Influence of the Milliamperage and Artifact Reduction Tool on the CBCT-Based Diagnosis of Buccal and Lingual Peri-implant Dehiscences: Comparison Between Two Types of Implants

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Purpose: To evaluate the influence of the milliamperage and artifact reduction (AR) tool on the diagnosis of buccal and lingual peri-implant dehiscences related to titanium-zirconia (Ti-Zr) and zirconia (Zr) implants using CBCT images. Materials and Methods: Ti-Zr and Zr implants were alternately inserted in 20 sites in the posterior region of three human mandibles that presented intact cortical (control) bones or simulated buccal and/or lingual peri-implant dehiscences. CBCT images were acquired with an OP300 Maxio unit, varied milliamperage (5 and 8 mA), and the use of AR tool. Three oral radiologists assessed the presence of dehiscences using a 5-point scale. The area under the receiver operator characteristic curve (Az), sensitivity, and specificity of each group (control and dehiscence) were obtained and compared using multiway ANOVA (α = .05). Results: The milliamperage and the AR tool did not influence the diagnosis of dehiscences, and there were no differences between the buccal and lingual cortices (P > .05). However, Zr implants showed a higher sensitivity (0.67 to 0.89) and lower specificity (0.26 to 0.44) than Ti-Zr implants (0.19 to 0.44 and 0.93 to 1.00, respectively; P < .05). Az values did not differ between the implant types (P > .05). Conclusions: Dehiscences were more detectable when related to Zr implants, while the absence of dehiscences was more correctly visualized adjacent to Ti-Zr implants. The use of varied milliamperages and the AR tool did not affect the diagnosis of peri-implant dehiscences, regardless of the involved cortical (buccal or lingual) bones. Int J Oral Maxillofac Implants 2022;37:1202–1209. doi: 10.11607/jomi.9682

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Dental implants are an effective treatment for oral rehabilitation, with titanium implants among the most common of these. However, although titanium implants have adequate biocompatibility and strength, they also have disadvantages that can cause esthetic problems—especially in thin periodontal tissues—such as corrosion and metallic color.1 On the other hand, in addition to the high osseointegration potential and tensile strength, zirconia has a tooth-like color and a smoother surface, which hinders the accumulation of biofilm.2,3 For these reasons, zirconia or titanium-zirconia implants are being used increasingly often.

Besides the implant type, an important factor to consider is the morphology of the bone ridge. In some cases, a steep inclination of the edge or insufficient bone volume can result in improper implant placement. This increases the chances of developing peri-implant bone defects such as dehiscences, which are characterized by the loss of the buccal or lingual cortex from the cervical portion of the implant.4,5 The progression of these defects can impair esthetics, local hygiene, and mobility and can also cause gingival recession and even the loss of the implant.6 Thus, its early detection is important for the treatment prognosis.

Diagnosing peri-implant dehiscences is challenging, as they may affect the buccal and lingual cortices, thereby contraindicating bidimensional imaging due to overlap in the buccolingual direction. CBCT has emerged as a three-dimensional alternative; however, artifacts can form due to a beam hardening phenomenon that occurs when high-density materials are present in the scanned volume.7–9 Such artifacts appear as light and dark streaks that impair the visualization of the bone tissue adjacent to the implants.10
The expression of the CBCT artifacts varies according to the type of material composing the implants. For example, zirconia implants (atomic number = 40) produce more artifacts than titanium-zirconia or titanium implants (atomic number = 22). Nevertheless, little is known about the impact of zirconia or titanium-zirconia implant artifacts on the diagnosis of peri-implant dehiscences in CBCT images. Also, it was recently demonstrated that the expression of artifacts is different between the buccal and lingual cortical plates. However, this factor has not yet been investigated in any study that has evaluated the performance of CBCT in the diagnosis of peri-implant bone defects. In addition, few studies on this subject have used human mandibles in their methodology, which is important for simulating the spread of the x-ray beam as it occurs in a clinical situation.

Some alternatives for reducing artifact expression consist of increasing the CBCT exposure parameters and using a reconstruction algorithm called the artifact reduction (AR) tool. The former is related to an increase in the patient radiation dose, which can be justified if it improves the image quality and the CBCT diagnostic performance. On the other hand, despite not changing the radiation dose for the patient, the AR tool is effective at reducing artifacts when they are pronounced in the image, though its influence on the evaluation of peri-implant bone defects is controversial.

Therefore, this study aimed to evaluate the accuracy of CBCT images obtained with different milliamperages—and with and without the activation of the AR tool—and their effect on the detection of buccal and lingual peri-implant dehiscences associated with titanium-zirconia and zirconia implants.

