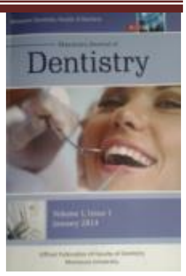
Mansoura Journal of Dentistry 2020;7(27):50-55.



Effect of Variant Milliampere Setting on Appearance of Metal Artifacts in Cone Beam Computed Tomography

Eslam Mohamed Elsaid Elmetwally Mowafy Prof.Dr. Hany Mahmoud Omar, Dr.Bassant Hamdy Mohamed Mowafy
Master's degree student, Department of Oral Diagnosis and Radiology, Faculty of Dentistry, Mansoura University, Egypt
Professor of Oral and Maxillofacial Radiology, Faculty of Dentistry, Cairo University, Egypt
Lecturer of Oral Diagnosis and Radiology, Faculty of Dentistry, Mansoura University, Egypt

Abstract:
Objective: This study aimed to evaluate the effect of variant milliampere setting on appearance of metal artifacts in Cone Beam Computed Tomography.
Methods: A dry human mandible with three titanium implants in anterior, premolar, and molar areas was scanned by CRANEX 3Dx CBCT unit utilizing variant mA setting, then, gray values were derived to detect metal artifacts in two different trials.

Results: In our study, both trials (trial I, trial II) showed insignificant difference as P-value > 0.05, gray values in different areas of the jaw (anterior, premolar, molar areas) showed that the amount of metal artifacts was generally insignificantly different when varying mA setting except few conditions, and there was significant difference between anterior area and posterior area (premolar, molar).
Conclusions: Our results revealed that metal artifacts exist constantly around dental implant in CBCT images and the anatomical region determine the amount of artifacts, which increased anteriorly more than posteriorly. Our findings revealed that there's no obvious difference by increasing mA setting, however, from interpretation of gray values, S2 exposure setting (8mA, 90 kVp and 2.3s with 6x8cm field of view) in anterior area, H4 exposure setting (10mA, 90 kVp and 6.1s with 6x8cm field of view) in premolar and molar areas have the least mean gray value, and thereafter less amount of metal artifacts.
Keywords: Cone-Beam Computed Tomography, Titanium implants, Metal artifacts, Gray value.

Introduction

With presentation of cone-beam computed tomography (CBCT) to the dental field as a beneficial scanning modality, this modality is widely utilized as it can allow three dimensional (3D), high resolution precise datum of hard tissues with a comparatively low radiation dose.1 It promotes diagnosis, treatment planning and follow up of patients in different dental fields involving implantology, surgery, orthodontics and endodontics.2-8

Numerous factors like field of view, X-ray beam quantity and quality, rotation arc and pixel size affect the diagnostic quality and image characteristics of CBCT image that may involve contrast resolution, artifacts and noise.1,9 Metal artifact is among the factors disintegrating image quality. Artifacts are doubtful, specifically in the dentoalveolar region due to metallic objects such as metallic restorative materials, cores, posts, and dental implants. These artifacts are presented as metal has high density, which is beyond the normal range that a computer can measure.

Since metals severely attenuate X-ray beams, beam attenuation in structures close to the metallic structures is not registered well. Due to image reconstruction techniques in 3D modalities like computed tomography (CT) and CBCT, presence of metal in scanned areas may result in production of dark and light bands that considerably decrease image quality.10

Fan-shaped beams in multi-detector computed tomography produce streak artifacts in the gantry path horizontally. But, the cone-shaped beams in CBCT result in artifacts in all dimensions around the metallic objects.10,11 As one purpose in usage of CBCT is precise measurement and notice of details of the anatomical structures, assessment of methods that can decrease metal artifacts is significantly important. There have been studies in this status; but, majority of these studies have concerned with utilization of artifact-reducing algorithms.12-15 Although these types of software programs would remove streaks away from the metallic object, the details around the metal-tissue interface, that might be the primary region of interest (ROI), remain probably not visible to the clinicians.16 Among the believed effective factors in image quality, exposure parameters are adjustable in some CBCT devices. Regardless of this, solely a few studies have concerned the effect of exposure parameters on metallic artifacts.11,17,18 Therefore, this study aimed to evaluate the effect of variant milliampere setting on appearance of metal artifacts in cone beam computed tomography.

Materials and Methods

Study model

This study has done on a dry human mandible, which obtained from Anatomy Department, Faculty of Medicine, Mansoura University. The permission of usage that human study model was allowed by the Committee of Research Ethics of Mansoura University under protocol no.18060318.

