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THE IMPACT OF METAL ARTIFACTS ON IMAGE QUALITY IN CBCT SECTIONS

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ABSTRACT
For a successful rehabilitation by dental implant, both preoperative surgical planning and postoperative evaluation are important. Cone beam computed tomography (CBCT) is recommended by many oral radiology guidelines as a preoperative examination for dental implant planning, while other guidelines recommend the use of this type of investigation only in situations where there are clinical uncertainties regarding the shape of the bone or the anatomical boundaries. The aim of this study is to quantify the formation of metal artifacts in CBCT sections produced by titanium dental implants inserted in different maxillary or mandibular regions, the influence of implant position at field of view (FOV) and the impact on CBCT image quality. The CBCT images used in this study were selected from the documentation of a private practice in Bucharest and the retrospective study was in accordance with the Helsinki Declaration of 1975. A total of 80 titanium dental implants were evaluated. Comparison of mandibular and maxillary metal artifacts using the Mann-Whitney test showed that there was no significant difference in the number of artifacts. When evaluating the number of artifacts related to implants inserted in the anterior and posterior regions, implants in the frontal region showed significantly more artifacts in all images. Implants placed alone or in the vicinity of other implants did not cause a significant difference in comparison ($P > 0.05$), nor did the evaluation of implants located centrally or peripherally in FOV. Kruskal-Wallis and Tukey tests revealed a statistically significantly greater difference in artifacts observed in cervical images compared to apical or middle images. Early detection of bone changes around the implant can prevent redundant, unnecessarily extended treatment and can reduce the risk of complications related to implant loss. It is essential to develop research that associates the number of artifacts with diagnostic accuracy until the actual level of interference of these unwanted images with clinical dental practice is found, as the need to improve resolution, including CNR, must be assessed in relation to increasing patient exposure to radiation.

KEYWORDS: dental implant, artifacts, cone beam computed tomography (CBCT), Mann-Whitney test, Tukey test.

INTRODUCTION
For a successful rehabilitation by dental implant, both preoperative surgical planning and postoperative evaluation are important. Cone beam computed tomography (CBCT) is recommended by many oral radiology guidelines as a preoperative examination for dental implant planning, while other guidelines recommend the use of this type of investigation only in situations where there are clinical uncertainties regarding the shape of the bone or the anatomical boundaries.[1-3] CBCT is not part of the routine protocol for postoperative implant examinations due to inherent limitations in imaging process, with appearance/ occurrence of artifacts that may prevent or hinder the proper diagnosis and / or analysis of the peri-implant area.[4–6] The purpose of CBCT examinations is always to overcome the disadvantages of intraoral radiography, a two-dimensional examination with diagnostic limitations due to overlaps and geometric distortions, but if the artifacts are very strong, then the image may become unusable and this may require repetition of the examination, which is against the principles of radiation protection (ALARA- as low as reasonably achievable).[2, 7]

Artifacts are always present in CBCT images, among which are those caused by the presence of materials with high atomic number or high density structures, such as the constituent materials of dental implants.[5,6,8] Dental implants included in the scanned region of examinations performed for other purposes may compromise image quality. In general, there is no evidence of a significant improvement in the use of high-dose scanning protocols based on the adjustment of exposure parameters, as CBCT has a limited range of value changes, plus radiation dose increases, as well as the use of metal artifact reduction (MAR) algorithms does not significantly correct modified gray values in the vicinity of implants.[9]

Recent studies have found that adjusting image settings in CBCT imaging has an influence on the detectability of peri-implant bone defects.[10] In particular, different combinations of pre-image settings ("Filters") allowed optimizing the visibility of periimplant bone dehiscences. It should be emphasized that there are currently no guidelines for the standardized setting of CBCT imaging (for example window level and width) for assessing bone around dental implants but only recommendations not to limit the assessment to a 2D cross-section and to analyze the volume in the whole region of interest.[11]

Some studies suggest the influence of the anatomical region or position of the object within the field of view (FOV) and the proximity of anatomical structures outside the FOV in the formation of metal artifacts, but there is no agreement as to which regions are more involved in the formation of artifacts or what are the effects of the location of the object within the FOV.[6,12,13]

The aim of this study is to quantify the formation of metal artifacts in CBCT sections produced by titanium dental implants inserted in different maxillary or mandibular regions, the influence of implant position at FOV and the impact on CBCT image quality.

