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Cone Beam Computed Tomography Artefacts-A Review

Dr Jaishri Pagare, Dr Bhagyashree Landage, Dr. Nimisha Pagare
Oral Medical and Radiology, Gov. Dental College and Hospital Aurangabad 431001 Maharashtra

Corresponding Author
Dr. Jaishri Pagare
Oral Medical and Radiology, Gov. Dental College and Hospital Aurangabad 431001 Maharashtra

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ABSTRACT
The state of art CBCT is an useful diagnostic tool in dentistry for 3D imaging of the facial structures. It is a valuable asset in dentistry, because of its lower cost, high resolution and relatively low radiation burden. Despite the growing trend of CBCT in dentistry it has some limitations like artefacts which cause deterioration of images. Artefacts are discrepancies between the reconstructed image and the actual content of the subject being studied. Every dentist almost is familiar with these artefacts while interpreting CBCT images. This article aims to present the most prominent artefacts and faults encountered during CBCT imaging.

Keywords: CBCT, Artefacts, Faults

INTRODUCTION

CBCT is a modern third dimension applied in the field of dentistry for imaging of oral and maxillofacial region. The introduction of this 3D technology has helped the dentist to diagnose the oral and maxillofacial lesions in 3 dimensions. Patients have benefited due to the CBCT imaging by reviewing better diagnostic enhanced treatment planning. This also facilitates better patient education, understanding and treatment acceptance. CBCT is a boon in the diagnosis of various lesions and has several clinical applications but the current CBCT technology has some limitations related to cone beam projection geometry, detector sensitivity and contrast resolution.(1) It is important to understand the difference between artefacts and fault. Fault is an imperfection, a mistake or error where flaws will hinder interpretation of a radiograph, whereas an artefact is any distortion or error in the image that is unrelated to the subject being studied.(1)

CLASSIFICATION OF ARTEFACTS

A. Physics based
B. patient based
C. scanner based
D. cone beam related artefacts

A. PHYSICS BASED

1. Noise
2. Beam hardening
   a. Cupping artifact
   b. Streaks and Dark bands
3. Photon starvation

B. PATIENT BASED

1. Motion artefacts
2. Artefacts due to metallic object
3. Unsharpness
4. Double image

C. SCANNER BASED

1. Ring artefacts

D. CONE BEAM RELATED ARTEFACTS

1. Partial volume averaging
2. Undersampling
3. Cone beam effect

A. PHYSICS BASED ARTEFACTS :

1. NOISE :

Noise is unwanted, randomly or unrandomly distributed disturbance of a signal that tends to obscure the signal's information content from the observer. Noise affects images produced by CBCT units by reducing low contrast resolution making it difficult to differentiate low density tissues, thereby reducing the ability to segment effectively.

The noise in traditional projection radiography is primarily from quantum mottle which is defined as a variation in image density due to statistical fluctuation of photon fluency in the radiation field. The Cone beam acquisition geometry results in a large volume being irradiated with every basis image projection. As a result a large portion of the photons engage in interactions by way of attenuation. This occurs due to scattered radiations which are produced in all directions- Compton scattering. This supplementary recorded x - ray attenuation reflecting non - linear attenuation is known as noise.[2]

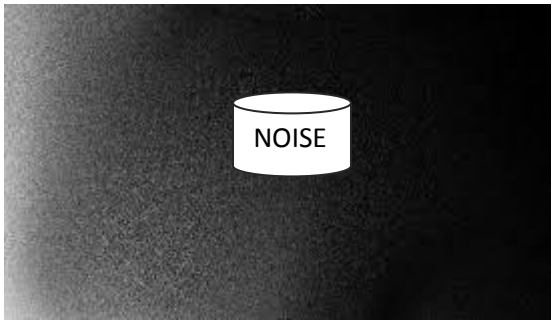

FIG. 1. SHOWING : NOISE

2. BEAM HARDENING :

Beam hardening is the most common type of artefact. Beam hardening manifests as two different artefacts within the reconstructed image.

a. Cupping artefacts
b. Streak artefacts

a. CUPPING ARTEFACTS :

