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ORIGINAL ARTICLE / ARAŞTIRMA MAKALESİ

Evaluation of the Frequency of Artifacts in CBCT Depending on the Different Size of Field of View

KIBT'ta Karşılaşılabilen Artefaktların Farklı Görüntüleme Alanlarında Görülme Sıklığının Değerlendirilmesi

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ABSTRACT

Objectives: Various artifacts can be encountered when examining Cone-beam computed tomography(CBCT) images. In recent years, no descriptive study has been conducted on CBCT artifacts in the literature. The aim of this study is to identify artifacts in CBCT images with different imaging fields taken on the same device, to determine their frequency, and also to reveal artifacts that are little known in the literature.

Materials and Methods: In the study, CBCT images of the Faculty of Dentistry between the years 2012-2021 were scanned retrospectively and a total of 359 Cone Beam Computed Tomography images with 50x55, 100x55, 100x90, 130x55, 130x90, 230x170, 230x270 field of views (FOV) in the database, which met the exclusion and inclusion criteria, were analyzed by three oral and maxillofacial radiology research assistants and the types of artifacts seen on these images were determined. The incidence of the identified artifact types in the specified imaging areas was evaluated.

Results: When looking at all images, the most common errors, regardless of FOV, were inevitable artifacts. Aliasing and motion artifacts were seen at higher rates on CBCT images with a larger FOV. In addition, the ring artifact was encountered in CBCT images with high imaging fields such as 130x90, 230x170 and 230x270.

Conclusion: To know the incidence and causes of artifacts in images; it will prevent the patient, the environment and the practitioner from receiving x-rays (radiation) unnecessarily, mixing these errors with different pathological conditions and repetition of the image.

Keywords: cone-beam computed tomography, artifacts, FOV

ÖZ

Amaç: Konik ışınlı bilgisayarlı tomografi (KIBT) görüntüleri incelenirken çeşitli artefaktlarla karşılaşılabilir. Son yıllarda literatürde KIBT artefaktları ile ilgili tanımlayıcı bir çalışma yapılmamıştır. Bu çalışmanın amacı, aynı cihaz üzerinde çekilen farklı görüntüleme alanlarına (FOV) sahip KIBT görüntülerindeki artefaktları tespit etmek, sıklıklarını belirlemek ve ayrıca literatürde az bilinen artefaktları ortaya çıkarmaktır.

Gereç ve Yöntem: Çalışmada 2012-2021 yılları arasında Diş Hekimliği Fakültesindeki KIBT görüntüleri geriye dönük olarak taranmış ve 50x55, 100x55, 100x90, 130x55, 130x90, 230x170, 230x270 görüntüleme alanlaına sahip toplam 359 Konik Işınlı Bilgisayarlı Tomografi görüntüsü alınmıştır. Dışlama ve dahil etme kriterlerine uygun veri tabanındaki KIBT görüntüleri üç oral ve maksillofasiyal radyoloji araştırma görevlisi tarafından incelendi ve bu görüntülerde görülen artefakt türleri belirlendi. Belirlenen görüntüleme alanlarında tanımlanan artefakt tiplerinin görülme sıklığı değerlendirildi.

Bulgular: Tüm görüntülere bakıldığında, FOV›dan bağımsız olarak en yaygın hatalar kaçınılmaz artefaktlardı. Daha geniş görüş alanına sahip KIBT görüntülerinde aliasing ve hareket artefaktları daha yüksek oranlarda görüldü. Ayrıca 130x90, 230x170 ve 230x270 gibi yüksek görüntüleme alanlarına sahip KIBT görüntülerinde halka artefaktı ile karşılaşıldı.

Sonuç: Görüntülerdeki artefaktların görülme sıklığını ve nedenlerini bilmek; hastanın, çevrenin ve uygulayıcının gereksiz yere röntgen (radyasyon) almasını, bu hataları farklı patolojik durumlarla karıştırmasını ve görüntünün tekrarını önleyecektir.

Anahtar Kelimeler: konik ışınlı bilgisayarlı tomografi, artefaktlar, FOV

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INTRODUCTION

Cone beam computed tomography (CBCT), also known as ortho CT, was developed in 1997 by Arai specifically for use in dentistry (Terakado et al., 2000). In CBCT, the area to be examined is scanned with cone-shaped X-rays. A 2-dimensional (2D) planar detector is used, and the cone beam irradiates a large volume area instead of a thin section (Terakado et al., 2000). This operating principle of CBCT allows 3D reconstructions from 2D images reconstructed in all planes with a low radiation dose (Arai et al., 1999). CBCT images include the following components: Acquisition configuration, image recognition, image reconstruction, and image display (Scarfe & Farman, 2008; Pauwels, 2018).