MATERIALS AND METHODS

The CBCT images used in this study were selected from the documentation of a private practice in Bucharest and the retrospective study was in accordance with the Helsinki Declaration of 1975, revised in 2000. All images were purchased with the same scanner - Morita Veraviewepocs 3De (J. Morita, Kyoto, Japan), with an acquisition protocol of 80kV, 5mA, 9.4sec rotation, 0.25mm voxel, FOV 4X4, WL and WW automatic settings, with the axes modified so that the image becomes clear. We included CBCT examinations of patients of both sexes and of any age performed over a period of 2 years, who had titanium dental implants with prosthetic restorations. Acquisitions with movement artefacts, with implants without prosthetic work and in the vicinity of teeth with large fillings with increased radiopacity, metal crowns or reconstructions that extended beyond the crown to the root and FOV other than 4X4 were excluded. Implants were subsequently classified according to position in FOV, central or peripheral and isolated or adjacent to other implants (maximum distance of 5 mm).

For each selected case, three axial reconstructions were chosen, one in the cervical third, one in the middle third and the last in the apical third, perpendicular to the center of the implant. The cervical image was considered the most cervical that allowed the visualization of the entire diameter of the implant before the prosthetic construction, the apical image being the most apical area that allowed the visualization of the entire diameter of the implant, and the middle third image was selected halfway between the apical and cervical images (Fig. 1).

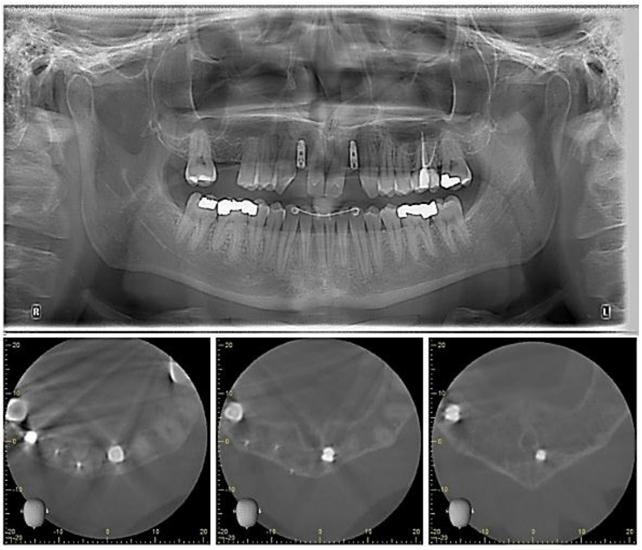

Figure 1: CBCT and the three axial reconstructions.

After selecting the examinations, the axial images were exported as uncompressed multi-file images in Digital Imaging and Communications in Medicine (DICOM) format from the proprietary software (iDixel image processing software, J. Morita USA, Inc., Irvine, USA) and imported into the Image J software (National Institutes of Health, Bethesda, MD, USA) for analysis. For each image, two regions of interest (ROI) were selected and the average gray value and standard deviation were obtained. A first region of interest was used in the axial visualization of the implant, with standardized dimensions of 10 mm in diameter. This ROI covered the entire implant, except for the metal itself, because in some cases the voxel values were more saturated well outside the metal area, and in other cases unsaturated voxel values were found in the center of the metal (Fig. 2). Metal removal from the selection was done manually, as no standardized segmentation method was available. The second region of interest, the control region, was selected at the edge of the volume where the artifact is minimal (Fig. 2).[11]

