. In other words, the defects had a 2-mm diameter and 1–1.5-mm depth. The width of bone loss was smaller than the implant diameter, and along the buccal implant surface; the defect margins were blended in the adjacent bone. It should be mentioned that the details of the location of defects in each arch were recorded by a researcher for later use as the standard reference.

The dental implant blocks in each arch first underwent digital PA radiography (Digora Optime, Soredex, Finland) in parallel and mesial shift modes using a size no: 2 photostimulable phosphor plate (Digora Optime, Soredex, Finland). The images were then processed (Digora Optime, Soredex, Finland). To obtain each PA radiograph, the photostimulable phosphor plate was positioned behind the block and parallel to the implant. All radiographs were obtained using the same exposure parameters (70 kVp, 6 mA, and 0.32 s) by the application of sharpen and noise reduction filters, one at a time, using the respective software program (Soredex, Finland). The observers were allowed to use other features of the software as well for an enhanced diagnosis. PA radiographs were obtained to ensure that the artificially created defects were not detectable on PA radiographs. For this purpose, the PA radiographs were observed by two experienced oral and maxillofacial radiologists, and no visibility of defects on the radiographs was confirmed.

The CBCT images were then obtained from the eight blocks mounted in the wax dental arch by a radiology technician using NewTom VGi CBCT scanner (Verona, Italy) in zoom mode (4-inch field of view) with the exposure settings of 110 kVp, 2 mA, 3.6 s time, and 0.20–0.24 mm^3 voxel size (adjusted automatically by the scanner) in each time. To reconstruct a soft tissue shadow, prepared dental arches were put in the center of a designed U-shaped water-containing lacuna fixed on a plexy plate.

Assessment of cone-beam computed tomography images

Two oral and maxillofacial radiologists with over 10 years of experience in the assessment of CBCT images, who were familiar with the study objectives, reconstructed the volumetric images in NNT Viewer software (NewTom, Verona, Italy). They reconstructed cross-sectional images in buccolingual and mesiodistal directions from each implant with 0.5–1 mm slice thickness and 0.5–1 mm slice interval. In this study, the change in grayscale range was applied by choosing the lower and upper range from 6% to 52% (regular or no grayscale alteration) to 10%–85% (with grayscale alteration). The alteration in the grayscale was standardized by the designer of this research (ZDK) in a pilot study. The observers were asked to use one of the two modalities at each assessment (regular or modified grayscale range). The time interval between the observation of images with and without the change in grayscale range was 2 weeks to 1 month.

All CBCT images were displayed on a medical monitor (EIZO Co., Japan). The observers were requested to express their opinion regarding the presence/absence of defects on each image using the following four-point Likert scale:

(I) The bone defect is definitely absent
(II) The bone defect is probably absent
(III) The bone defect is definitely present
(IV) The bone defect is probably present.

In addition to reporting the presence/absence of defects, the observers were requested to express their opinion regarding the level of the defect (its presence in the cervical, middle, or apical third). Figures 1 and 2 indicate bone defects in the apical third in the buccal cortex with and without altered grayscale range.

Four weeks after the final observation, 20% of the CBCT images were randomly selected and reevaluated by the same examiners to assess the intra- and inter-observer agreements. The diagnostic accuracy, sensitivity, and specificity values were also calculated and reported.

Statistical analysis

Data were analyzed using SPSS version 24 (SPSS Inc., Chicago, IL, USA) and MedCalc version 19.0.5 (Ostend, Belgium). Assessment of the intra-observer and inter-observer agreements was performed by calculating the kappa agreement coefficient. The AUC was calculated to compare the diagnostic accuracy of the two modalities for the detection of defects in the cervical, middle, and apical thirds. The level of significance was set at 0.05.

RESULTS

The inter-observer agreement was calculated to be 70%. The intra-observer agreement was calculated to be 75%. Considering the minimum acceptable