**MATERIALS AND METHODS**

**Ethical Aspects**

The present in vitro study was approved by the local Institutional Research Review Board without restrictions (protocol number #24952219.0.0000.5418).

**Phantom Preparation**

Three dry human edentulous mandibles were used in this study. First, an implant dentistry specialist prepared 20 sites for the placement of dental implants in the posterior region of the mandibles, consisting of 8 sites in one mandible and 6 sites in each of the other two mandibles, equally distributed between the right and left sides of the molar and premolar regions. Also, two types of dental implants were used: a titanium-zirconia implant (Ti-Zr; alloy composed of 15% Zr and 85% Ti; Straumann SLActive, Institut Straumann) and a zirconia implant (Zr; PURE Ceramic, Institut Straumann), both with the same size of 3.3 mm × 8 mm.

From the 20 implant sites prepared (i.e., encompassing 40 cortical plates), one operator (E.H.L.N.) prepared 19 dehiscence defects randomly in the buccal or lingual cortices (Fig 1). All bone defects were created using a standardized approach with a #1014 spherical diamond bur (KG Sorensen). A digital caliper with an accuracy of 0.01 mm was used to guarantee a standardized implant position regarding the height of the adjacent bone crest and the size of the dehiscence defects. Further, the cortices without dehiscence defects were used as the control. The thickness of the control cortices ranged from 1.0 to 2.0 mm (average = 1.47 ± 0.38 mm), as a thick cortical plate could facilitate detection of the bone defects. The distribution of the bone defects and control cortices according to the mandible and the cortical involved (buccal and/or lingual) was equivalently performed, as seen in Fig 2.

**Image Acquisition and Sample Composition**

After simulating the bone defects, each mandible was inserted in a cylindrical plastic container (160 mm in diameter) and fixed with the aid of wax. The container was filled with water to simulate the attenuation and scattering of the x-ray beam by the soft tissues in a clinical scenario. The phantom was placed in the platform of the OP300 Maxio CBCT unit (Instrumentarium) parallel to the ground and centralized in the field of view using the orientation lights of the CBCT unit (Fig 3).
Each dental implant was inserted individually in each implant site, and two sets of images were acquired: one Ti-Zr implant set and one Zr implant set. Thus, there was only one dental implant in the scanned area for each image acquisition, avoiding a synergistic effect from the simultaneous presence of multiple implants inside the field of view. No torque was applied to the dental implants so that the implants could be changed between acquisitions. The acquisition parameters were fixed at a 6 × 8 cm–field of view size, 90 kVp, and 0.2-mm voxel size. In contrast, two mA levels were tested: 5 mA and 8 mA. At first, each protocol was acquired without the AR tool. After the first volume reconstruction (ie, without the AR tool), each CBCT volume was then reconstructed again, this time with the AR tool activated. A previous study showed no difference in the image quality regarding the activation mode of the AR tool (ie, activation before or after the CBCT acquisition).9 Thus, for each acquisition, two volumes—with and without activation—were obtained regarding the AR condition. To summarize, 160 CBCT volumes were evaluated (20 implant sites × 2 dental implants × 2 mA levels × 2 AR tool conditions). Figure 4 shows CBCT images comparing the buccal and lingual defects, type of implant, use (or lack thereof) of the AR tool, and milliamperage level (5 and 8 mA).

### Image Evaluation

Three oral and maxillofacial radiologists with a minimum of 5 years of expertise in CBCT evaluation performed the image evaluation. The examiners were blinded for the studied factors. After randomization of the CBCT volumes, the examiners assessed the buccal and lingual cortical plates of the implant sites for the presence of dehiscence defects using a 5-point scale (1 = dehiscence absent, 2 = dehiscence probably absent, 3 = uncertain, 4 = dehiscence probably present, 5 = dehiscence present). All analyses were performed using the OnDemand 3D software (Cybermed Inc) in a dim and silent room. The CBCT images were visualized on a high-resolution medical display (MDRC-2124, Barco NV), and the use of postprocessing tools (eg, brightness, contrast, and zoom) was allowed at the discretion of the examiners. To calculate intraexaminer agreement, 30% of the sample was reassessed 30 days after completion of the evaluation.

### Statistical Analysis

The intra- and interexaminer agreements were calculated using weighted Kappa test and interpreted according to the Landis and Koch18 scale (0.00 to 0.20 = slight, 0.21 to 0.40 = fair, 0.41 to 0.60 = moderate, 0.61 to 0.80 = substantial, 0.81 to 1.00 = almost perfect). The
diagnostic values (area under receiver operator characteristic [ROC] curve [Az], sensitivity, and specificity) were calculated for each examiner according to the studied factors (cortical plate location, dental implant type, mA level, and AR tool condition) and summarized as mean and SD. These results were compared using ANOVA multiway test with Tukey post hoc test with the significance level set at .05. In addition, positive predictive value (PPV) and negative predictive value (NPV) were calculated considering a prevalence of 50%, according to the present study sample. All analyses were performed using the SPSS software version 24.0 (IBM Corp). The null hypothesis was that the studied factors did not influence the diagnosis of the peri-implant dehiscence.