Cupping artefact which is distortion of metallic structures due to differential absorption.[3]Cupping artefacts from beam hardening occur when x ray passing through the centre of large object become harder than those passing through the edges of the object due to greater amount of material the beam has to penetrate because the beam becomes harder in the centre of the object the resultant profile of the linear attenuation coefficient appears as a "cup".[4]

b. STREAK AND DARK BAND :

Streak and dark band appears between two dense objects. In dental imaging, this type of artefact can be seen between two implants located in the same jaw that are in close proximity to each other. This occurs because the portion of the beam that passes through both objects at certain tube positions becomes harder than when it passes through only one of the objects at other tube positions.[4]

The x- ray beam used in cone beam imaging is polychromatic. This means the x – ray beam is not composed of x- ray photons of a single energy level. Instead the x-ray beam is made up of x- ray photons of many different energy levels, the maximum energy level being equal to the Kvp setting selected on the CBCT unit. When the primary beam passes through the subject, the low energy x-ray photons which interact with the subject, mainly the denser objects such as metal restorations and bone, they are attenuated or removed from the x-ray beam. The portion of the x-ray beam that exists from the subject and strikes the detector is composed of a greater percentage of high energy x-ray photons than the beam origination at the tube head. [5-10] For simplicity and reduced cost with faster image reconstruction times, the mathematical algorithm that processes the information from the detector and reconstructions the cone beam image assumes the primary x-ray beam exiting the tube head monochromatic.

This discrepancy may cause the algorithm to mis interpret the amount of attenuation especially the denser objects. It assumes low gray scale values for the areas within the subject. This undervaluation combined with the back projection mathematical process to construct the image volume produces the characteristic dark areas and streaks seen in cone beam images. These artefacts may project over and mask underlying structures or they may provide false

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information regarding the almostly and morphology of those with the subject. [10-16]

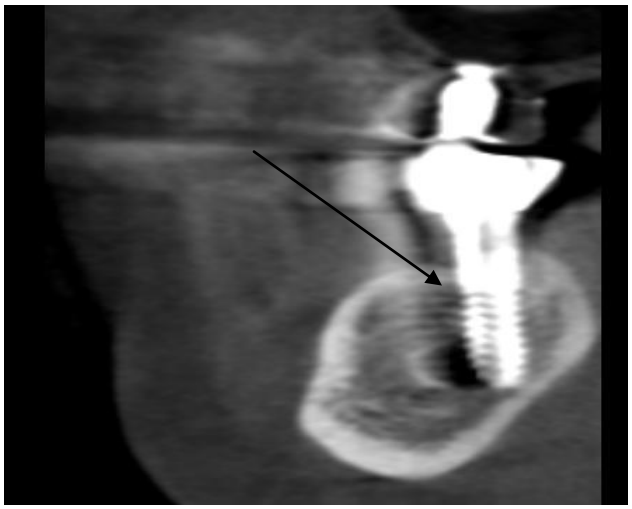

FIG. 2. IMAGE SHOWING CUPPING EFFECT, STREAK AND DARK BANDS AS A RESULT OF BEAM HARDENING.

A. 3. PHOTON STARVATION :

Photon saturation is seen in zones with highly attenuated the x-ray beam. It results in streaking artifacts as the x-ray beam travels horizontally. The attenuation is maximum and insufficient photons which reach the detectors result in producing. [17]

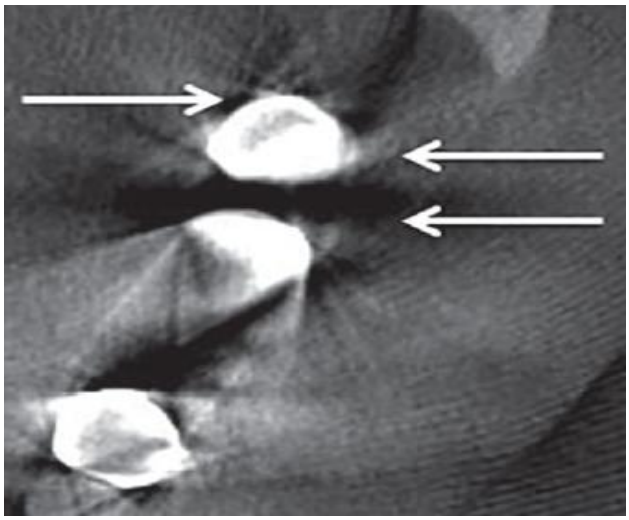

FIG. 3. PHOTON STARVATION

B. PATIENT BASED CBCT AREFACTS :

1. MOTION ARTEFACTS:

This is a commonly observed artifact in dental cone beam imaging. This artifact appears as shading or streaking in the reconstructed image, double outlines of corticated surfaces or double outlines of the posterior border of tongue.

