Original Article

Effects of artifact removal on cone-beam computed tomography images

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ABSTRACT

Background: Dental implants and metal fillings may cause artifacts in cone-beam computed tomography (CBCT) images and reduce image quality and anatomic accuracy. The purposes of this study are a subjective evaluation of anatomic landmarks and linear bone measurements after applying artifact removal (low–medium) option on CBCT images.

Materials and Methods: In this cross-sectional study, thirty CBCT images from thirty qualified patients were selected in a private radiology center. Low and medium artifact removal was applied to images. Three radiologists assessed the visibility of the mandibular canal, mental foramen, and lamina dura in images. Crestal width and bone length were also measured in three groups of images and was compared by exact McNemar test. ICC test (two-way random model, absolute agreement types) was calculated for comparison of linear bone measurements in three images groups. $P \leq 0.05$ was considered statistically significant.

Results: Percent agreement of determining mental foramen (outline and location), mandibular canal (outline and location), and lamina dura between three groups of images were 100%, 100%, 83.3%, 96.7%, and 56.6%, respectively. The results of exact McNemar test revealed that medium artifact removal group had a statistical difference in lamina dura observation with none and low artifact removal groups ($P < 0.001$). Intraclass correlation coefficient showed no statistical differences in crestal width and bone length between groups ($P < 0.001$).

Conclusion: Applying artifact removal does not affect the visibility of large anatomical structures and linear bone measurements, but delicate structures such as lamina dura may become less clear after artifact removal.

Key Words: Anatomical landmarks, artifact, removal, cone-beam computed tomography

INTRODUCTION

Cone-beam computed tomography (CBCT) is a new technology which is utilized in dental practices immensely.[1-5] Metal objects cause artifacts in computed tomography (CT) images as well as CBCT images by producing nonuniformities in gray level. These artifacts can affect image quality and anatomic accuracy.[6] CBCT artifacts may be physics-based, patient-based, or scanner-based artifacts.[7] The most common artifacts are streak lines that are created

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by beam hardening or insufficient angular sampling. X-ray beam is polychromatic, and low-energy photons are absorbed, when passing the object, and thus X-ray beam gets hard. This phenomenon is called beam hardening which leads to two types of artifacts called cupping artifact and streak lines.[6,8] Streak lines and dark bands are created between the dense objects, for example, between two close implants in the jaw. Since the density of the metal is beyond the range that computer can calculate, so objects such as metal restorations, surgical plates, implants, pins, and radiographic markers produce artifacts.[7] Wedge or bowtie filters, scatter correction algorithm, beam hardening correction software, and anti-scatter grids can be used for correction, but omitting useful information is possible.[7-13]

The purpose of this study was to evaluate the effect of artifact removal on localizing anatomical landmarks and moreover the accuracy of bone width and height linear measurements.

MATERIALS AND METHODS

In this cross-sectional study, archived information of CBCT images in a Maxillofacial Radiology Center was used. Images of thirty patients with oral implants, metal restorations, crowns, or posts were selected. Their information in DICOM format images was achievable [Figure 1]. Images of patients with cleft lip and palate, trauma, bone lesions, and severe bone erosions were excluded from the study. Imaging procedures were performed using ProMax 3D Max (Planmeca, Helsinki, Finland) by 82–84 KVp,

11–12 mA. Then, low and medium artifact remover was applied on each image by Romexis version 2.9.1 software (Planmeca, Helsinki, Finland). In the next step, quite similar panoramic and cross-sectional views were made for three series of CBCT images in each patient [Figure 2].

Three expert radiologists assessed the visibility of five anatomical landmarks as well as the bone height and width in the cross sections. The procedures were repeated 2 weeks later. The visibility of mandibular canal (location and outline), mental foramen (location and outline), and lamina dura was assessed. The crestal bone width and bone height (crest to lower border or mandibular canal) were measured by observers. All ninety images were assessed by the same monitor (Samsung, Sync Master P23700) in a day.

Inter- and intra-observer reliability were also calculated.

