Review article:

Artifacts-The Black Spot of CBCT

Dr.Malav Thakrar, Dr.Aakash Solanki ,Dr Shaveta Bhargava, Dr Geeta Asthana , Dr.Girish Parmar

Dept.of Conservative Dentistry and Endodontia, Govt.Dental College and Hospital, Ahmedabad, Gujarat, India.
Corresponding author : Dr Malav J Thakrar

Abstract

Cone-beam computed tomography (CBCT) has been one of the most sought after diagnostic aid in present day endodontics, owing to its 3-Dimensional depiction of structures. Despite a continuous upswing in its application, there is a soft spot, spoiling its image, named artifact. Artifacts are discrepancies between the reconstructed visual image and the actual content of the subject which derogates the quality of CBCT images, making them diagnostically ambiguous. Additionally, structures that are not part of normal subject may appear within images. Such structures can occur because of patient motion, the image capture and reconstruction process. To enhance image quality, it is necessary to understand the types of artifacts. This article aims to shed light on the numerous types of artifacts associated with CBCT images.

Introduction

The introduction of cone-beam computed tomography (CBCT) has revolutionised the diagnosis of complicated cases in endodontic practice. There is no doubt about its wide spectrum of usefulness and application in Endodontics. However, CBCT technology has not been recommended as a routine radiographic aid for all patients in need of endodontic treatment due to risk of radiation exposure (1).

Despite the numerous advantages of using CBCT as a diagnostic aid in clinical practice, some limitations have been described. The presence of gray-level non-uniformities in CBCT contributes to artifact formation in reconstructed CBCT images. In CT, the term "artifact" refers to any systematic discrepancy between the CT numbers in the reconstructed image and the true attenuation coefficients of the object.[2,3] Artifacts are commonly encountered in clinical CT, and may obscure or simulate pathology. There are many different types of CT artifacts [Figure 1], including noise, beam hardening, scatter, pseudo-enhancement, motion, cone beam, helical, ring, and metal artifacts. X-RAY BEAM ARTIFACTS

1.Beam hardening

Among the most obvious image artifacts are dark bands caused by a process known as beam hardening. The x-ray beam used in cone beam imaging is termed polychromatic.

Beam hardening is one of the most prominent sources of artifacts. An X-ray beam is composed of individual photons with a range of energies. As the beam passes through an object, it becomes "harder," i.e., its mean energy increases, because the lower-energy photons are abs orbed more rapidly than the higher-energy photons. These artifacts may project over and mask underlying structures, or they may provide false information regarding the density and morphology of those areas within the subject. Two types of artifact can result from this effect: The so-called cupping artifacts and the appearance of dark

5

bands or streaks between dense objects in the image(3,4,5,6,7,8,9).In clinical practice, it is advisable to reduce the field of view (FOV)[10] to avoid scanning regions susceptible to beam hardening (e.g., metallic restorations, dental implants), which can be achieved by collimation, modification of patient positioning, or separation of the dental arches.[9,11]

Filtration

A flat piece of attenuating, usually metallic material is used to "pre-harden" the beam by filtering out the lower-energy components before it passes through the patient. An additional "bowtie" filter further hardens the edges of the beam, which will pass through the thinner parts of the patient.[5]

Calibration correction

Manufacturers calibrate their scanners using phantoms in a range of sizes. This allows the detectors to be calibrated with compensation tailored for the beam hardening effects of different parts of the patient.[5]

Beam hardening correction software

An iternative correction algorithm may be applied when images of bony regions are being reconstructed. This helps minimize blurring of the bone–soft tissue interface in brain scans and also reduces the appearance of dark bands in non-homogeneous cross sections.[5]

Avoidance of beam hardening by the operator

It is sometimes possible to avoid scanning bony regions, either by means of patient positioning or by tilting the gantry.[5]

Cupping artifact

The cupping effect artifact is demonstrated when a uniform cylindrical object is imaged. X-rays passing through the middle portion of a uniform cylindrical

phantom are hardened more than those passing though the edges because they are passing though more material.Therefore, the resultant attenuation profile differs from the ideal profile that would be obtained without beam hardening and displays a characteristic cupped shape artifact.[3,5]

Go to:

2.PATIENT-RELATED ARTIFACTS

Patient motion can cause misregistration of data, which appears as unsharpness [Figure 3] in the reconstructed image. This unsharpness can be minimized by using a head restraint and as short a scan time as possible.[2,4]

Metal artifacts

White streaks, often referred to as star effect or metallic artifact, can also be seen in

association with metallic structures such as crowns, surface restorations, implants,

and surgical plates or screws.

A recent investigation demonstrated that the presence of metallic post reduced both sensitivity and specificity of CBCT for the detection of horizontal root fracture [12,13].

Patients are normally asked to take off removable metal objects such as jewellery before scanning commences. For non-removable items, such as dental fillings, prosthetic devices, and surgical clips, it is sometimes possible to use gantry angulation to exclude the metal inserts from scans of nearby anatomy.