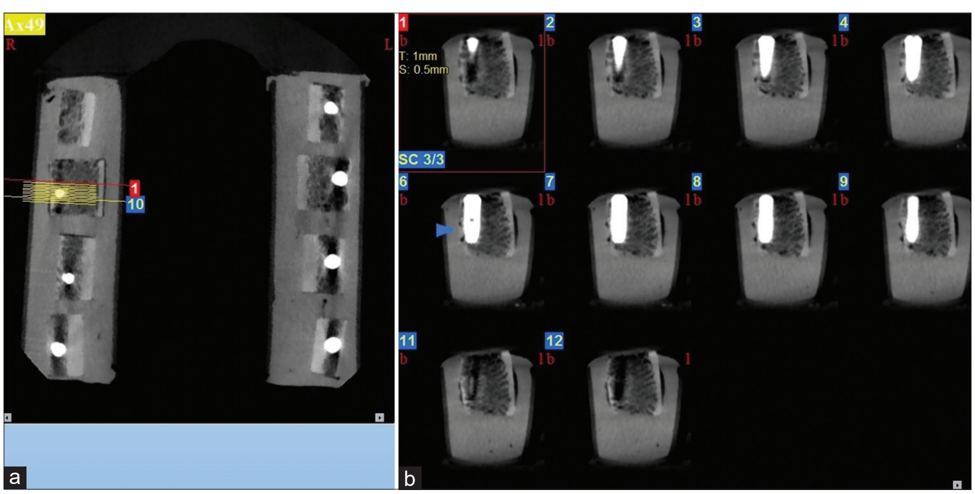

Figure 1: Cone-beam computed tomography images of a defect in the apical third with no change in grayscale range. (a) Axial view. (b) Buccolingual cross-sectional view (blue arrow points to the defect site).

agreement of 70%, the inter- and intra-observer agreements were both acceptable.

Diagnostic accuracy of cone-beam computed tomography with and without an altered grayscale range for detection of buccal cortical plate defects

Table 1 presents the diagnostic accuracy of CBCT with and without an altered grayscale range for the detection of buccal cortical plate defects. As shown in Figure 3, both modalities showed acceptable diagnostic accuracy. The diagnostic sensitivity of CBCT with and without change in the grayscale range was 51% and 52%, respectively, with a specificity of 100% for both.

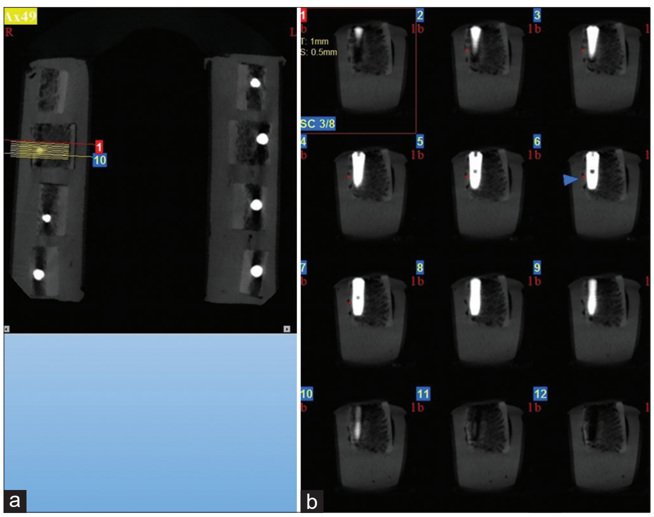

Figure 2: Cone-beam computed tomography images of a defect in the apical third with altered grayscale range. (a) Axial view. (b) Buccolingual cross-sectional view (blue arrow points to the defect site).

A comparison of the diagnostic accuracy of the two modalities for the detection of buccal cortical bone defects revealed no significant difference (P = 0.716; mean AUC = 0.008, 95% confidence interval: 0.03–0.05).

Diagnostic accuracy of cone-beam computed tomography with and without an altered grayscale range for detection of buccal cortical plate defects in the apical, middle, and cervical thirds

Table 2 presents the diagnostic accuracy of CBCT with and without an altered grayscale range for the detection of buccal cortical plate defects in the apical, middle, and cervical thirds. The results showed maximum AUC for the middle third and minimum AUC for the third cervical defect.

Table 3 compares the diagnostic accuracy of CBCT with and without an altered grayscale range for the detection of buccal cortical plate defects in the apical, middle, and cervical thirds pairwise. The diagnostic accuracy of CBCT with altered grayscale range had no significant difference for apical and middle third defects (P = 0.066). However, the diagnostic accuracy of CBCT with altered grayscale range for detection of apical and middle third defects was significantly higher than that for third cervical defects (P = 0.002 and P < 0.001, respectively). Similarly, the diagnostic accuracy of regular CBCT (without altering the grayscale range) was the same for apical and middle-third defects (P = 0.502). However, the diagnostic accuracy of this modality for the detection of apical and middle-third defects was significantly higher than that for cervical third defects (P = 0.007 and P < 0.001, respectively).