RESULTS

Table 1 displays data regarding the diagnostic values calculated for the dehiscence detection among the variables under study (tube current, cortical plate, material of the implant, and AR tool activation). No statistically
significant influence of the tube current, cortical plate location, or AR tool was observed for any of the diagnostic values ($P > .05$). The material of the implant did not influence the Az values ($P > .05$); however, it did influence dehiscence detection with regards to sensitivity and specificity ($P < .05$). Higher sensitivity values were observed for Zr (ranging from 0.67 to 0.89) compared to Ti-Zr (from 0.19 to 0.44), irrespective of tube current, cortical plate, or AR activation. Conversely, specificity values were higher for Ti-Zr (ranged from 0.93 to 1.00) compared to Zr (ranging from 0.26 to 0.44). Figure 5 shows the Az values for Ti-Zr (Fig 5a) and Zr (Fig 5b). The curves are displaced more inferior and in the left of the graph for Ti-Zr, which represents low sensitivity and high specificity values. For Zr, the curves are displaced more superior and in the right of the graph, representing high sensitivity and low specificity values. It is also noted that, in general, the curves in each graph preserved the same format, which reveals that the other factors studied did not influence the values.

Table 2 shows data regarding PPV and NPV among the conditions under study. The PPV was higher for
Ti-Zr compared to Zr implants for all conditions under study. When analyzing images with AR, PPV was all 1.00 for Ti-Zr implants, regardless of mA or cortical plate. In contrast, NPV were slightly higher for Zr implants in all studied conditions.

Mean agreement values were 0.30 (ranging from 0.10 to 0.67) for intraexaminer, and 0.39 (ranging from 0.11 to 0.76) for interexaminer, which may be classified from slight to substantial for both agreements.

DISCUSSION

According to the best of the authors’ knowledge, this is the first study that has evaluated dehiscences associated with zirconia and titanium-zirconia implants by simulating a clinical situation using human mandibles, controlling the size of defects and the thickness of control cortices, and comparing their detection in the buccal and lingual cortical plates. As a result, the only factor that significantly influenced the diagnosis of peri-implant dehiscence was the type of implant.

In this study, dehiscences were diagnosed more correctly (higher sensitivity values) when next to zirconia implants. In contrast, control cortices were better detected when next to titanium-zirconia implants (higher specificity values). According to previous studies, zirconia implants generate more artifacts than other types of implants.7,8,11,12 In this sense, the visualization of the buccal and lingual cortices may have been impaired by the artifacts derived from the beam-hardening and blooming phenomena,14 resulting in more cases of both true and false positives for the zirconia implant. In contrast, the titanium-zirconia implant results were similar to those reported in the literature for titanium implants,5,16,19 with higher specificity and lower sensitivity values.

Predictive values refer to the probability of a dehiscence being detected (PPV) or classified as normal/control (NPV), considering the prevalence of this defect. Both predictive values from previous studies present high variability.19,20 In the present study, PPV was higher for titanium-zirconia implants compared to zirconia implants regardless of the conditions under study, which may be related to the fact that artifacts were less pronounced in the vicinity of titanium-zirconia implants. On the other hand, NPVs were lower and mostly similar between the two types of implants. This may be a consequence of the difficulty of diagnosing peri-implant dehiscences regardless of implant material, as the observer must subjectively differentiate between image artifacts or true defects.

The present study had accuracy values that ranged from 0.63 to 0.74. These values were similar to those of certain previous studies,5,13,16 including two meta-analyses,19,20 but lower compared to others.17,21 However, it is important to highlight some methodologic differences between the present study and other studies. First, most others only evaluated dehiscences associated with titanium implants.5,16,17 In addition, none of the studies mention standardizing the size of the control cortices. This is relevant because healthy thick cortices may be easier to detect, thus increasing the value of specificity and accuracy, which may be the case for the results found by Schriber et al.21 In the present study, the control cortices were maintained with the minimum recommended bone thickness around implants22 in order to make the condition as close to a clinical setting as possible.