Three parallel Neo Biotech implants with 3.5 mm diameter and 10mm height were placed in the mandible. The anterior implant was drilled at the canine site, the middle implant was created at the second premolar site, and the posterior implant was created at the distal root of the first molar site. The distance from the anterior and posterior implants to the middle implant was the same. In order to simulate the beam attenuation effect of soft tissue, the bone surface was covered with layers of soft base plate wax with a total thickness of 15mm.

Exposure setting/Radiographic evaluation

Implants were placed and the mandible was scanned by the CRANEX 3Dx unit (Soredex, Tuusula, Finland) with different milliampere)mA(settings :

Standard Resolution

(S) exposure setting was at 5mA, 90 kVp and 2.3s with 6x8cm field of view, (S1) at 6.3mA , 90 kVp and 2.3s with 6x8cm field of view, (S2) at 8mA , 90 kVp and 2.3s with 6x8cm field of view, (S3) at 10mA, 90 kVp and 2.3s with 6x8cm field of view, (S4) at 12.5mA , 90 kVp and 2.3s with 6x8cm field of view.

High Resolution

(H) exposure setting was at 4mA, 90 kVp and 6.1s with 6x8cm field of view, (H1) at 5mA, 90 kVp and 6.1s with 6x8cm field of view, (H2) at 6.3mA, 90 kVp and 6.1s with 6x8cm field of view, (H3) at 8mA, 90 kVp and 6.1s with 6x8cm field of view, and (H4) at 10mA, 90 kVp and 6.1s with 6x8cm field of view.

The study model was settled on the supporting surface as supplied by the instructions of manufacture for scanning, permitting parallelism of the occlusal plane with the horizontal plane and the lower mandible border with the floor, and positioning in the field of view (FOV) centrally utilizing the laser beam directions to be identical in all scans.

Image acquisitions

Reconstruction and assessment of all CBCT scans was done by the Dental OnDemand3D software (Cybermed, Seoul, Korea). The traced arch for every scan had to be modified primarily to obtain an accurate image for every implant, in addition to cross-sections passed throughout the middle of study model were right to them.

Axial reconstructions upright to the longitudinal axis of the implant were utilized for data analysis. The determined axis area and the implant axis were the same. The region of interest (ROI) was entirely within the bone and in the immediate approach of each implant, so that the body of implant was utilized as a guide to determine region of interest in aim of having identical ROIs around the implants as possible.

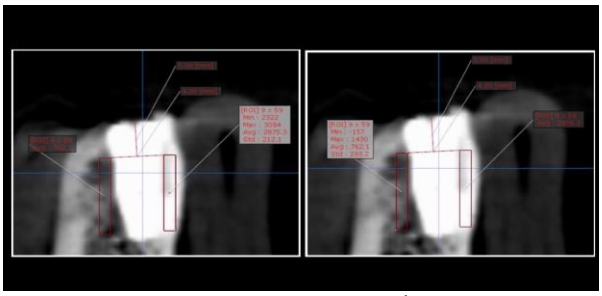
While probing the region of interest, a distance of 0.5 mm away from the implant has to be taken to assure the accuracy of results, because some implants have severe metal artifacts. The region of interest (ROI) was detected at 1mm thickness around the probe axially, a 7mm in the longitudinal axis of the implant, and apically to the implant shoulder in the buccal and lingual directions.

X.ray attenuation during scanning mentioned by gray value (GV), which considered as a reference or index for metal artifact assessment. Gray values were measured in buccal and lingual surfaces of study model in anterior, premolar and molar regions. The software allowed one mean GV for each ROI, and each gray value has mean and standard deviations, minimum and maximum values. This index allows an overall evaluation of the extent of darkening and brightening produced by metals.

The measurements of gray values were recorded twice (Trial 1, TrialI) by two observers to avoid eye fatigue, faulty readings and to assess the reproducibility by evaluation of the inter-observer and intra-observer agreements.

Statistical analysis

Data were statistically analyzed by Microsoft Excel®2016, Statistical Package for Social Science (SPSS)®Ver.24, and Minitab® statistical software Ver.16. Descriptive study between trial (I) and trial (II) was performed using mean ± standard deviation, minimum and maximum gray values for anterior, premolar and molar areas from buccal and lingual directions. For further comparative study for each area, independent t test was performed to reveal the level of significance between both trials which calculated at $P \leq 0.05$. Additionally, One Way ANOVA and Tukey's Post Hoc tests were used to reveal the significant difference between different exposures. Inter-observer agreement (reliability) was also performed to detect the reliability level between both trials for each exposure.



a. b.