Statistical analysis
Statistical software IBM SPSS (statistical package for social sciences) Statistics 21.0 was used for data analysis. The percent agreement of anatomical landmarks visibility was evaluated in three images groups and was compared by exact McNemar test (with STATA: Data Analysis and Statistical Software release 11). Intraclass correlation coefficient (ICC) test (two-way random model, absolute agreement types) was calculated for comparison of linear bone measurements in three images groups. $P \leq 0.05$ was considered statistically significant.
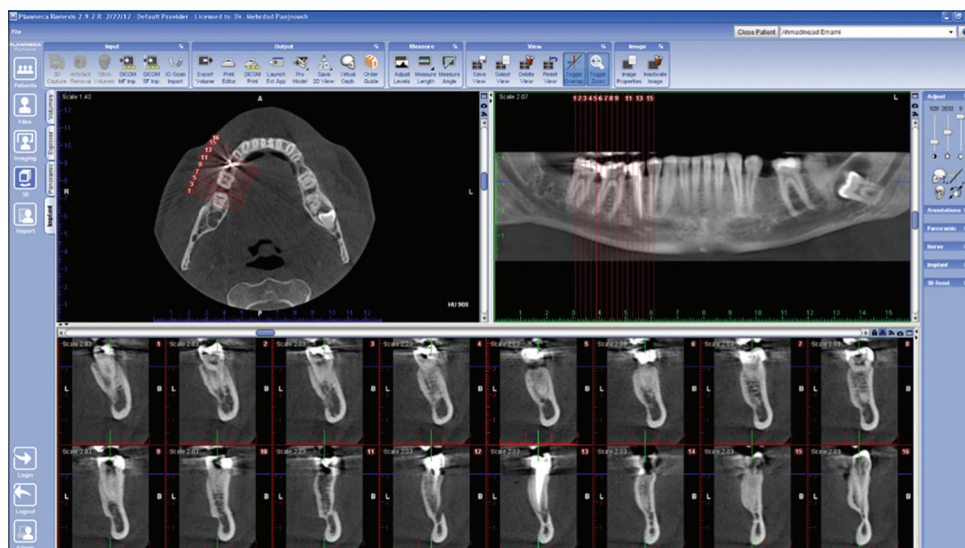

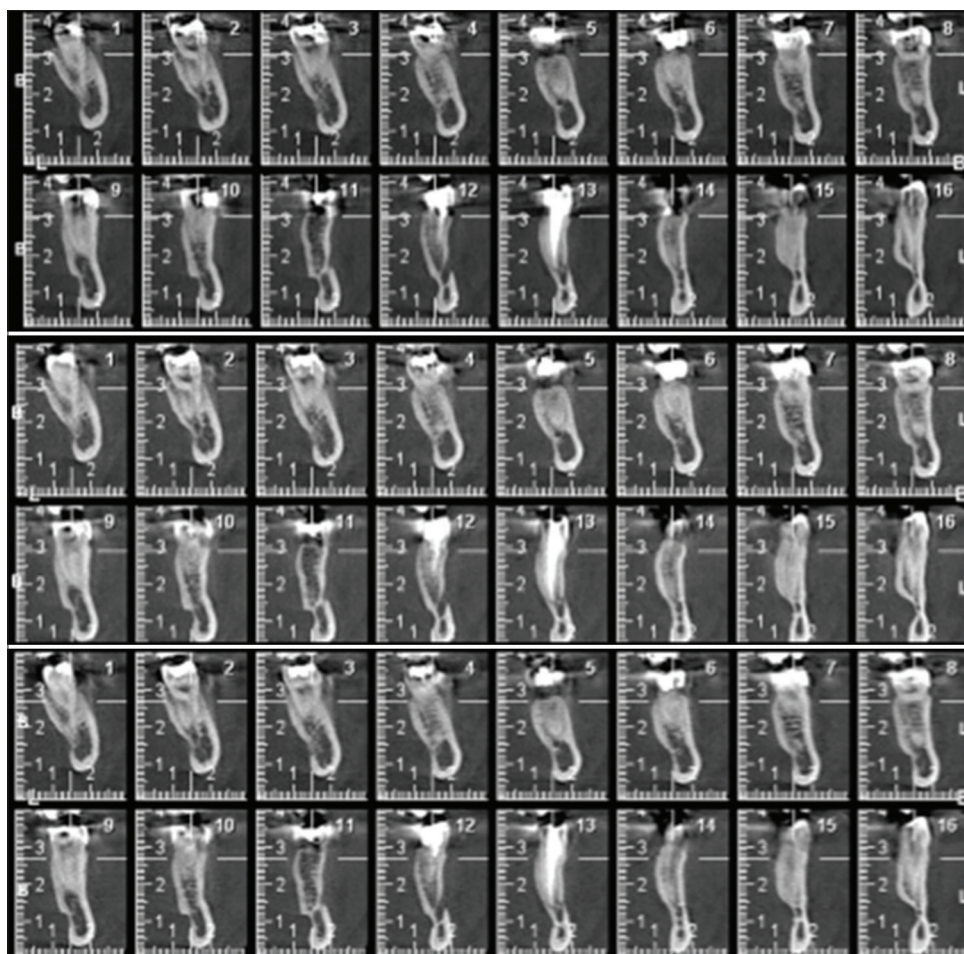**Figure 1:** An example of prepared CBCT image for a patient.