Table 1: Diagnostic accuracy of cone-beam computed tomography with and without an altered grayscale range for detection of buccal cortical bone defects

CBCT modality	Sensitivity (%)	Specificity (%)	AUC	SE	95% CI	P
Altered grayscale range	51	100	0.754	0.022	0.68–0.82	<0.001
Regular	52	100	0.762	0.022	0.69–0.82	<0.001

AUC: Area under the receiver operating characteristic curve; SE: Standard error; CI: Confidence interval; CBCT: Cone-beam computed tomography

Table 2: Diagnostic accuracy of cone-beam computed tomography with and without an altered grayscale range for detection of buccal cortical defects in the apical, middle, and cervical thirds

CBCT modality	Defect level	Sensitivity (%)	Specificity (%)	AUC	SE	95% CI	P
Altered grayscale range	Apical	55	100	0.774	0.039	0.67–0.86	<0.001
	Middle	74	100	0.869	0.034	0.78–0.93	<0.001
	Cervical	24	100	0.619	0.033	0.51–072	<0.001
Regular	Apical	60	100	0.798	0.038	0.7–0.88	<0.001
	Middle	67	100	0.833	0.037	0.74–0.91	<0.001
	Cervical	31	100	0.655	0.036	0.54–0.75	<0.001

AUC: Area under the receiver operating characteristic curve; SE: Standard error; CI: Confidence interval; CBCT: Cone-beam computed tomography

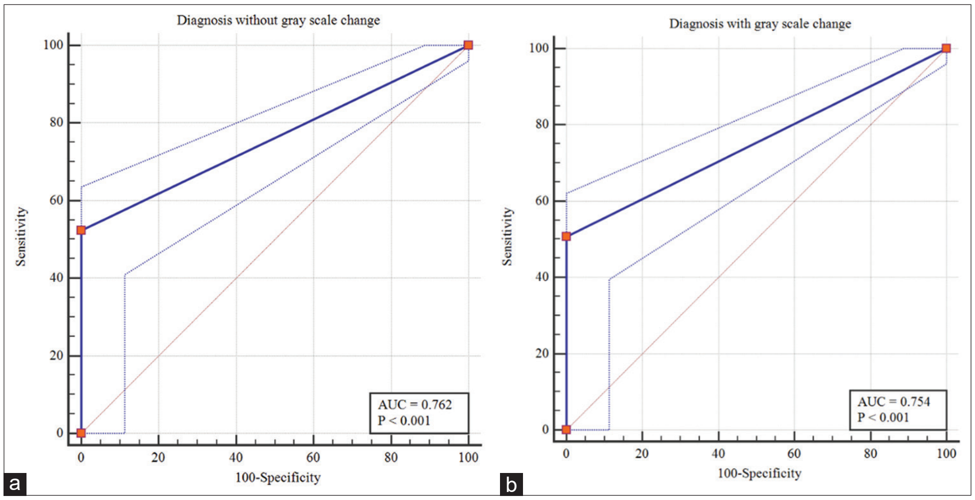

Figure 3: Area under the receiver operating characteristic curve for regular cone-beam computed tomography (a) and altered grayscale range (b). AUC: Area under the curve.

Table 3: Pairwise comparisons of the diagnostic accuracy of cone-beam computed tomography with and without an altered grayscale range for detection of buccal cortical defects in the apical, middle, and cervical thirds

CBCT modality	The two levels compared	Mean difference in AUC (%)	95% CI	P
Altered grayscale range	Apical~middle	9.5	−0.006–0.20	0.066
	Apical~cervical	15.5	0.05–0.25	0.002
	Middle~cervical	25	0.16–0.34	<0.001
Regular	Apical~middle	3.6	−0.07–0.14	0.502
	Apical~cervical	14.3	0.04–0.25	0.007
	Middle~cervical	17.9	0.08–0.28	<0.001

AUC: Area under the receiver operating characteristic curve; CI: Confidence interval; CBCT: Cone-beam computed tomography

A comparison of the two modalities revealed no significant difference in diagnostic accuracy for detection of apical (P = 0.530), middle (P = 0.407), or cervical (P = 0.255) third defects.

DISCUSSION

This study assessed the diagnostic accuracy of CBCT with a modified grayscale range for the detection of buccal cortical plate defects around dental implants. The results showed that the AUC was not significantly different between the two modalities with and without altered grayscale range (0.754 vs. 0.762, respectively, P = 0.716). The diagnostic sensitivity of CBCT with and without change in the grayscale range was 51% and 52%, respectively, with a specificity of 100% for both. The diagnostic accuracy of CBCT with and without altered grayscale range had no significant difference for apical and middle third defects (P > 0.05) and was significantly higher than that for the cervical third defects (P < 0.05).