Figure1. Gray value of an area of interest with 1-mm thickness axially, a 7mm in the implant longitudinal axis, and apically to the implant shoulder (a) Lingual , (b) labial

Table1 Variant Milliampere Setting Efficiency and Reliability of Appearance of Metal Artifact in Cone Beam Computed Tomography (Labial/Buccal Standard Resolution).

	Exposure	mA	kVp	Timing (Seconds)	Field of View	Tukey`s Post Hoc	Trial (I)	Trial (II)	P-value	IOC
Labial (Anterior area)	S	5	90	2.3	6x8 cm	A			>0.5*	0.837
	S1	6.3	90	2.3	6x8 cm	A			>0.5*	0.884
	S2	8	90	2.3	6x8 cm	B			>0.5*	0.95
	S3	10	90	2.3	6x8 cm	A			>0.5*	0.807
	S4	12.5	90	2.3	6x8 cm	C			>0.5*	0.958
Buccal (Premolar area)	S	5	90	2.3	6x8 cm	B			>0.5*	0.469
	S1	6.3	90	2.3	6x8 cm	D			>0.5*	0.95
	S2	8	90	2.3	6x8 cm	D			>0.5*	0.704
	S3	10	90	2.3	6x8 cm	D			>0.5*	0.95
	S4	12.5	90	2.3	6x8 cm	D			>0.5*	0.95
Buccal (Molar area)	S	5	90	2.3	6x8 cm	D			>0.5*	0.95
	S1	6.3	90	2.3	6x8 cm	D			>0.5*	0.948
	S2	8	90	2.3	6x8 cm	D			>0.5*	0.597
	S3	10	90	2.3	6x8 cm	D			>0.5*	0.95
	S4	12.5	90	2.3	6x8 cm	D			>0.5*	0.597
P-value (One Way ANOVA)							0.00**	0.00**		

mA; Milliampere, kVp; Kilo Voltage, P; Probability Level, IOC; Inter observer Correlation Coefficient.

_ **significant Difference

_ Same letter regarding Tukey`s post hoc test of multiple comparisons revealed (insignificant difference in the same column).

_ Different letter regarding Tukey`s post hoc test of multiple comparisons revealed (significant difference in the same column).

Discussion

CBCT is commonly utilized in the pre-operative phase of dental implant treatment assessing bone quantity and quality.19,20 But, in the post-operative phase of previously positioned implants, tomographic images reveal metal artifacts, that decreases the desire for CBCT at that phase.

CBCT interpretations are difficult in presence of metal artifacts. Generally, when a polychromatic X-ray beam passes throughout an object, absorption of low energy photons is greater than high energy photons increasing the X.ray beam average energy and then, beam hardening. Beam hardening would be increased in case of less X-ray beam energy, high density, and increased atomic number of the irradiated material.21,22 Thus, artifacts would be more and severe in presence of metal.

In CBCT modality, there are various factors affecting the amount of metallic artifact that produced by dental implant, like field of view (FOV), voltage (KVP), time, milliampere (mA) and system type.

The voltage in all CBCT systems is fixed at 90 to 95 kV in aim of scattered radiation decline. Additionally, the impact of mA and time in producing metallic artifacts is identical in CBCT scans, but the time has to be fixed at the minimum to decrease patient movement artifacts (motion blurs), and the impact of metal artifacts around dental implants is varying because patients have a variability of jawbone density in different locations of the jaw, therefore, in this study, the mA effect has been only evaluated to assess metallic artifact around dental implants that positioned in various areas (anterior, premolar, molar areas).

Furthermore, in all CBCT systems, the field of view is determined according to the desired area ordered by the doctor, the patient's size mA dependent, and the CBCT models, so that, the field of views in this study had set at a midi FOVs (6x8cm) in order to decrease metal artifacts beyond dental implants by decreasing the irradiated size area and therefore, decline of scattered radiation, noise, and image artifacts. This procedure of using midi FOVs to decrease artifacts is harmonious with finding of Parsa et al.23 , who stated that gray values and artifacts would be declined at the site of implant by decreasing the FOV in Accuitomo X-ray device.