Figure 2: Quite similar panoramic and cross sectional views were made with A(none), B(low), C(medium) artifact removal.

RESULTS

Intraobserver percent agreement for determining anatomic landmarks such as location and outline of mental foramen and location and outline of mandibular canal was more than 83.3%, whereas for lamina dura was more than 60% ($P < 0.001$).

On the other hand, interobserver percent agreement for determining anatomic landmarks (location and outline of mental foramen, location and outline of mandibular canal and lamina dura) was at least 100%, 100%, 96.7%, 86.7%, and 46.7%, respectively. Interobserver percent agreement and confidence interval (CI) 95% for determining anatomic landmarks have been shown in Table 1.

Odds ratio and exact McNemar test showed no statistically significant differences between groups for mental foramen and mandibular canal determination, but there were significant differences between groups for lamina dura visibility ($P < 0.001$). It was decreased by medium artifact removal.

Table 1: Interobserver percent agreement and 95% confidence interval in the diagnosis of anatomical landmarks

Anatomical landmarks	Artifact removal		
	None	**Low**	**Medium**
Mental foramen location			
Percent agreement	100	100	100
95% CI	88.6-100	88.6-100	88.6-100
Mental foramen extent			
Percent agreement	100	100	100
95% CI	88.6-100	88.6-100	88.6-100
Mandibular canal location			
Percent agreement	96.7	96.7	96.7
95% CI	83.3-99.4	83.3-99.4	83.3-99.4
Mandibular canal extent			
Percent agreement	90	90	86.7
95% CI	74.3-96.5	74.3-96.5	70.3-94.6
Lamina dura			
Percent agreement	80	63.3	46.7
95% CI	90.5-62.6	45.5-78.1	30.2-63.8

CI: Confidence interval

Details of odds ratio and *P* value gained by exact McNemar test are seen in Table 2. Percent agreement

Table 2: Percent agreement and 95% confidence interval in the diagnosis of anatomical landmarks between three modes of artifact removal (none, low, and medium)

Anatomical Landmarks	Percent agreement	95% CI
Mental foramen location	100	88.6-100
Mental foramen extent	100	88.6-100
Mandibular canal location	96.70	83.3-99.4
Mandibular canal extent	83.30	66.4-92.6
Lamina dura	56.60	39.2-72.6

CI: Confidence interval

Table 3: Comparison of odds ratio and *P* value obtained from exact McNemar test for the diagnosis of anatomical landmarks between three modes of artifact removal (none, low, and medium)

Comparison of percent anatomical landmarks visibility	OR	*P*
Mental foramen location		
Comparison none with low option	1	1
Comparison none with medium option	1	1
Comparison low with medium option	1	1
Mental foramen extent		
Comparison none with low option	1	1
Comparison none with medium option	1	1
Comparison low with medium option	1	1
Mandibular canal location		
Comparison none method with low	1	1
Comparison none with medium option	0.03	1
Comparison low with medium option	1	1
Mandibular canal extent		
Comparison none with low option	0.03	1
Comparison none with medium option	0.91	0.06
Comparison low with medium option	1.51	0.12
Lamina dura		
Comparison none with low option	1	1
Comparison none with medium option	3.05	<0.001
Comparison low with medium option	3.05	<0.001

OR: Odds ratio

Table 4: Intraclass correlation coefficient for interobserver reliability in bone linear measurement in three artifact removal options

	Artifact removal		
	None (%)	Low (%)	Medium (%)
Bone length	98.4	98.4	97.1
Crest width	92.1	88.3	85.3

and CI 95% in anatomic landmarks determining between three groups of artifact removal are shown in Table 3.