The most important factors affecting image quality are high potential difference (kV), tube current (mA), exposure time (s), reconstruction algorithms, and field of view (FOV). Large FOVs produce low-resolution images with high noise, while low FOVs produce high-resolution images with less noise. FOV does not affect contrast (Wolbarst et al., 2013; Geleijins, 2014; Nasseh & Al-Rawi, 2018; Samei & Peck, 2019). In addition to spatial resolution and contrast, which determine image quality, noise and artifacts must also be known. All these technical parameters, together with other deficiencies in the measurement and reconstruction process, cause artifacts in the images (Sharp et al., 2007; Kalender & Kyriakou, 2007; Zhang et al., 2007; Schulze el al., 2011). Some studies (Holberg et al., 2005; Hsieh et al., 2007; Stuehmer et al., 2008) have found that CBCT has fewer metallic artifacts compared with classical CT. However, this is technically controversial because the midplane back reflection proposed by the Feldkamp algorithm is the same as the inverse Radon transform used in the classical CT. The different appearance of these artifacts in CBCT data can only be attributed to cone beam geometry or low energy spectra (Schulze et al., 2011).

Artifacts, defined as the inclusion of nonexistent images in radiographs, are the main factor that degrades the quality of CBCT images. Source: artifacts, which may be the device, incorrect clinical practice, the patient, or even external factors, affect image quality and in some cases even lead to misdiagnosis by physicians. Although in some cases it is quite difficult to detect artifacts in a patient image, in most cases they can be detected (Samei et al., 2019). More artifacts occur with CBCT than with MDBT for reasons such as the use of a low energy spectrum, cone beam geometry, cone beam separation, aliasing artifact caused by scattering, and high noise level (Scarfe & Farman, 2008; Pauwels, 2018).

In recent years, there has been no descriptive study of CBCT artifacts in the literature. The aim of this study is to examine CBCT images with different FOVs acquired with the same device and to determine the frequency and type of artifacts in the images according to FOV. In addition, rare artifacts will be revealed.

MATERIALS AND METHODS

Study design and ethical considerations

The Declaration of Helsinki was followed for this study, and the local ethics committee approved this retrospective study (IRB approval no:14/07).

In the study, firstly, the existing articles were examined. In this way, the previous classifications were determined. Then, the CBCT images of dental faculty between 2012 and 2021 were retrospectively scanned. A total of 360 images in the database with 50x55, 100x55, 100x90, 130x55, 130x90, 230x170, 230x270 FOVs were analyzed. The CBCT images were examined by three oral and maxillofacial radiology residents. And the types of artifacts seen in these images were determined. The frequency of the identified artifact types in the indicated image areas was evaluated.

The CBCT images were scored according to the following 12 common artifact types:

1. Scattering: Scattering occurs due to the deviation of X-ray photons interacting with matter from their original direction and causes linear artifacts on the image (Fig.1).
2. Beam-hardening: Beam-hardening occurs when photons with low energy are absorbed before photons with high energy when X-rays interact with the object (Fig.1).
3. Extinction: When radiation hardening occurs between two dense objects, it results in a cancelation artifact in the form of dark streaks.
4. Cupping: This is the distortion of metal structures due to the differential absorption of X-rays by the object (Fig.1).
5. Scanner artifact: Any inadequacy or error in the calibration of the scanner, the presence of a detection error can lead to various artifacts on the image.

6. Aliasing: Too many gaps between the base projections can cause the data not to be captured correctly. This can lead to the formation of a streaky hyper-dense and hypo-dense pattern, especially at the periphery of the image (Fig.2).
7. Partial Volume Averaging: If the detected voxel size is much larger than the object size, the displayed pixel will reflect the average of the brightness values of the adjacent bones and soft tissues.
8. Noise: The interaction between the detector signal and the scattered radiation results in a grainy appearance of the image (Fig.2).
9. Motion: Due to the movement of the patient or the detector, there may be an erroneous or incomplete recording of the data in the generated image. This artifact appears as a double contour on the image (Fig.2).
10. Exponential edge: This effect is caused because of the sharp edges of the metallic crown borders producing high contrast, as it reduces the computed density value (Fig.2).
11. Operator-related artifacts: Errors such as incorrect FOV selection by the applicator, incorrect positioning of the detector, or inability to correctly determine the ROI can cause the image to repeat.
12. Ring: As a result of repeated measurement at each angular position of the detector due to lack of scanner calibration, it appears as a circular artifact (Fig.2).
13. Cone-beam Effect: The cone-beam effect is the streaking and noise artifact around the image field due to the divergence of the x-ray beam (Joseph & Spital, 1981; White & Pharoah, 2018).