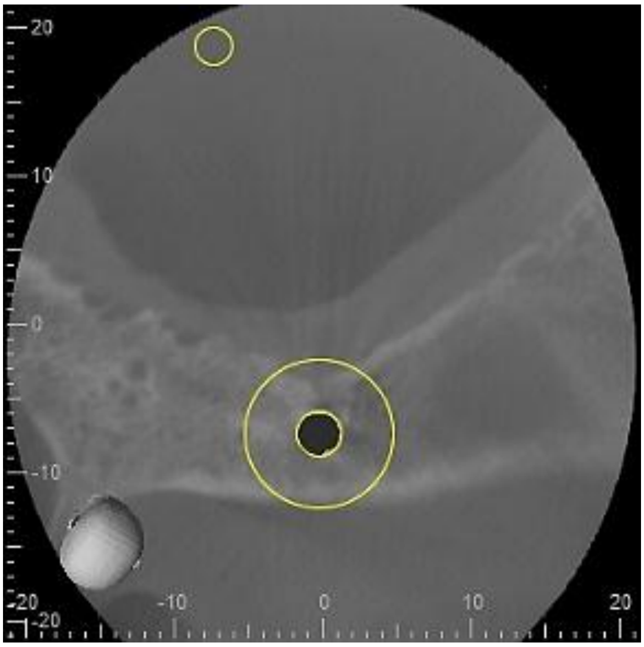

Figure 2: The regions of interest.

Among the parameters used to control the image quality of CBCT devices are: uniformity, voxel density values, geometry evaluation, noise, low contrast resolution and spatial (high contrast) resolution.[11] Low contrast resolution is the ability to distinguish a signal against its background when the value of the signal is similar to the value of the background. This ability can be quantified by measuring the contrast-to-noise ratio (CNR), which is considered more closely related to image quality than image noise.[14] In this study CNR was calculated using the formula:

$$CNR = \frac{|Mean_{Im\ plant} - Mean_{Control}|}{\sqrt{SD^2_{Im\ plant} + SD^2_{Control}}}$$

where "mean" is the mean gray value in the region of interest and SD is the standard deviation of the gray value in the same area.[15,16,17] CNR is very dependent on local contrast. As the CNR is increased, the objects are visualized more easily in relation to the background, and when the CNR is reduced, the detectability of the objects decreases.[11,15,16,17]

Statistical analysis

The contrast-to-noise ratio of the images with titanium implants was analyzed and the significance level adopted was 5% ($p \leq 0.05$). Before performing the analysis, the grouped independent variables were analyzed to determine normality, using the Kolmogorov-Smirnov test, for the normally distributed data a variance analysis (ANOVA) and the Mann - Whitney test were performed, and for comparing the data corresponding to the cervical, middle and apical images, Kruskal- Wallis and Tukey tests.

RESULTS

A total of 80 titanium dental implants were evaluated, divided into groups according to their anatomical location, proximity to other implants and position within the FOV (Table 1). The evaluated implants were between 8 and 13 mm in length and between 3.3 and 4.8 mm in diameter. Figure 3 shows various axial reconstructions of the implants.

Table 1 - Evaluated titanium dental implants.

Anatomical region	Isolated implants	Adjacent implants	Total	Anatomical region	Central in FOV	Peripheral in FOV	Total
Maxillary frontal	11	9	**20**	Maxillary frontal	13	7	**20**
Maxillary lateral	6	14	**20**	Maxillary lateral	10	10	**20**
Mandibular frontal	8	12	**20**	Mandibular frontal	10	10	**20**
Mandibular lateral	7	13	**20**	Mandibular lateral	13	7	**20**
Total	**32**	**48**	**80**	**Total**	**46**	**34**	**80**

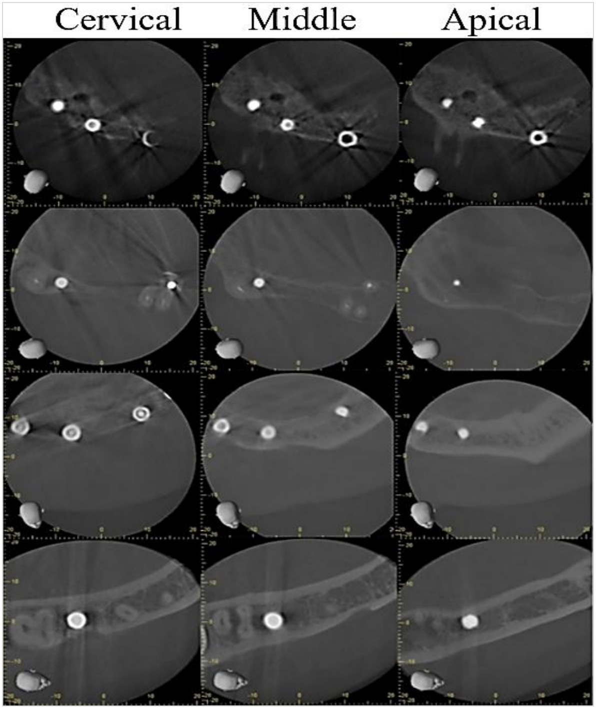

Figure 3: Various axial reconstructions of the implants.