In our study, both trials (trial I, trial II) showed insignificant difference as P-value > 0.05 and gray values in different areas of the jaw (anterior, premolar, molar areas) showed that the amount of metal artifacts regarding labial/buccal standard resolution exposures, was generally insignificantly different when varying mA setting buccally in (S1, S2, S3, S4) of premolar area, and (S, S1, S2, S3, S4) of molar area, except gray value of S exposure of premolar showed significant difference, but significantly different from anterior area labially in which there was insignificant difference between (S, S1, and S3) except S2, S4. There was also insignificant difference in gray value between S2 of anterior and S of premolar areas.

Additionally, regarding labial/buccal high resolution exposures, there was generally insignificant difference in gray values when varying mA setting buccally in cases of (H, H1, H2, H3,H4) of premolar and (H, H1, H2, H3) of molar areas except gray value of H4 exposure of molar area showed significant difference, but significantly different from anterior area labially in which there was insignificant difference between (H, H1, H2, H3, H4) except gray value of H exposure showed significant difference.

Regarding lingual standard and high resolution exposures, both trials (trial I, trial II) showed insignificant difference as P-value > 0.05 and gray values showed that the amount of metal artifacts was generally insignificantly different when varying mA setting in all exposures of anterior, premolar, molar areas. P-value of trial (I) was (0.156) and P-value of trial (II) was (0.172) in standard resolution exposures and P-value of trial (I) was (0.267) and P-value of trial (II) was (0.212) in high resolution exposures.

From interpretation of gray values, it was noticed the least mean gray value in anterior area was S2 exposure _8mA, 90 kVp and 2.3s with 6x8cm field of view_ (1782.7) in Trial I and (1794.9) in Trial II. Regarding premolar area, the least mean gray value was H4 exposure _10mA, 90 kVp and 6.1s with 6x8cm field of view_ (794.1) in Trial I and (888.1) in

Trial II, additionally, S4 exposure _12.5mA , 90 kVp and 2.3s with 6x8cm field of view_ did show decreased mean gray

value (953.5) in Trial I and (953.2) in Trial II close to H4 exposure. Finally in molar area, the least mean gray value was seen in H4 exposure _10mA, 90 kVp and 6.1s with 6x8cm field of view_ (595.8) in Trial(I) and Trial(II).

Results of insignificant difference when varying amperage (mA setting) in anterior, premolar and molar areas except few conditions, were due to the narrow range of mA value in CBCT and the variation between the minimum and maximum mA in utilized CRANEX 3Dx CBCT unit in current study was nearly eight variations.

Results of insignificant effect of amperage on metal artifacts were also in coincidence with the findings of Pauwelse et al. 24 of no variation was noticed in metallic artifacts between low and high amperage modes regardless of amperage impact in metal artifacts of lead and titanium rods in 10–180 degree range, in addition to usage of thirteen various CBCT models. Even with a 88% increase in mA, metal artifacts revealed no variation. Pauwels et al, 21 in their review article in 2015 noted that changes in mA affected noise rather than beam hardening.

On the other side, in the study by Kataoka et al, 25 utilizing CT, higher tube currents resulted in metal artifacts decrease. But, have to be known that the range of current intensity utilized in the study by Kataoka et al, 25 was various than that of the current study. In the current study, the variation between the minimum and maximum mA was nearly 8, rather than the study by Kataoka et al, 25 in which, the current intensity ranged from 100 to 500 mA.

Results of significant difference in gray values between anterior and posterior areas (premolar, molar areas) were due to the density of bone, the higher the bone density is, the lower is the amount of photons crossed the bone and then, the amount of photons at the implant declines and X-ray beam scattering decreases and this explained why gray value decreased in premolar and molar areas rather than anterior area. Additional reasons of increased metal artifacts anteriorly were due to different projection paths, information processing, and reconstruction procedures.