For the CBCT images included in the study, only the incidence of artifacts occurring during image acquisition and caused by the operator, or the patient was determined without considering the effect on the diagnostic value. Descriptive statistics were applied to the data. The data obtained were presented as numbers and percentages.

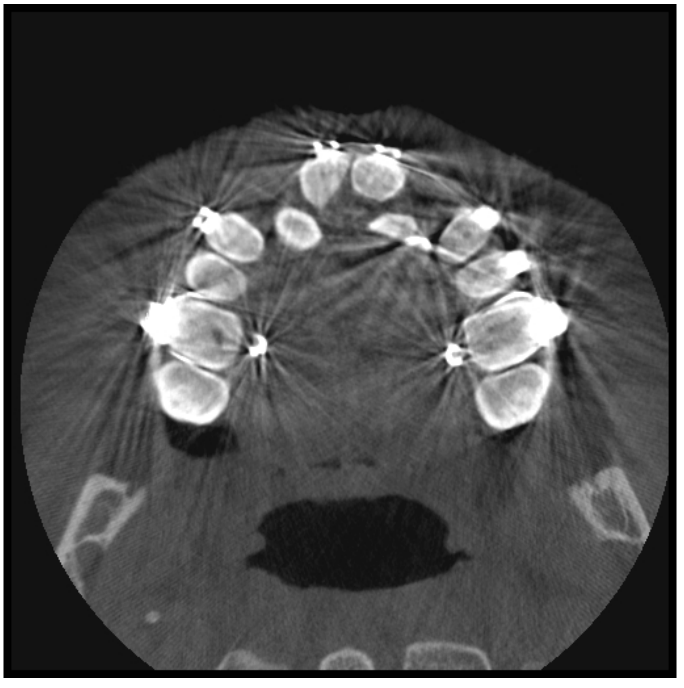

Figure 1. Axial view showing beam hardening (dark bands), scattering (white lines), and cupping artifacts (image distortion) seen around metal brackets.

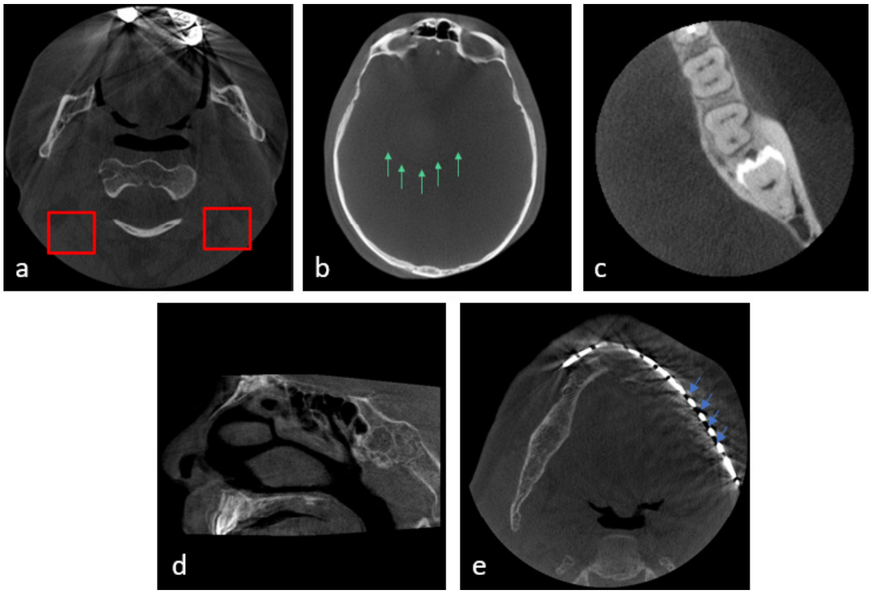

Figure 2. a) Aliasing b) Ring c) Noise d) Motion e) Exponential edge gradient effect

RESULTS

A total of 360 images with 5 different FOVs were included in the study. Different identified artifact types were evaluated on the images and the obtained data were summarized in descriptive statistics. The different types of artifacts identified in the different FOVs, and their frequencies are listed in Table 1.