Comparison of mandibular and maxillary metal artifacts using the Mann-Whitney test showed that there was no significant difference in the number of artifacts, $P > 0.05$ (Table 2).

Table 2- Comparison of mandibular and maxillary metal artifacts according to the Mann-Whitney test.

Section		Median	p
Cervical	maxillary	0.675	0.08
	mandibular	0.531	
Middle	maxillary	0.661	0.12
	mandibular	0.709	
Apical	maxillary	0.622	0.22
	mandibular	0.696	

When evaluating the number of artifacts related to implants inserted in the anterior and posterior regions, implants in the frontal region showed significantly more artifacts in all images (Table 3).

Table 3 - Comparison of anterior and posterior metal artifacts according to the Mann-Whitney test.

Section		Median	p
Cervical	frontal	0.681	0.009*
	lateral	0.525	
Middle	frontal	0.739	0.01*
	lateral	0.665	
Apical	frontal	0.825	<0.0001*
	lateral	0.538	

Implants placed alone or in the vicinity of other implants (Fig. 4) did not cause a significant difference in comparison (P > 0.05), nor did the evaluation of implants located centrally or peripherally in FOV (Fig. 5).

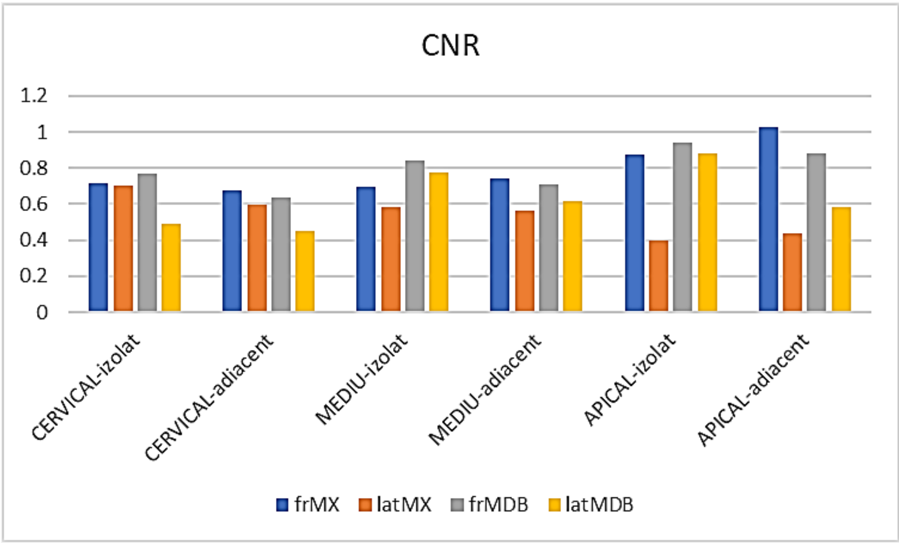

Figure 4: Contrast-to-noise ratio of the images with implants placed alone or in the vicinity of other implants.