In the present investigation, the bone defects were created in three human mandibles. In contrast, other in
vitro studies have used sheep heads,\textsuperscript{13} fresh pig mandibles,\textsuperscript{21} and bovine bone ribs\textsuperscript{5,10,16,17} to simulate peri-implant defects. Although these phantoms are usually employed to reproduce this diagnostic task, the use of a human mandible is the most suitable scenario to mimic a clinical situation.\textsuperscript{23}

One of the variables investigated here was the comparison of dehiscences involving the buccal and lingual cortices. In an objective evaluation, Nascimento et al\textsuperscript{9} found that artifacts related to zirconia implants spread more expressively in the lingual cortices than in the buccal cortices of the mandibular posterior region. Nevertheless, in the present study, such an influence was not detected in the diagnostic values.

One way to reduce artifact expression is to improve the diagnosis in CBCT images using the AR tool. It has been reported that this tool works more effectively in areas where artifacts are more pronounced.\textsuperscript{7,9} Therefore, it was expected that the AR tool would improve the detection of dehiscences mainly related to zirconia implants, which generate more artifacts. However, its use did not influence this diagnostic task. Such behavior was also observed in studies on the diagnosis of dehiscences related to titanium implants, which found no influence\textsuperscript{16} or even a negative influence of the AR tool,\textsuperscript{17} which reinforces the questions surrounding the clinical utility of this tool.

The change in the tube current (milliamperage) also represents a means to improve image quality by reducing noise and artifact expression, as previously shown.\textsuperscript{15} This is because increased milliamperage generates a greater amount of signal during the image acquisition process. But despite this benefit, increasing milliamperage also increases patient exposure to x-ray radiation\textsuperscript{24}; therefore, its use must be well justified (according to the ALADA [as low as diagnostically acceptable] principle). As there were no differences in evaluator performance for the images acquired with 5 or 8 mA, the clinical use of the lowest tested milliamperage (ie, 5 mA) is recommended.

Intra- and interexaminer agreements in the present study varied from slight to substantial, and the mean was considered fair. Previous studies also reported lower agreement values, such as 0.401 to 0.478 for interexaminer and 0.402 to 0.475 for intraexaminer,\textsuperscript{16} and 0.200 to 0.634 for interexaminer and 0.300 to 0.700 for intraexaminer.\textsuperscript{13} CBCT-based diagnosis of dehiscence is a difficult task, especially with defects limited to the cervical third of the implant, which is associated with thin cortices, making the diagnosis more challenging. In addition to the inherent difficulty of the diagnosis, the presence of metal artifacts arising from the implant are more expressive in the vicinity of high-density materials.\textsuperscript{12} Such image quality deterioration can influence not only the diagnosis itself, but also the agreement of different observers due to the subjectivity of the task.

In the present study, dehiscences were limited to the cervical third of the implant, simulating an initial bone loss. Defects in this stage are often not yet accompanied by gingival recession,\textsuperscript{6} meaning that an early diagnosis combined with periodontal therapies is crucial for improving the prognosis for the patient. In the present study, all peri-implant defects had a standardized vertical depth of 3 mm, as this size clinically represents an initial bone defect, as aforementioned. Considering that the primary aim of the current study was to investigate the influence of the CBCT scanning parameters on the diagnosis of peri-implant dehiscence, the standardization of the bone defect size was essential to prevent the morphology of the bone defect from influencing the assessment. However, it is encouraged for future studies to evaluate the influence of the bone defect size on the accuracy of peri-implant defect diagnosis.

A limitation of this study is the lack of correlated clinical examination, which can provide additional important information for the diagnosis of peri-implant dehiscences. Nonetheless, it was important to standardize the conditions in the present study design, subjecting the same region to multiple tomographic acquisitions with different types of implants and exposure protocols, which is not possible in an in vivo study. Further, it is important to highlight that the results of the present study cannot be directly compared to other devices, considering differences in the inherent technical parameters of each unit.\textsuperscript{26} However, the use of a CBCT unit that would allow the mA level and AR mode to be varied without changing the other acquisition parameters was necessary. Thus, it was possible to evaluate several study factors (implant material, cortical plate, mA level, and metal artifact reduction effectiveness) without the biased interference of other technical parameters. However, future studies are recommended to compare different CBCT units for the detection of peri-implant bone defects, as long as the energetic parameters are standardized among units.

**CONCLUSIONS**

For the OP300 Maxio CBCT unit, the milliamperage and AR tool did not affect the diagnosis of peri-implant dehiscences, regardless of whether the buccal or lingual cortical plate of the mandible were involved. Dehiscences were more detectable when next to zirconia implants, while the absence of dehiscence was more correctly visualized when adjacent to titanium-zirconia implants. It is recommended to use lower milliamperage (5 mA) to avoid exposing the patient to higher radiation doses without diagnosis benefits.
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REFERENCES