Table 1. The different types of artifacts identified in the different FOVs and their frequencies

	50x55	100x55	100x90	130x55	130x90	230x170	230x270	Total number of artifacts
Scatter	100	100	100	100	100	100	100	359
Beam Hardening	100	100	100	100	100	100	100	359
Extinction-missing value	100	100	100	100	100	100	100	359
Cupping	96	100	95,5	100	100	100	100	355
Scanner-Related artifacts	96	100	100	77,7	90,1	95,1	100**	321
Moire effects(Aliasing, undersampling)	38**	63,6	61,8	71,1	78,4	93,5	92,1	258
Partial-volume averaging	96	94,5	95,5	97,7	94,1	91,9	98,03	342
Noise	34	85,4	69,09	60	56,8	17,7	21,5	164
Motion	4	27,2	13,3	11,1	33,3	29,03	23,5	74
Exponential Edge Gradient Effect	2	18,1	34,5	35,5	49,01	4,8	21,5	82
Operator-Related artifact	0	0	0	2,2	13,7	3,2	1,9	11
Ring	0	0	0	0	35,2	22,5	33,3	49

- Excluded are unavoidable artifacts and artifacts that were not found in that FOV;
- The most common artifacts at all of FOVs are beam hardening and extinction artifacts (100%).
- Scatter and Partial volume averaging were observed in all FOVs as inherent artifacts.
- The smallest number of artifact at 55 x 55 mm FOV is the exponential edge (2%).
- The lowest number of artifact at 100 x 55 mm FOV is at the exponential edge (18.1%).
- The minimum visible artifact at 100 x 90 mm FOV is motion artifact (13.3%).
- The minimum visible artifact at 130 x 55 mm FOV is operator-related artifact (2.2%).
- The minimum visible artifact at 130 x 90 mm FOV is operator-related artifact (13.7%).
- The minimum visible artifact at 230 x 170 mm FOV is operator-related artifact (3.2%).
- The minimum visible artifact at 230 x 270 mm FOV is operator-related artifact (1.9%).

Apart from the artifacts of scattering and partial volume averaging, which are unavoidable when all images are examined, the phenomenon of beam hardening and extinction is the most common artifact with a frequency of 100% in all FOVs. Operator-related artifacts are the least common artifacts with a frequency of 3.06% in all FOVs.

The frequency of aliasing artifacts was found to increase as the imaging area was increased. Similarly, motion artifacts occurred more frequently in CBCT images with larger viewing areas.

Ring artifacts and associated artifacts occurred in CBCT images with large imaging fields of 130x90, 230x170, and 230x270 mm.

When evaluating the percentages of artifacts per image, the maximum amount of artifacts was found at 130x90 mm FOV and the minimum amount of artifacts was found at 50x55 mm FOV (Table 2).

Table 2. The number of images evaluated and the number of artifacts seen in certain FOVs.

	Total number of artifacts	Number of images
50x55	316	50
100x55	395	55
100x90	304	45
130x55	313	45
130x90	408	51
230x170	462	62
230x270	379	51

DISCUSSION

Artifacts occurring in radiographs affect image quality. This situation may cause physicians to miss some findings during diagnosis and make an incorrect diagnosis. The effects of artifacts in CBCT images on image quality are among the issues that are attracting much attention and further research today. Artifacts can be caused by the patient, the physical environment, the device, and technical factors.

The aim of this study was to evaluate the occurrence of artifacts in different imaging areas in CBCT. In CBCT, a single parameter can make a big difference in terms of dose, image quality, and artifacts (Jakobs, 2011; Jakobs & Quirynen, 2014; Bornstein et al., 2014). In addition, knowing the occurrence of artifacts due to FOV is important to take precautions against the parameters that can change and the artifacts depending on the operator, given the high radiation dose and cost of CBCT (Vercruyssen et al., 2015)

In their study, Donaldson et al. (Donaldson et al., 2013) investigated the frequency of motion artifacts in CBCT images and the repetition of images associated with these artifacts. They reported that no motion artifacts were observed in 95.5% of initial images and that 99.5% of all images had diagnostic accuracy that did not require repetition. They noted that the occurrence of these artifacts increased in patients younger than 16 years and older than 65 years. Because in this study examined the effect of FOV on artifacts, patients younger than 18 years were excluded from the study to eliminate motion artifacts caused by age-related lack of cooperation. Motion artifacts were observed in 20.6% of the patients included in the study. However, there was no correlation between the frequency of motion artifacts and the FOV variable.

CBCT's beam projection geometry, reduced trajectory rotation arcs, and image reconstruction methods produce causes scatter, Partial volume averaging and Cone-beam effect artifacts. In this study, scatter and Partial volume averaging artifacts were found to be 100% in line with this literature (Jakobs & Quirynen, 2014). The frequency of beam hardening artifact in the images included in the study was 100%, consistent with this information. Although partial volume averaging artifact is also an unavoidable artifact (Jakobs & Quirynen, 2014), this rate is not 100% in any FOV in this study. This may be due to the dense noise ratio or motion artifacts hiding this artifact. The reason why cone-beam effect artifacts were not included in the study is that these artifacts were not observed with the CBCT device used. This could be due to the anti-artifact programs used.