A search of the literature by the authors yielded no study on the effect of altered grayscale range of CBCT on the detection of bone defects adjacent to dental implants. However, some other studies showed that changing the grayscale range increased the diagnostic accuracy of CBCT for the detection of details.[13,18] Neshandar Asli *et al.*[13] evaluated the success rate of the NewTom CBCT scanner with an altered grayscale range to estimate the location and direction of screw access holes in implant-supported cement-retained abutments. They showed that the use of a long grayscale zone improved the visualization of abutment details and enhanced the detection of the position and direction of the screw access hole. Kajan *et al.*[18] evaluated the efficacy of altered grayscale range for assessment of bone-implant interface in comparison with digital PA radiography. They found that changing the grayscale range significantly enhanced the observation of details in this region. In addition, they demonstrated that although both PA radiography and CBCT had optimal diagnostic accuracy for the detection of gaps at the bone-implant interface, PA radiography had higher sensitivity than CBCT with an altered grayscale range for this purpose (100% vs. 83.33%). However, in the absence of gaps at the bone-implant interface, the performance of CBCT was superior to PA radiography and had higher specificity (92.68% vs. 83.33%). Nonetheless, in the present study, CBCT with and without altered grayscale range had no significant difference in the detection of buccal cortical bone defects, and altering the grayscale range even slightly complicated the detection of defects. Thus, alteration of the grayscale range is not recommended for this purpose.

Previous studies have reported relatively acceptable diagnostic accuracy of CBCT for measurement of bone thickness adjacent to implants and detection of bone defects.[8,14] The present results confirmed the findings of previous studies in this respect since the diagnostic accuracy of CBCT for the detection of buccal plate defects at all levels of cervical, middle, and apical thirds was acceptable with/without altered grayscale range (the AUC values were all acceptable).

Several factors can affect the diagnostic accuracy of CBCT in the detection of thickness and status of cortical bone, such as the type of CBCT scanner,[8,14] voxel size,[5,19] the rotational arc of scanner,[5] application of MAR algorithms,[10,20] and thickness of bone covering the implant.[21] Eskandarloo *et al*.[14] compared the diagnostic accuracy of different CBCT scanners and PA radiography for the detection of fenestration around dental implants. They found that all CBCT scanners had comparable diagnostic accuracy for the detection of fenestration with no significant difference. However, the NewTom scanner showed maximum sensitivity (75.81%) and specificity (100%) with the exposure parameters of 110 kVp and 10.65 mAs. Similarly, we used a NewTom scanner with the exposure parameters of 110 kVp, 2 mA, and 3.6 s in the present study, and the results showed that the specificity of CBCT with/without altered grayscale range was 100% (it was successful in detection of all cases correctly without defects). In other words, there was no false positive result, which agrees with the findings of Eskandarloo *et al*.[14] However, alteration of the grayscale range had no positive effect and even slightly decreased the sensitivity to a value (51%) lower than that reported by Eskandarloo *et al*.[14] Nonetheless, it should be noted that the bone thickness was 2 mm in their study.

Voxel size is another important factor that affects the resolution of CBCT and its diagnostic accuracy for the detection of cortical bone defects. Kurt *et al*.[19] evaluated the effect of voxel size (0.075, 0.100, 0.150, 0.200, and 0.400 mm^3) on the detection of fenestration defects around dental implants using ProMax 3D CBCT scanner. They concluded that CBCT with 0.150 mm^3 voxel size had maximum diagnostic accuracy for the detection of fenestration defects around dental implants. In the present study, a NewTom CBCT scanner with 0.20–0.24 mm^3 voxel size was used, and the obtained AUC in the use of regular CBCT was 0.762, which was comparable to the AUC for 0.200 mm^3 voxel size in the study by Kurt *et al*.[19] Comparing the two studies, it appears that reduction of voxel size has a greater effect than alteration of grayscale range for enhancement of diagnostic accuracy of CBCT for detection of defects. However, it should be noted that they did not mention the thickness of the overlying cortical bone and used a different CBCT scanner. Nonetheless, the effect of voxel size should preferably be analyzed in combination with other exposure parameters, such as the rotational arc. Accordingly, de-Azevedo-Vaz *et al*.[5] showed that in the detection of dehiscence, the imaging protocol with 0.2 mm^3 voxel size and 360° rotational arc had no significant difference with 0.12 mm^3 voxel size and 360° rotational arc. However, the imaging protocol with 0.2 mm^3 voxel size and 180° rotational arc yielded significantly poorer results. They concluded that voxel size had no significant effect on the detection of dehiscence, and full-scan is superior to half-scan for the detection of this type of defect.