These artefacts can be attributed to improper patient stabilization. Small motion cause blurring of the image where as larger motions cause physical displacements. The artifact appear as double images or ghost images and results in poor image quality. The resolutions of the present CBCT is very high and it ranges from 0.08 mm - 0.4 mm, so even a small motion has a detrimental effect on image quality. Poisoning aids can be used to prevent voluntary moments in most of the patients.[18]

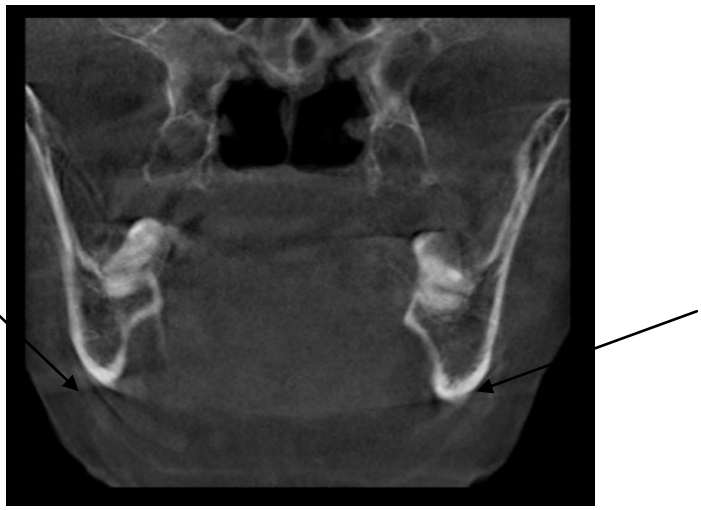

FIG. 4. TYPICAL DOUBLE CONTOURS (ARROW) INDUCED BY THE PATIENTS MOVEMENT DURING IMAGE ACQUISITION.

2. ARTIFACTS DUE TO METALLIC OBJECTS:

These are caused by the presence of high attenuation objects in the field of view such as Metallic dental restorations, surgical plates, pins and radiographic markers. The metals highly attenuate the x- ray beam; the attenuation values of objects behind the object are incorrectly high. Due to the reconstruction of the beam image, the metal causes the effect of bright and dark streaks in CT images with significantly degrade the image quality. In CBCT, the metallic streak artefacts occur in all directions from the high attenuation object because of the cone beam.

Patients are normally asked to remove the metal objects before scanning. Patients with long metallic

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bridges, cast partial dentures and full mouth metallic restorations may not be indicated for fine details in CBCT.

Metal objects such as jewelary before the scanning. For non- removable things like the dental restorations and surgical clips, it is sometimes possible to use gantry angulation to enhance metal interts from scans of nearby anatomy when it is impossible to scan the required anatomy without enhancing metal objects, increasing technique, especially kilovoltage, may help penetrate bone objects and using thin sections will reduce the contribution due to partial volume artefacts. [19]

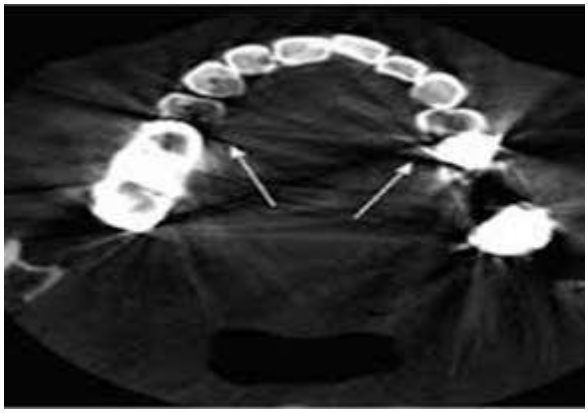

FIG. 5. ARTIFACTS DUE TO METALLIC OBJECTS

C. SCANNER BASED ARTEFACTS

1. RING ARTEFACTS:

Ring artefacts are concentric circular rings centered around the location of the axis of rotation. They are most dominant when homogeneous media are imaged. They are caused by defect or uncalibrated detector elements. Consist reading at each angular positon of the detector.

