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Artifacts in Cone Beam Computed Tomography – A Retrospective study

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Abstract

Aim **–** To assess the prevalence of image artifacts in cone beam computed tomography (CBCT) images

Methods & materials – Forty two repeated CBCT images were retrospectively studied to identify artifacts and the prevalence of different types of artifacts were recorded.

Result- The most prevalent image artifact recorded was motion artifact and hence the most common type of artifact was patient- based.

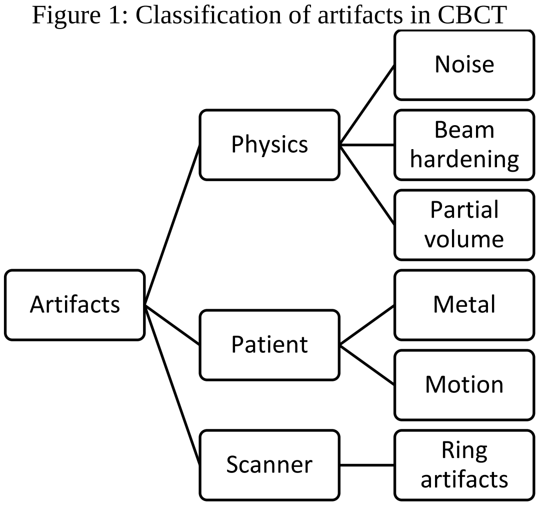
Conclusion – Artifacts in CBCT can be minimized by proper patient preparation through patient instructions and stabilization.

Keywords – artifacts, cone beam computed tomography, prevalence, beam hardening, streak artifact

INTRODUCTION

The first Cone Beam Computed Tomography (CBCT) machine for head and neck imaging was developed in the year 1998 (1) . CBCT had the merits over conventional radiography and Computed Tomography (CT) in terms of three dimensional images and lower radiation dose respectively (2). Unfortunately CBCT technique results in artifact formation due to presence of gray-level non-uniformities. Artifact in general refers to an object observed in an investigation that is not naturally present but occurs as a result of the preparative procedure. Specifically in CBCT and CT, artifacts refer to any systemic discrepancy between numerical data in reconstructed image and true attenuation coefficient of the object (3). These are frequent in CBCT images and can hinder proper diagnosis by simulating pathology .

Figure 1: Classification of artifacts in CBCT



Nosie is any undesirable random or non-random disturbance of a signal that obscures the information content of that signal from the observer. Noise affects the diagnostic quality of the image by reducing the contrast resolution thereby hindering the ability to segment effectively (4). Conventional CT machines produce images with little noise since they use a high mA and also because of the fact that pre and post patient collimation significantly lessen the scattered radiation. In contrast, CBCT images tend to produce more noise owing to the lower mA used and the high amount of scattered radiation as there is absence of post patient collimation (5). Dose-related noise that appear as granular streaks arising from attenuation regions are known as quantum mottle artifacts.

A beam of X ray is made up of individual photons possessing a wide range of energies. When this beam passes through an object the lower energy photons get absorbed faster than high energy photons (6). Thus the beam gets “harder”. Metals being high absorbing materials act as a filter (7). During the phenomenon of beam hardening a non linear error is introduced into the recorded data. This error is induced into the volume when 3D reconstruction is attempted, resulting in dark streaks (8). Beam hardening can lead to two types of artifacts in images- cupping artifacts and appearance of dark bands or streaks. Cupping artifacts result while imaging a cylindrical object. The photons passing through the centre of the cylinder encounters more material than those passing through the periphery. Hence the beam passing through the middle portion is hardened more and the rate of attenuation decreases. The resultant modified attenuation profile demonstrates a characteristic cup shaped artifact. Reduction of the field of view by collimation, modification of patient position or by imaging required dental arch separately ; to avoid scanning regions prone to beam hardening such as metallic restorations, implants ; can be a practical solution to avoid these artifacts (9).

Another group of artifacts called ring artifacts appear as concentric rings centered around axis of rotation. These are a consequence of poor calibration or scanner detector imperfections and are most conspicuous when homogenous structures are scanned. In CBCT images these artifacts are visible in the axial sections since the inconsistencies occur in planes coplanar with the movement plane of the source. This can be attributed to the circular trajectory and the discrete sampling process (10).