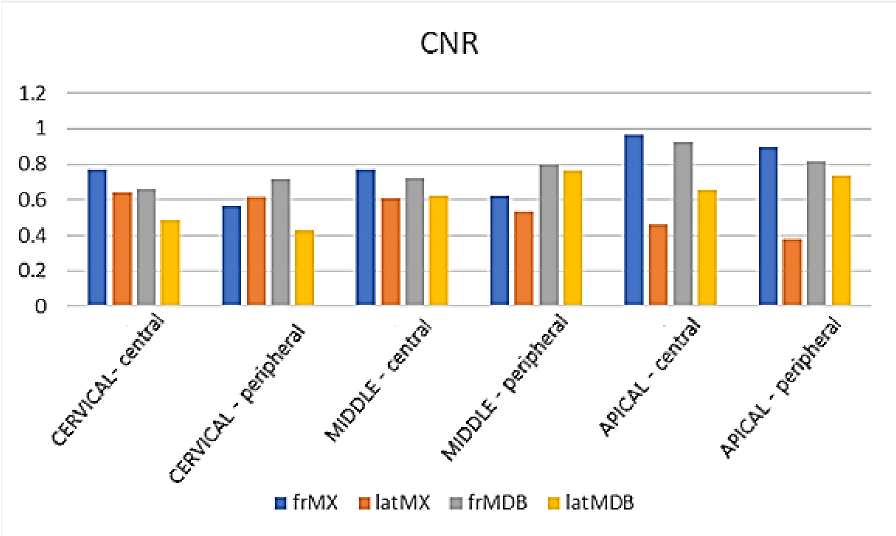

Figure 5: Contrast-to-noise ratio of the images with implants located centrally or peripherally in FOV.

Kruskal-Wallis and Tukey tests revealed a statistically significantly greater difference in artifacts observed in cervical images compared to apical or middle images (Table 4).

Table 4 - Comparison of metal artifacts in the cervical, middle and apical sections.

Compared section		**H**	**p**
Cervical- Middle	maxillary	4.85	0.18
	mandibular	23.12	<0.0001*
	frontal	1.27	0.73
	lateral	15.76	0.0012*
	isolated	13.28	0.06
	adjacent	15.59	0.02*
	central in FOV	20.3	0.0049*
	peripheral in FOV	17.51	0.01*
Cervical- Apical	maxillary	30.18	<0.0001*
	mandibular	21.62	<0.0001*
	frontal	9.31	0.025*
	lateral	19.27	0.00024*

	isolated	24	<0.0001*
	adjacent	29.32	0.00012*
	central in FOV	34.179	<0.0001*
	peripheral in FOV	22.62	0.0019*
Apical- Middle	maxillary	39.08	<0.0001*
	mandibular	5.07	0.11
	frontal	6.46	0.09
	lateral	13.84	0.003*
	isolated	21.83	0.002*
	adjacent	52.341	<0.0001*
	central in FOV	28.16	0.0002*
	peripheral in FOV	21.27	0.0033*

DISCUSSION

Early detection of bone changes around the implant can prevent redundant, unnecessarily extended treatment and can reduce the risk of complications related to implant loss. Therefore, optimal image quality in CBCT is one of the desired properties. The X-ray beam is composed of individual photons with a wide range of energies.[8] As the beam passes through an object, it becomes "heavier", meaning the average energy increases, because the lower energy photons are absorbed faster than the higher energy photons.[4,8] Highly absorbent materials, such as metal, function as a filter positioned inside the object, generating beam-strengthening artifacts that are influenced by the density of the object.[4,8] If the emitted spectrum contains several relatively smaller rays than those recorded on the detector, namely the beam is hardened, a nonlinear error will be recorded in the path of the beam behind the high absorption materials and will be induced in the recorded data.[8] In 3D reconstruction, the error is projected back in volume, resulting in either light streaks radiating from metal objects, or blackening of adjacent areas or even complete loss of gray value, causing CNR reduction by decreasing contrast and reducing the clarity of areas of interest investigated.[18,19] In general, a lesion-background contrast is related to CNR, which is one of the main factors influencing image quality in CBCT. CNR was considered to be more closely related to image quality than image noise.[11,15,16,17]

The acquisition protocol used in this study was selected according to the manufacturer's recommendations as the optimal exposure setting for an average adult patient, although it is known that exposure parameters should ideally consider both patient characteristics and indications related to specific diagnostic tasks to achieve dose reduction to satisfactory image quality.[20,21] The acceptable noise level for CBCT dedicated to dental devices is normally higher than in conventional CT, because the high contrast between the studied tissues (teeth, bones and soft tissue) cancels out the effect of high noise.[22] Similar to previous studies the objective evaluation of artifact production in CBCT images was performed by calculating gray and CNR values.[5,13,15,23,24] SD values generally allow an overall estimate of dark stretch and brightness caused by high-density materials, measured by varying gray values, a higher SD value, or a greater variation indicating higher artifact production. The evaluation of CNR in this study was made after selecting another region of interest located at the edge of the volume, where the artifact was minimal, similar to studies of other authors.