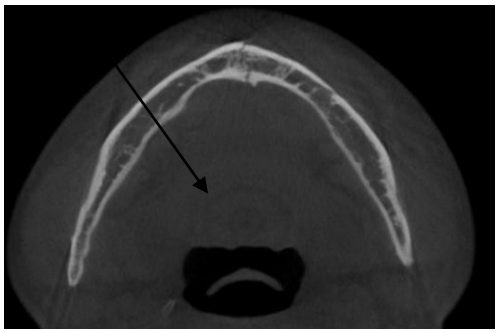

FIG. 6. RING ARTEFACT (arrow) CENTERED AROUND THE LOCATION OF THE AXIS OF ROTATION. MOST CLEARLY VISIBLE IN AXIAL SLICE.

D. CONE BEAM RELATED ARTEFACTS :

1. PARTIAL VOLUME AVERAGING

It is an arefacts that happens when a structure is only partly which is imaging section pixel or voxel resulting in the signals of the structures and the adjacent or surrounding structures becoming averaged. It occurs when the selected voxel resolution of the scan is greater than the spatial in contrast resolution of the object to be imaged.

2. UNDERSAMPLING

This is a type of aliasing artefact which is seen when few basis projections are provided for the reconstructions. They appear as wavy lines that diverge outwards towards the periphery of a cone beam image-Moire pattern. [5-8]

3. CONE BEAM EFFECT

Cone beam effect is seen due to the divergence of the x-rays in peripheral portions of the scan. It results in image distortion, streaks and peripheral noise

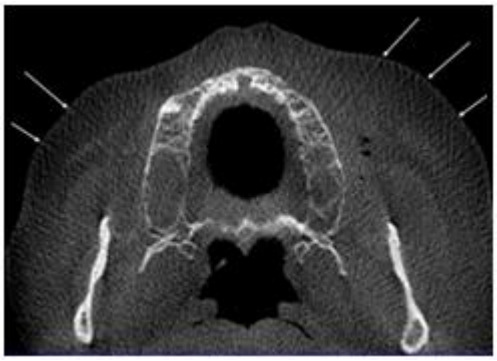

FIG. 7. TYPICAL ALIASING PATTERNS (MOIRE PATTERN) IN CBCT THE LINES DIVERGE FROM CENTRE TO THE PERIPHERI MOST PROBABLY CAUSED BY UNDERSAMPLING.

METHODS TO REDUCTE CBCT ARTEFACTS:

1. Most of the dental CBCT manufacturer introduced the artifact reduction technique algorithms within the reconstruction process. These algorithms reduce image noise, metal and motion related artifacts. [20-24]

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2. Manufacturer minimizes beam hardening by using filtration, calibration correction and beam hardening correction software. [19]
3. Metal artifacts can be avoided by asking the patients to take off removable metal objects (jewelry) before scanning. For non removable items (dental fillings, prosthetic devices and surgical clips) it is sometimes possible gantry angulations to exclude the metal insert from scans of nearby anatomy. [19]
4. Motion artifacts can be avoided by the use of positioning aids. Sometimes in pediatric patients it may be necessary to immobilize the patient by means of sedation. Use of short scan time helps to minimize artifacts when scanning region is prone to movement. Respiratory motion can be minimize by telling the patient to hold the breath during scanning.[19,25-28]
5. Beam hardening effect can be reduced by field of view and modifying arch selection to avoid scanning region susceptible to beam hardening.

CONCLUSION:

The artifacts presented in this article are some of the common artifacts seen in the CBCT images. These artifacts may interfere with the diagnostic process so it is necessary to recognize imaging artifacts to prevent inaccurate diagnosis.

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