The amount of metal artifacts is increased in the mandible and in anterior regions (incisors and canines) more than the maxilla due to the fact of difference in bone density and thickness between the maxilla and mandible, and effect of neighboring anatomical structures as stated in Oliveira et al 26 findings , who assessed the effect of anatomical location on the gray values in CBCT images and noted that the same object may have various gray values according to the anatomical location.
One of the most significant strengths of our study was usage of a dry human mandible simulating the clinical setting, rather than a gypsum study model 27,28-30 or poly-methyl methacrylate 24 that utilized in beforehand studies that couldn't assess scattering radiation well like the physiological bone structures. It have to be noted that usage of phantom has similar gray scale value in whole points because of its homogeneity. But, on the clinical side, jaw-bones are

heterogeneous, which influence the gray value measurements.24

There are factors that may affect beam hardening such as the amount of machine rotation, the X-ray beam configuration, and the algorithms utilized for CBCT data processing. 31-33 Algorithms of metal artifact reduction (MAR) have been searched for along time. Mostly, searched algorithms can be classified to projection interpolation, refined reconstruction, and filtering algorithms, utilizing various modalities or collections to decrease the impact of metallic objects in the image (Wang et al. 1999; Watzke & Kalender 2004; Bal & Spies 2006; Zhang et al. 2007; Prell et al. 2009).

Regarding our study, these techniques and algorithms hadn't utilized to decrease metallic artifacts of images. It is have to be widely assessed in coming studies in aim of reducing artifacts of CBCT images.

Limitations of our study included effect of mA setting only on metal artifacts in different areas of the jaw rather than other exposure factors like voltage (KVP), system type, field of view (FOV). Additionally, assessment of metallic artifact -expressed by gray value- had done only after implant insertion rather than measurement of gray value before and after insertion of implant to determine impact of various parameters in metallic artifacts.

Conclusions

Our results revealed that metal artifacts exist constantly around dental implant in CBCT images and the anatomical region determine the amount of artifacts, which increased anteriorly more than posteriorly. Our findings revealed that there's no obvious difference by increasing mA setting, however, from interpretation of gray values, S2 exposure in anterior, H4 or S4 exposure in premolar area, and H4 exposure in molar area have the least mean gray value, and thereafter less amount of metal artifacts.

References

1. Brullmann D, Schulze RK. Spatial resolution in CBCT machines for dental/maxillofacial applications-what do we know .today? Dentomaxillofac Radiol. 2015; 44(1):20140204

2. Bornstein MM, Scarfe WC, Vaughn VM, Jacobs R. Cone beam computed tomography in implant dentistry: a systematic review focusing on guidelines, indications, and radiation dose risks. Int J Oral Maxillofac Implants. 2014 Jan; 29 Suppl: 55-77

3. Benavides E, Rios HF, Ganz SD, An CH, Resnik R, Reardon GT, et al. Use of cone beam computed tomography in implant dentistry: the International Congress of Oral Implantologists .consensus report.Implant Dent. 2012 Apr; 21(2):78-86

4. Harris D, Horner K, Grondahl K, Jacobs R, Helmrot E, Benic GI, et al. 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 Nov; .23(11):1243-53

5. American Association of Endodontists; American Academy of Oral and Maxillofacial Radiology. Use of cone-beam computed tomography in endodontics Joint Position Statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral .Pathol Oral Radiol Endod. 2011 Feb; 111(2): 234-7

6. Scarfe WC, Levin MD, Gane D, Farman AG. Use of cone beam computed tomography in endodontics. Int J Dent. 2009; .2009:634567

7. Garib DG, Calil LR, Leal CR, Janson G. Is there a consensus for CBCT use in Orthodontics? Dental Press J Orthod. 2014 Sep-.Oct; 19(5):136-49

8. Ahmad M, Jenny J, Downie M. Application of cone beam computed tomography in oral and maxillofacial surgery. Aust .Dent J. 2012 Mar; 57 Suppl 1:82-94

9. Pauwels R, Araki K, Siewerdsen JH, Thongvigitmanee SS. Technical aspects of dental CBCT: state of the art. .Dentomaxillofac Radiol. 2015; 44(1):20140224

10.Jaju PP, Jain M, Singh A, Gupta A. Artefacts in cone beam .CT. Open J Stomatol. 2013 Jul; 3(05):292

11.Schulze RK, Berndt D, d'Hoedt B. On cone-beam computed tomography artifacts induced by titanium implants. Clin Oral .Implants Res. 2010 Jan; 21(1): 100-7

12.Bechara B, McMahan CA, Geha H, Noujeim M. Evaluation of a cone beam CT artefact reduction algorithm. Dentomaxillofac .Radiol. 2012 Jul; 41(5): 422-8

13., Huang KH, et al. Clinical evaluation of the normalized metal artefact reduction algorithm caused by dental fillings in CT. .Dentomaxillofac Radiol. 2013; 42(4):20120105