In Machado's study the number of artifacts was higher in the mandible and in the anterior regions, showing that the gray values of the object vary depending on its location and adjacent anatomical structures.[6] Variations in the density and thickness of maxillary and mandibular bone tissue may explain the difference in the number of artifacts, which is consistent with Oliveira's findings, which evaluated the effect of anatomical localization on gray values in CBCT images and showed that the same object can have different values depending on the anatomical location.[13] In this study, implants in the frontal region showed significantly more artifacts in all images, similar to previous studies, but when comparing mandibular and maxillary metal artifacts no significant difference was found in the number of artifacts, possibly due to insufficient data analyzed or to the use of a small 4X4 FOV, so that the effect of the exomass, meaning the entire craniofacial area located inside and outside the FOV affects more or less the measurements of the gray value in the jaw and mandible.[7]

Artifacts, scattering radiation and noise in CBCT systems are not evenly spread across FOVs.[25] The current study was conducted to evaluate the effect of implant position in the field of view of CBCT on CNR. According to Valizadeh's study, depending on the location in the FOV, the sensitivity of the central position was significantly higher than that of the other positions, and the specificity was significantly higher at the 3 o'clock position.[26] Queiroz, which evaluates the effect of an instrument reduction of metal artifacts when the generating object was placed in different positions within the FOV, also noticed that the noise levels were different depending on the changes of position.[27] According to this study, the implants positioned centrally or peripherally in the FOV did not determine a significant difference in comparison.

In this study, a higher number of artifacts was observed in the cervical third of the dental implant, similar to Machado's study, probably only due to the presence of prosthetic work, as when comparing the number of artifacts around isolated implants with those around the adjacent implants no significant difference was observed neither in cervical, middle or apical positions.[6] One possible explanation is related to the use of a small ROI, so that the effect of adjacent implants was minimized in the middle and apical thirds. The prosthetic work seems to be the one that generates the dramatic decrease of CNR in the cervical area, its constituent metals being chromium, cobalt or zirconia alloys, which have higher atomic number than titanium from the structure of the implants in the images analyzed in this study, generating a larger X-ray absorption and beam strengthening.[22-24,27,28,40]

Image quality, seen as the contrast-to-noise ratio (CNR), can be improved by changing parameters during the scanning procedure such as visual field of view, electric current (mAs), tube voltage (kVp), exposure time, use MAR, voxel size and number of basic images.[11,15,16,23] It is also necessary to evaluate the other parameters used to control the image quality of CBCT devices.

This study has some limitations. The first limitation is related to the limited sample. Further research is also needed regarding the use of different types of scanners available on the market with an assessment of the influence of different settings recommended by manufacturers.

Therefore, it is necessary to develop future studies that take these variables into account when evaluating artifacts generated by implants. Moreover, it is essential to develop research that associates the number of artifacts with diagnostic accuracy until the actual level of interference of these unwanted images with clinical dental practice is found, as the need to improve resolution, including CNR, must be assessed in relation to increasing patient exposure to radiation.

CONCLUSION

Early detection of bone changes around the implant can prevent redundant, unnecessarily extended treatments and can reduce the risk of complications related to implant loss.

Comparison of mandibular and maxillary metal artifacts using the Mann-Whitney test showed that there was no significant difference in the number of artifacts.

When evaluating the number of artifacts related to implants inserted in the anterior and posterior regions, implants in the frontal region showed significantly more artifacts in all images.

Implants placed alone or in the vicinity of other implants did not cause a significant difference in comparison, nor did the evaluation of implants located centrally or peripherally in FOV.

Kruskal-Wallis and Tukey tests revealed a statistically significantly greater difference in artifacts observed in cervical images compared to apical or middle images.

It is essential to develop future research that associates the number of artifacts with diagnostic accuracy until the actual level of interference of these unwanted images with clinical dental practice is found, as the need to improve resolution, including CNR, must be assessed in relation to increasing patient exposure to radiation.