The masking of areas beyond the metal object can be reduced by placing a cotton roll between the anterior teeth and raising or lowering the patient's chin, so the artifact streaks are not projected over the entire arch as they are when the occlusal plane is parallel to the floor[3,7,14-22]

6

Motion artifacts

Another commonly observed artifact in dental cone beam imaging is associated with patient motion. This artifact may appear as shading or streaking in the reconstructed image, double outlines of corticated surfaces, or double outlines of the posterior border of the tongue.

Patient motion can cause misregistration artifacts within the image. If an object moves during the scanning process, the reconstruction does not account for that move since no information on the movement is integrated in the reconstruction process.[2,4,23]

Avoidance of motion artifacts by the operator

The use of positioning aids is sufficient to prevent voluntary movement in most patients. However, in some cases (e.g., pediatric patients), it may be necessary to immobilize the patient by means of sedation. Using as short a scan time as possible helps minimize artifacts when scanning regions prone to movement. Respiratory motion can be minimized if patients are able to hold their breath for the duration of the scan. The sensitivity of the image to motion artifacts depends on the orientation of the motion. [5,24,25,26,27]

3.SCANNER-RELATED ARTIFACTS

Ring artifacts

Visible as concentric rings centered around the location of the axis of rotation that result from imperfections in scanner detection or poor calibration. They are most prominent when homogeneous media are imaged. Owing to the circular trajectory and the discrete sampling process, these inconsistencies appear as rings in the planes coplanar with the movement plane of the source (axial planes in CBCT).[2,4,26,28,29,30]

Avoidance and software corrections

The presence of circular artifacts in an image is an indication that the detector gain needs recalibration or may need repair services. Selecting the correct scan field of view may reduce the artifact[11] by using calibration data that fit more closely to the patient anatomy. All modern scanners use solid-state detectors, but their potential for ring artifacts is reduced by software that characterizes and corrects detector variations.[5]

4.IMAGE NOISE

Noise is defined as an unwanted, randomly and/or non-randomly distributed disturbance of a signal that tends to obscure the signal's information content from the observer. Noise affects images produced by cone-beam CT units by reducing low contrast resolution.[31] making it difficult to differentiate low-density tissues, thereby reducing the ability to segment effectively.

Scatter

Scatter, on the other hand, is caused by those photons that are diffracted from their original path after interaction with matter. This additional share of scattered X-rays results in increased measured intensities, since the scattered intensities simply add to the primary intensity. Scatter causes streak artifacts[33] in the reconstruction that are very similar to those caused by beam hardening. Scatter is well known to further reduce soft-tissue contrast and it will also affect the density values of all other tissues.[2,4,5 ,28 ,29,32]

Extinction artifacts

These are often termed "missing value artifacts." If the object under study contains highly absorbing material, e.g., prosthetic gold restorations, then the signal recorded in the detector pixels behind that material may be close to zero or actually zero.Thick

gold restorations will result in zero incident intensity on the detector. Consequently, no absorption can be computed and severe artifacts are induced as these zero entries are projected.[2,4,28,29]

Aliasing artifacts

Aliasing in CBCT lies in the divergence of the cone beam. In each projection, the voxels close to the source will be traversed by more recorded "rays" than those close to the detector. This causes aliasing which represents itself as line patterns (moire patterns), commonly diverging toward the periphery of the reconstructed volume.It occurs due to undersampling of structures.They do not resemble any naturally occurring structure. [2,4,28,29]

Summary

No imaging modality—periapical, panoramic, cephalometric, cone beam, medical computed tomography, or magnetic resonance image—is completely free of distortion or artifacts. Therefore, no system provides images that perfectly represent the subject of interest.

Artifacts are part and parcel of present day CBCT. So one should be able to differentiate artifacts in the cbct images so as to prevent mis-diagnosis.
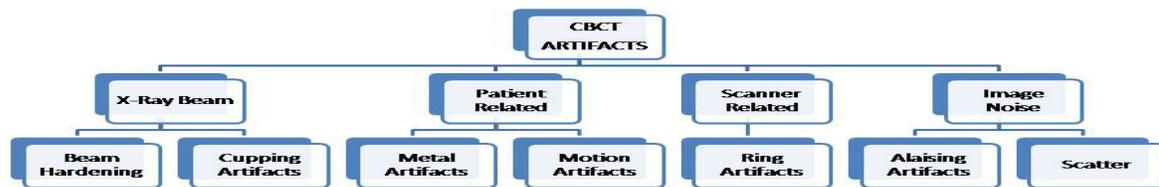
References

1) 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 surgery, oral medicine, oral pathology, oral radiology, and endodontics. 2011;111:234

2) Schulze R, Heil U, Groβ D, Bruellmann DD, Dranischnikow E, Schwanecke U, et al. Artefacts in CBCT: A review. Dentomaxillofac Radiol. 2011;40:265–73.

3) Hunter AK, McDavid WD. Characterization and correction of cupping effect artefacts in cone beam CT.Dentomaxillofac Radiol. 2012;41:217–23.

4) Makins RS. Artifacts interfering with interpretation of cone beam computed tomography images. Dent Clin North Am. 2014;58:485–95.