With respect to the use of the MAR algorithm, Kamburoglu *et al*.[10] reported no significant improvement in the detection of defects following the application of this algorithm. However, Bayrak *et al*.[20] showed significant improvement in the diagnostic accuracy of CBCT for the detection of defects following the application of MAR and Adaptive Image Noise Optimizer enhancement filters. But, it should be noted that defects had a 3-mm diameter in their study.

The thickness of the buccal cortical plate around dental implants is a highly influential factor in the detection of cortical bone defects, especially when the thickness is ≤1 mm.[21] Domic *et al*.[21] indicated that in bone plates with a thickness ≤1 mm, the percentage of false positive results was high. In the present study, the specificity was 100% with/without altered grayscale range, indicating that alteration of grayscale range and regular CBCT prevents false diagnosis of bone defects in cases with normal cortical bone coverage.

Variations in amperage may also be responsible for the diversity in the results of studies. Misch *et al*.[16] and Pinsky *et al*.[22] used much higher amperage values (47.7 mA, 20 s, and 98 mA, 20 s, respectively) compared with the present study (2 mA and 3.6 s). They reported that CBCT detected all defects created in alveolar bone and had very high measurement accuracy. In the present study, however, CBCT could not detect all cortical defects with/without alteration of the grayscale range (sensitivity of 51% and 52%, respectively). Leung *et al*.[9] also used 2 mA amperage and 9.6 s time and reported that CBCT could not detect all naturally occurring defects in human dry skulls. Thus, it appears that higher amperage has a positive effect on the diagnostic accuracy of CBCT for the detection of cortical defects. However, the "as low as reasonably achievable" principle should be adhered to in all clinical scenarios.

Sheikhi *et al*.[23] used the gray value (GV) of CBCT for measuring the bone density of the peri-implant area and evaluating the relationship between the bone density and primary stability of dental implants. They observed a significant relationship between the GV and the maximum insertion torque of the implants. Therefore, based on their study GVs obtained from CBCT scanners can be used for the preoperative selection of edentulous sites, which allow for better implant stability.

In the present study, the diagnostic accuracy for the detection of cervical defects was significantly lower than that for the detection of apical and middle-third defects with/without the altered grayscale range. Lower available bone in the cervical third and low density of thin bone adjacent to very low density of soft tissue (in the clinical setting) are probably responsible for the more difficult detection of cervical defects and higher frequency of false negative results in this region. This result was in agreement with the findings of de-Azevedo-Vaz *et al*.[5] and Leung *et al*.[9]

de-Azevedo-Vaz *et al*.[5] reported higher inter-observer agreement in the detection of fenestration compared with dehiscence around dental implants in all three imaging protocols. Furthermore, the diagnostic sensitivity for the detection of fenestration was higher than that for dehiscence by all observers.

It should be noted that artificially created defects often have smooth, well-defined margins since they are created by bur, while clinical defects do not have sharp margins and often have tapered gradual borders. Thus, in the present study, we tried not to create sharp, well-defined margins in the defects. For this purpose, first, the primary defect was created by a round bur, and then the defect margins were blended by using inverted and cylindrical burs to better simulate the naturally occurring defects. This was a strength of this study. Leung *et al*.[9] evaluated naturally occurring defects in dry skulls and found higher diagnostic accuracy of CBCT for the detection of fenestration compared with dehiscence defects. They reported high sensitivity and specificity (both 80%) for the detection of fenestration, while the sensitivity and specificity values were 40% and 95%, respectively, for dehiscence defects. Their results were close to the present findings regarding cervical defects. However, the diagnostic sensitivity for cervical defects in the present study was 24% and 31% with and without altered grayscale range, respectively, which were lower than the values reported by Leung *et al*.[9] The presence of implants instead of natural teeth and the resultant beam hardening artifacts can explain this difference. It should be noted that in the clinical setting, detection of cortical defects is more difficult, and the diagnostic accuracy of CBCT would be lower than the values obtained *in vitro* due to the presence of teeth and metal restorations, as well as other parameters generating artifacts. Although bovine bone was used in the present study, the clinical setting could not be precisely simulated; nonetheless, *in vitro* studies can provide a good estimate of the clinical scenarios.[5]

Future studies are recommended to assess the effect of altered grayscale range along with alterations in some other influential parameters on the detection of defects to find strategies to improve the diagnostic accuracy of CBCT for this purpose.

CONCLUSION

CBCT with/without alteration in the grayscale range showed acceptable diagnostic accuracy for the detection of cortical bone defects adjacent to dental implants. Changing the grayscale range did not improve the diagnostic accuracy of CBCT for the detection of buccal cortical plate defects adjacent to dental implants.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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