Authors' contributions

All authors contributed equally with the first-author, in the preparing, review and editing of the article. All authors read and approved the final version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

1. Tyndall DA, Price JB, Tetradis S, Ganz SD, Hildebolt C, Scarfe WC. Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol, 2012; 113(6): 817-826. doi:10.1016/j.oooo.2012.03.005.
2. European Commission. Radiation Protection 172, “Evidence Based Guidelines on Cone Beam CT for Dental and Maxillofacial Radiology. Luxembourg” Office for Official Publications of the European Communities: 2012. Available from: http://ec.europa.eu/energy/nuclear/radiation.protection/doc/publication/172.pdf.
3. Harris D, Horner K, Gröndahl K, Jacobs R, Helmrot E, Benic GI, Bornstein MM, Dawood A, Quirynen M. E.A.O. guidelines for the use of diagnostic imaging in implant dentistry 2011. A consensus workshop organized by the European Association for Osseointegration at the Medical University of Warsaw. Clin Oral Implants Res., 2012; 23(11): 1243-1253. doi:10.1111/j.1600-0501.2012.02441.x
4. Scarfe WC, Farman AG. What is cone-beam CT and how does it work?. Dent Clin North Am., 2008; 52(4): 707-v. doi:10.1016/j.cden.2008.05.005.
5. Vasconcelos TV, Bechara BB, McMahan CA, Freitas DQ, Noujeim M. Evaluation of artifacts generated by zirconium implants in cone-beam computed tomography images. Oral Surg Oral Med Oral Pathol Oral Radiol, 2017; 123(2): 265-272. doi:10.1016/j.oooo.2016.10.021.
6. Machado AH, Fardim KAC, de Souza CF, Sotto-Maior BS, Assis NMSP, Devito KL. Effect of anatomical region on the formation of metal artefacts produced by dental implants in cone beam computed tomographic images. Dentomaxillofac