Extinction artifacts or missing value artifacts can result when the scanning region contains any highly absorbing material like prosthetic gold restorations which cause the signal recorded in the pixels behind these objects to be zero or close to zero (11). Aliasing artifacts appear as moire patterns or line patterns, which commonly diverge toward periphery of reconstructed volume. These can be a cause of a crude interpolation between the back projected lines and the voxel traversed by them (12).

Patient movement leads to unsharpness due to misregistration of data. This can be controlled by using head restraints to stabilize the patient and by keeping the scan time as short as possible. Smaller the voxel size, smaller the movement necessary to cause misregistration. Movement artifacts mostly present as double contours (13). Also patients should be instructed to remove metallic objects like jewellery to avoid metal artifacts. In case of non- removable objects like prosthetic devices, dental restorations, implants and surgical clips, increasing technique, like kilovoltage can be used for better penetrance. Using thinner sections will reduce the incorporation of such objects by partial volume averaging (14).

The radiologist should be aware of these artifacts that can be encountered in CBCT images so that repeated exposure of the patient can be avoided and also the images taken can be ensured of diagnostic quality. Hence the aim of this study was to assess the prevalence of various artifacts in CBCT images.

MATERIALS AND METHODS

The CBCT image registery of the oral radiology department of a dental hospital was checked for repeated scans taken between January 2018 and June 2018. Out of 900 scans 42 images were repeated due to poor image quality owing to presence of artifacts. These images were retrospectively analyzed to study the prevalence of various artifacts in CBCT and were classified into three major types ( ) to identify the source of artifact.

RESULT

The proportion of patients who were subjected to repeated CBCT exposure due to presence of artifacts were 4% (Figure 1). The most prevalent artifact was motion artifact followed by metal artifact both of which fall under the patient based artifact category (Table 1) . Under the physics based type the most prevalent was noise artifact followed by partial volume imaging and beam hardening . No scanner based artifacts were encountered in this study (Figure 2) .

Table 1 : Prevalence of different types of artifacts in CBCT

Physics Based	Number out of 42	Prevalence %	**Patient based**	Number out of 42	Prevalence %	**Scanner based**	Number out of 42	Prevalence %
Noise	10	23.81 %	**Metal**	11	26.19%	**Ring artifacts**	0	-
Beam hardening	3	7.14 %	**Motion**	12	28.57 %			
Partial volume	6	14.29 %						
Total		45.24 %	**Total**		54.76 %			