The presence of dense materials, especially metals, causes various artifacts in CBCT. The most common of these artifacts are beam-hardening, extinction, and exponential edge artifacts (Kuusisto et al., 2015). These artifacts occur in a variety of ways, from bright lines in the image area to dark areas near metal objects to complete loss of the image (Pauwels et al., 2015; Pauwels et al., 2013). The images included in the study had 100% beam hardening and resulting extinction artifacts in all FOVs. Exponential edge artifacts were observed maximally at 130x90 (49.01%) FOV and minimally at 50x55 (2%) FOV. It is noteworthy that exponential edge artifacts gradually increased from 50x55 FOV to 130x90 FOV, while they decreased at larger FOVs. The reason could be that metals do not enter the field of view at small FOVs, and other artifacts mask this artifact from 130x90 FOV. In clinical practice, it has been suggested that the FOV should be reduced to avoid scanning areas that are susceptible to radiation hardening (e.g., metallic restorations, dental implants) and to reduce the associated artifacts (Bechara et al., 2012). The CBCT device does not have a HU unit as in CT bone healing, grafting, and implantation. complicates comparative tracking of placement (Pauwels et al., 2015). The CBCT device is not designed to be used in the same way. Therefore, in this study, attention is taken to selecting the correct FOV to minimize artifacts caused by metal and foreign bodies.

In CBCT, the aliasing artifact is caused by the divergent effect of the cone beam and is more apparent as a line pattern (moire) toward the periphery of the reconstructed image (Scarfe & Farman, 2008; Schulze et al., 2011; Bhoosreddy & Sakhavalkar, 2014; Makins, 2014).

In this study, most artifacts were found in the 130x90 FOV. Errors related to the device are particularly noticeable in the 130x90 FOV. Staff training is very important to minimize device-related errors that are not related to the technical features of the CBCT.

A limitation of this study is that we focused only on the presence or absence of artifacts. This led to insufficient results in this study, especially regarding the severity of unavoidable artifacts. Scarfe and Farman (2008) reported that beam hardening artifacts that may occur in imaged regions are less visible in smaller image areas and that images should be acquired in this manner. Aydogmus et al. (2021) investigated the effects of FOV and voxel size on artifacts associated with sealing in CBCT images. In their study, they found that the artifact of beam hardening decreased with decreasing FOV and voxel size, but the cupping artifact increased. They attributed this to the reduction of beam hardening artifacts in the image and that the cupping artifact became more visible.

In the same study, Scarfe and Farman (2008) found that there may be degradation of image quality in terms of noise and contrast resolution, particularly due to the higher incidence of scattered radiation in larger FOVs. In this study, it was expected that noise artifacts would increase with increasing image area, but the results we obtained did not confirm this. When we questioned this situation, it turned out that the noise reduction filter (Planmeca AINO) was applied only after a certain date, and the inconsistency was attributed to this situation.

de Oliveira Pinto et al. (2021) found that the least amount of artifacts were found in small areas of the image. Although the number of artifacts per unit was very close in this study, in parallel with this study, the least amount of artifacts were detected in the smallest image area.

Another limitation of this study is that we cannot evaluate all artifacts seen on the CBCT. This is because there is limited information about CBCT artifacts and there is no standard classification. This led us to include only the artifacts we encountered in the study.

The results of this study also demonstrate the importance of choosing the right FOV in the right case by explaining the rate of FOV-related artifacts. The lack of studies in the literature investigating the occurrence of artifacts in different FOVs in CBCT limits the comparison of this data with other studies. Similarly, there are very few studies investigating the effects of CBCT parameters other than FOV on artifacts.

CONCLUSION

In this study examining the frequency of artifacts that occur when the imaging area on the CBCT is changed while other parameters are held constant, it was found that motion artifacts, ring artifacts, practice-related artifacts, and aliasing artifacts occur more frequently at larger FOVs. Scatter and partial volume averages, which are unavoidable artifacts, and beam hardening, extinction, and cupping artifacts, which are acquisition artifacts, were observed in almost all images analyzed.

CBCT is becoming an increasingly important imaging technique in dentistry. Therefore, the causes and frequency of artifacts that occur in CBCT should be well known. It is recommended that more studies be conducted to investigate the effects of CBCT parameters on artifacts. This will help to minimize the problem of misdiagnosis and mistreatment caused by artifacts.

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