5) Barrett JF, Keat N. Artifacts in CT: recognition and avoidance. Radiographics 2004;24(6):1679–91.

6) Katsumata A, Hirukawa A, Noujeim M, et al. Image artifact in dental cone-beam CT. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;101(5):652–7.

7) Esmaeii F, Johari M, Haddad P, et al. Beam hardening artifacts: comparison between two cone beam computed tomography scanners. J Dent Res Dent Clin Dent Prospects 2012;6(2):49–53.

8) Hunter AK, McDavid WD. Characterization and correction of cupping artifact in cone beam CT. Dentomaxillofac Radiol 2012;41:217–23.

9) Esmaeili F, Johari M, Haddadi P. Beam hardening artifacts by dental implants: Comparison of cone-beam and 64-slice computed tomography scanners. Dent Res J (Isfahan) 2013;10:376–81.

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

11) Nabha W, Hong YM, Cho JH, Hwang HS. Assessment of metal artifacts in three-dimensional dental surface models derived by cone-beam computed tomography. Korean J Orthod. 2014;44:229–35.

12) Costa FF, Gaia BF, Umetsubo OS, Cavalcanti MG. Detection of horizontal root fracture with small-volume cone-beam computed tomography in the presence and absence of intracanal metallic post. J Endod.2011;37:1456–9.

13) Parirokh M, Ardjomand K, and Manochehrifar H.Artifacts in Cone-Beam Computed Tomography of a Post and Core Restoration: A Case Report. Iran Endod J. 2012 Spring; 7(2): 98–101.

14) Kataoka ML, Hochman NG, Rodriguez EK, et al. A review of factors that affect artifact from metallic hardware on multi-row detector computed tomography. Curr Probl Diagn Radiol 2010;39(4):125–36.

15) Naitoh M, Saburi K, Gotoh K, et al. Metal artifacts from posterior mandibular implants as seen in CBCT. Implant Dent 2013;22(2):151–4.

16) Karimi S, Cosman P, Wald C, et al. Segmentation of artifacts and anatomy in CT metal artifact reduction. Med Phys 2012;39(10):5857–68.

17) Benic G, Sancho-Puchades M, Jung R, et al. In vitro assessment of artifactsinduced by titanium dental implants in cone beam computed tomography. Clin Oral Implants Res 2013;24:378–83.

18) Schulze R, Berndt D, d'Hoedt B. On cone beam computed tomography artifacts induced by titanium implants. Clin Oral Implants Res 2010;21:100–7.

19) Bechara B, Moore WS, McMahan CA, et al. Metal artifact reduction with conebeam computed tomography: an in vitro study. Dentomaxillofac Radiol 2012;41(3):248–53.

20) Pauwels R, Stamatakis H, Bosmans H, et al. Quantification of metal artifacts in cone beam CT. Dentomaxillofac Radiol 2012;41:217–33.

21) Boas FE, Fleischmann D. Evaluation of two iterative techniques for reducing metal artifacts in computed tomography. Radiology 2011;259(3):894–902.

22) Lucklow M, Deyhle H, Beckmann F, et al. Tilting the jaw to improve image quality or to reduce the dose in cone-beam computed tomography. Eur J Radiol 2011;80:e389–93.

23) Leng S, Zambelli J, Tolakanahalli R, Nett B, Munro P, Star-Lack J, et al. Streaking artifacts reduction in four-dimensional cone-beam computed tomography. Med Phys. 2008;35:4649–59.

24) Zhang Q, Hu CY, Liu F, Goodman K, Rosenzweig EK, Mageras GS. Correction of motion artefacts in cone-beam CT using a patient-specific respiratory motion model. Med Phys. 2010;37:2901–9.

25) Sureshbabu W, Mawlawi O. PET/CT imaging artifact. J Nucl Med Technol. 2005;33:156. quiz 163-4.

26) LU W, Parikh PJ, Hubenschmidt JP, Politte DG, Whiting BR, Bradley JD, et al. Reduction of motion blurring artifacts using respiratory gated CT in sinogram space: A quantitative evaluation. Med Phys.2005;32:3295–304.

27) Marchant TE, Price GJ, Matuszewski BJ, Moore CJ. Reduction of motion artefacts in on-board cone beam CT by warping of projection images. Br J Radiol. 2011;84:251–64.

28) Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin North Am.2008;52:707–30, v.

29) Bhoosreddy AR, Sakhavalkar UP. Image deteriorating factors in cone beam computed tomography, their classification, measure to reduce them: A pictorial essay. J Indian Acad Oral Med Radiol. 2014;26:293–7.

30) Kincade K. Cone-beam CT artifacts: What's a dentist to do? Dentomaxillofac Radiol. 2011;40:265–73.

31) 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;54:227–32.

32) Zhao W, Zhu J, Wang L. Fast scatter artifacts correction for Cone-Beam CT without system modification and repeat scan. Med Phys. 2015

33) Miracle AC, Mukherji SK. Conebeam CT of the head and neck, Part 1: Physical principles. AJNR Am J Neuroradiol. 2009;30:1088–95.