Figure 2 : Proportion of repeated CBCT scans

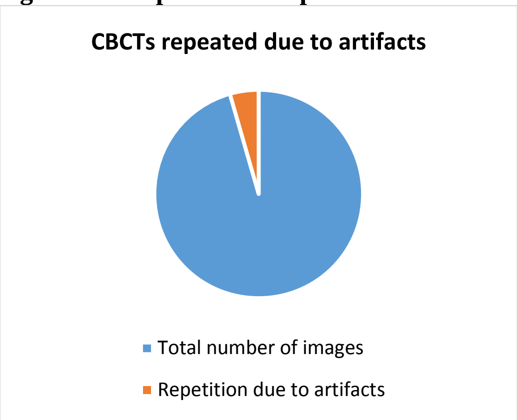


Figure 3 : Prevalence of artifact based on type

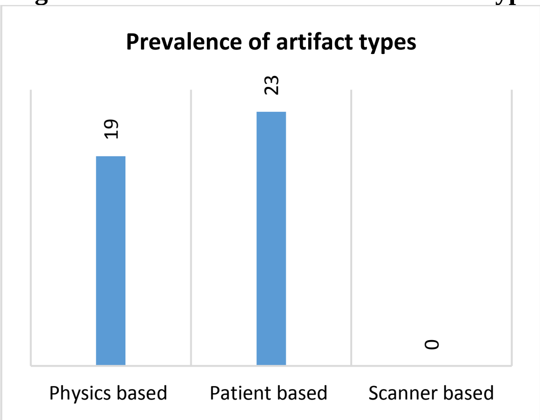


Figure 4 : Noise artefact

Figure 5 : Metal artifacts

Figure 6 : Partial volume artefact

Figure 7 : Beam hardening

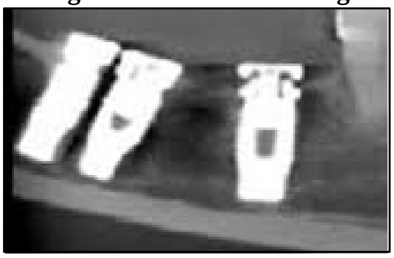


Figure 8 : Motion artefact

DISCUSSION

Issa Al-Shkhrah et al studied the artifacts in 432 CT scans repeated due to image artifacts out of a total of 7197 scans. Majority of artifacts were streaks, rings, black and white bands in contrary to our study which found a higher prevalence of patient based artifacts (15).

Beam hardening or streak artifacts constituted 7.14% of the total artifacts in our study. According to Joseph et al streak artifact is formed due to two reasons – 1) individual measurement involves assessment of a single ray through the slice 2) when there is an abrupt discrepancy between views , this being a more subtle cause. Beam hardening artifacts occur by preferential absorption of low energy photons from the beam with effects being greater in regions of larger attenuation. These accounted for 21% of repeat scans in their study. Use of special filters, correction algorithm, calibration correction, beam hardening correction softwares can reduce these artifacts (Haaga JR et al). Iterative reconstruction can also reduce streak formation. Given the fact that CBCT X ray beam is heterochromatic with lower peak energy , these artifacts are seen more in CBCT compared to CT (16).

Joseph et al reported motion artifacts being manifested as black or white bands, dark spots, loss of resolution, or distortion of anatomy whereas in our study motion artifacts were identified as the latter two. These accounted for 15 % of the repeated images in his study compared to 28.57 % in our study. These artifacts with devastating effects on the image quality can be avoided by fast scanning, gating, tube alignment, corrective reconstruction or post processing of scan (17).

When a voxel constitutes tissues of widely ranging absorption, the beam attenuation is proportional to average of attenuation coefficient of the voxel. When the average is calculated for such voxels a partial volume error occurs. Morgan CL suggested the use of thin sections and selection of sections that lie towards centre of the object of measurement to decrease the incidence of these artifacts (18). Joseph reported 16 % incidence of partial volume artifacts compared to 14.29 % in our study.

14 out of 20 CT images were affected by noise artifacts in a study by Dietrich U et al whereas in our study we came across 10 images out of 42, with noise. Joseph et al reported 7 % quantum mottle artifacts. Adaptive median filters can be introduced for noise suppression and to prevent streaking artifacts due to quantum noise according to Hsieh et al (19).

Joseph reported 6 % artifacts related to scanner and incorrect calibrations. But in our study no images with scanner related artifacts were observed. Scanner related artifacts are reported to be common especially arising from errors in detector measurements or any imbalance. When intercalibration of the detectors are not accurate , the backprojection of each ring would differ causing ring shaped artifacts. These can be corrected by repair and good preventive maintenance. Morgan CL hinted that a drastic change in room temperature and a change in humidity level can often lead to unexplained malfunctioning of the equipment and increase the number of artifacts from inappropriate responses to given instructions.

The most prevalent artifact in our study was motion artifact. In cases of paediatric patients, patient may require immobilization using sedation. Adult Patients can be instructed to hold their breath along the scan duration to minimize respiratory motion.

Films repeated due to presence of image artifacts accounted for 6 % in 1 year period as reported by Joseph et al compared to 4% in five month period in our study. He concluded that patient cooperation, thin sections, good maintenance of the machine, suitable temperature and humidity to be the factors that can control and reduce the occurences of image artifacts.

Lately artifact reduction algorithms have been incorporated within reconstruction process such as Scanora 3D. These have been proven to tone down image noise, metal, and motion artifacts. Additionally these are known to lower the acquisition dose by reducing the number of projection images (20).

CONCLUSION

Repetitive CBCT exposures can be avoided to a large extent by proper patient preparation. Patients should be carefully instructed to remove metallic jewellery , be stabilized accordingly and scan time be kept minimum to reduce the incidence of patient based artifacts in CBCT images. Physics based artifacts and scanner based artifacts can be avoided by focusing on the X ray parameters and scanner detector status respectively.

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