Radiol, 2018; 47(3): 20170281. doi:10.1259/dmfr.20170281.
7. Benic GI, Sancho-Puchades M, Jung RE, Deyhle H, Hämmerle CH. In vitro assessment of artifacts induced by titanium dental implants in cone beam computed tomography. Clin Oral Implants Res., 2013; 24(4): 378-383. doi:10.1111/clr.12048.
8. Schulze R, Heil U, Gross D, Bruellmann DD, Dranischnikow E, Schwanecke U, Schoemer E. Artefacts in CBCT: a review. Dentomaxillofac Radiol, 2011; 40(5): 265-273. doi:10.1259/dmfr/30642039.
9. Parsa A, Ibrahim N, Hassan B, Syriopoulos K, van der Stelt P. Assessment of metal artefact reduction around dental titanium implants in cone beam CT. Dentomaxillofac Radiol, 2014; 43(7): 20140019. doi:10.1259/dmfr.20140019.
10. de-Azevedo-Vaz SL, Alencar PN, Rovaris K, Campos PS, Haiter-Neto F. Enhancement cone beam computed tomography filters improve in vitro periimplant dehiscence detection. Oral Surg Oral Med Oral Pathol Oral Radiol, 2013; 116(5): 633-639. doi:10.1016/j.oooo.2013.06.029.
11. de Las Heras Gala H, Torresin A, Dasu A, Rampado O, Delis H, Hernández Girón I, Theodorakou C, Andersson J, Holroyd J, Nilsson M, Edyvean S, Gershan V, Hadid-Beurrier L, Hoog C, Delpon G, Sancho Kolster I, Peterlin P, Garayoa Roca J, Caprile P, Zervides C. Quality control in cone-beam computed tomography (CBCT) EFOMP-ESTRO-IAEA protocol (summary report). Phys Med., 2017; 39: 67-72. doi:10.1016/j.ejmp.2017.05.069.
12. Valizadeh S, Vasegh Z, Rezapanah S, Safi Y, Khaeazifard MJ. Effect of Object Position in Cone Beam Computed Tomography Field of View for Detection of Root Fractures in Teeth with Intra-Canal Posts. Iran J Radiol, 2015; 12(4): e25272. doi:10.5812/iranjradiol.25272.
13. Oliveira ML, Tosoni GM, Lindsey DH, Mendoza K, Tetradis S, Mallya SM. Influence of anatomical location on CT numbers in cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol, 2013; 115(4): 558-564. doi:10.1016/j.oooo.2013.01.021.
14. Grech L, Mallia B, Camilleri J. Investigation of the physical properties of tricalcium silicate cement-based root-end filling materials. Dent Mater, 2013; 29(2): e20-e28. doi:10.1016/j.dental.2012.11.007.
15. Bechara B, McMahan CA, Moore WS, Noujeim M, Geha H, Teixeira FB. Contrast-to-noise ratio difference in small field of view cone beam computed tomography machines. J Oral Sci., 2012; 54(3): 227-232. doi:10.2334/josnusd.54.227.
16. Bechara BB, Moore WS, McMahan CA, Noujeim M. Metal artefact reduction with cone beam CT: an in vitro study. Dentomaxillofac Radiol, 2012; 41(3): 248-253. doi:10.1259/dmfr/80899839.
17. Bechara B, McMahan CA, Geha H, Noujeim M. Evaluation of a cone beam CT artefact reduction algorithm. Dentomaxillofac Radiol, 2012; 41(5): 422-428. doi:10.1259/dmfr/43691321.
18. Demirturk Kocasarac H, Helvacioglu Yigit D, Bechara B, Sinanoglu A, Noujeim M. Contrast-to-noise ratio with different settings in a CBCT machine in presence of different root-end filling materials: an in vitro study. Dentomaxillofac Radiol, 2016; 45(5): 20160012. doi:10.1259/dmfr.20160012.
19. Katkar R, Steffy DD, Noujeim M, Deahl ST 2nd, Geha H. The effect of milliamperage, number of basis images, and export slice thickness on contrast-to-noise ratio and detection of mandibular canal on cone beam computed tomography scans: an in vitro study. Oral Surg Oral Med Oral Pathol Oral Radiol, 2016; 122(5): 646-653. doi:10.1016/j.oooo.2016.08.006.
20. Bushberg JT. Eleventh annual Warren K. Sinclair keynote address-science, radiation protection and NCRP: building on the past, looking to the future. Health Phys., 2015; 108(2): 115-123. doi:10.1097/HP.0000000000000228.
21. Oenning AC, Jacobs R, Pauwels R, Stratis A, Hedesiu M, Salmon B. Cone-beam CT in paediatric dentistry: DIMITRA project position statement. Pediatr Radiol, 2018; 48(3): 308-316. doi:10.1007/s00247-017-4012-4019.
22. Demehri S, Muhit A, Zbijewski W, Stayman JW, Yorkston J, Packard N, Senn R, Yang D, Foos D, Thawait GK, Fayad LM, Chhabra A, Carrino JA, Siewerdsen JH. Assessment of image quality in soft tissue and bone visualization tasks for a dedicated extremity cone-beam CT system. Eur Radiol, 2015; 25(6): 1742-1751. doi:10.1007/s00330-014-3546-6.
23. Pauwels R, Stamatakis H, Bosmans H, Bogaerts R, Jacobs R, Horner K, Tsiklakis K. Quantification of metal artifacts on cone beam computed tomography images. Clin Oral Implants Res., 2013; 24 Suppl A100: 94-99. doi:10.1111/j.1600-0501.2011.02382.x.
24. Kursun-Cakmak EŞ, Demirturk Kocasarac H, Bayrak S, Ustaoğlu G, Noujeim M. Estimation of contrast-to-noise ratio in CT and CBCT images with varying scan settings in presence of different implant materials. Dentomaxillofac Radiol, 2019; 48(8): 20190139. doi:10.1259/dmfr.20190139.
25. Parsa A, Ibrahim N, Hassan B, van der Stelt P, Wismeijer D. Influence of object location in cone beam computed tomography (NewTom 5G and 3D Accuitomo 170) on gray value measurements at an implant site. Oral Radiology, 2014; 30(2): 153–159. doi: 10.1007/s11282-013-0157-x.
26. Valizadeh S, Vasegh Z, Rezapanah S, Safi Y, Khaeazifard MJ. Effect of Object Position in Cone Beam Computed Tomography Field of View for Detection of Root Fractures in Teeth with Intra-Canal Posts. Iran J Radiol, 2015; 12(4): e25272. doi:10.5812/iranjradiol.25272.
27. Queiroz PM, Santaella GM, da Paz TD, Freitas DQ. Evaluation of a metal artefact reduction tool on

different positions of a metal object in the FOV. Dentomaxillofac Radiol, 2017; 46(3): 20160366. doi:10.1259/dmfr.20160366.

28. Kuusisto N, Vallittu PK, Lassila LV, Huumonen S. Evaluation of intensity of artefacts in CBCT by radio-opacity of composite simulation models of implants in vitro. Dentomaxillofac Radiol, 2015; 44(2): 20140157. doi:10.1259/dmfr.20140157.