14.Ibraheem I. Reduction of artifacts in dental cone beam CT images to improve the three dimensional image reconstruction. J .Biomed Sci Eng. 2012 Aug; 5 (8):409-15

15., Noujeim M. Metal artefact reduction with cone beam CT: an .in vitro study. Dentomaxillofac Radiol. 2012 Mar; 41 (3):248-53

16. and avoidance. Radiographics. 2004 Nov-Dec; 24(6): 1679-.91

17. s R, Jacobs R, Horner K, et al. Quantification of metal artifacts on cone beam computed tomography images. Clin Oral .Implants Res. 2013 Aug; 24 Suppl A100:949

18. Okumura S, Naitoh M, Fujishita M, et al. Image artifact in dental cone-beam CT. Oral Surg Oral Med Oral Pathol Oral .Radiol Endod. 2006 May; 101(5):652-7

19. -Sotelo LR, Vasconcelos KF,Campos PS, Haiter-Neto F. Efficacy of a cone beam computed tomography metal artifact reduction algorithm for the detection of peri-implant fenestrations and dehiscences. Oral Surg OralMedOralPatholOralRadiol2016;121:5506.doi:https://doi.org/10.1016/j.oooo.2016.01.013

20.Pauwels R, Stamatakis H, Bosmans H, Bogaerts R, Jacobs R, Horner K, et al. Quantification of metal artifacts on cone beam computed tomography images. Clin Oral Implants Res 2013; 24(Suppl A100): 94–9. doi: https://doi.org/10.1111/j.1600-0501. 2011.02382.x

21.Pauwels R, Araki K, Siewerdsen JH, Thongvigitmanee SS. Technical aspects of dental CBCT: state of the art. .Dentomaxillofac Radiol. 2015;44(1):20140224

22.Dranischnikow E, Schwanecke U, et al. Artefacts in CBCT: a .review. Dentomaxillofac Radiol. 2011 Jul;40(5):265-73

23.Parsa A, Ibrahim N, Hassan B, Motroni A, van der Stelt P, Wismeijer D. Influence of cone beam CT scanning parameters on gray value measurements at an implant site. Dentomaxillofac .Radiol. 2013;14:178–84

24.Pauwels R, Stamatakis H, Bosmans H, Bogaerts R, Jacobs R, Horner K, et al. Quantification of metal artifacts on cone beam computed tomography images. Clin Oral Implants Res. .2013;24:94–9

25.Kataoka ML, Hochman MG, Rodriguez EK, Lin PJ, Kubo S, Raptopolous VD. A review of factors that affect artifact from metallic hardware on multi-row detector computed tomography. .Curr Probl Diagn Radiol. 2010 Jul-Aug;39(4):125-36

26.Oliveira ML, Tosoni GM, Lindsey DH, Mendoza K, Tetradis S, Mallya SM. Influence f anatomical location on CT numbers in cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol 2013; 115: 558–64. doi: https://doi.org/10.1016/ j.oooo.2013.01.021

27.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. 2012;24:378–83

28.Hasan I, Dominiak M, Blaszczyszyn A, Bourauel C, Gedrange T, Heinemann F. Radiographic evaluation of bone density around .immediately loaded implants. Ann Anat. 2015;199:52–7

29.Zhang Y, Zhang L, Zhu XR, Lee AK, Chambers M, Dong L. Reducing metal artifacts in cone-beam CT images by preprocessing projection data. Int J Radiat Oncol Biol Phys. Naitoh M, Saburi K, Gotoh K, Kurita K, Ariji ..2007;67:924–32 E. Metal artifacts from posterior mandibular implants as seen in .CBCT. Implant Dent. 2013;22:151–4

30.Schulze D, Heiland M, Blake F, Rother U, Schmelzle R. Evaluation of quality of reformatted images from two cone-beam computed tomographic systems. J Craniomaxillofac Surg. 2005 .Feb;33(1): 19-23

31.Hunter A, McDavid D. Analyzing the beam hardening . artifact in the Planmeca Promax. Oral Surg Oral Med Oral .Pathol Oral Radiol Endod. 2009 Apr;107(4):e28-9

32. Draenert FG, Coppenrath E, Herzog P, Muller S, Mueller-Lisse UG. Beam hardening artefacts occur in dental implant scans with the NewTom cone beam CT but not with the dental 4-row multidetector CT. Dentomaxillofac Radiol. 2007 May;36(4):198-203.