ICC results for crestal width and bone length reliability between three artifact removal groups were 0.937 and 0.993, respectively (*P* < 0.001). ICC results for interobserver and intraobserver reliability

Table 5: Intraclass correlation coefficient for intraobserver reliability in bone linear measurement in three artifact removal options

	Artifact removal		
	None (%)	Low (%)	Medium (%)
First observer			
Bone length	99.9	99.9	99.9
Crest width	99.7	99.2	99.5
Second observer			
Bone length	98.9	97.7	98.8
Crest width	97.2	87.8	87.3
Third observer			
Bone length	99.4	99.2	99.5
Crest width	98.3	89.4	95.5

in bone width and length measurements are shown in Tables 4 and 5, respectively.

DISCUSSION

Metal objects such as dental fillings, implants, and metal crowns can create severe streak artifacts in CBCT images.[14] Most of the artifacts are due to beam hardening or photon starvation.[15] Filtration, proper calibration, anti-scatter grids, and scatters correction algorithms are proposed as remedies. Different algorithms have been written to eliminate artifacts in CT and CBCT images.[7] The effectiveness of these algorithms is shown in many studies.[14-20] Zbijewski and Beekman evaluated Monte Carlo artifact reduction algorithm and stated that all cupping artifacts in the cone-beam micro-CT are almost eliminated by this method.[17]

Zhang *et al*. introduced a three steps computer algorithm to reduce artifacts in CBCT images and stated that the artifacts caused by dental amalgam fillings had been significantly reduced.[14]

Noël *et al*. studied about computational geometric methods that effective in decreasing metal artifacts in the CBCT images and showed that metal artifacts are significantly diminished using these methods.[16]

Bechara *et al*. conducted an investigation on the artifact reduction algorithm (metal artifact reduction [MAR]) in CBCT images taken from the Picasso Master 3D (VATECH). Their results indicated that this algorithm leads to artifacts reduction and increasing signal to noise intensity.[19]

Gong *et al*. compared three types of algorithms reducing metal artifacts including weighted filtered back projection, linear interpolation MAR, and

normalized MAR (NMAR). Two observers assessed the intensity and effect of metal artifacts on the surrounding structures in CT images obtained from patients with metal fillings, using the five-point scale. Their results showed that all three algorithms reduce metal artifacts, but NMAR algorithm was able to significantly reduce more artifacts.[18]

No study has been done about the visibility of anatomical landmarks or linear bone measurements after applying MAR algorithm. The present study evaluated the effect of artifact removal option on CBCT images in locating anatomical landmarks and accuracy of bone linear measurements.

Based on the results of this study, the percent agreement of anatomic landmarks recognition was noticeable except lamina dura between three groups. The results of the exact McNemar analysis showed no statistical significant differences between groups except lamina dura. There were statistically significant differences between none and medium artifact removal as well as low and medium artifact removal option in lamina dura recognition. By applying medium artifact removal option, visibility of lamina dura was declined.

Liang *et al.* compared visibility of anatomical structures (mental foramen, mandibular canal, cortical bone, pulp, dentin, lamina dura, etc.,) between five CBCT scanners and a Multi-Slice CT system. They stated that large anatomical structures such as mental foramen or mandibular canal are seen satisfactory in all systems, while delicate structures such as trabecular bone or periodontal ligament are significantly less visible between different systems.[21] The same findings have been achieved in the present study, approximately.

In the present study, ICC showed no statistical differences in bone linear measurements between groups.

Patient movement, metal artifacts, and soft tissue beam attenuation can reduce image quality and lead to not precise measurements on CBCT images. In this technique, measurement tools perform calculations on midpoints of voxels, so half of the voxels does not considered in the measurement. Although this calculation is not very significant in large structures, it will be noticeable in smaller structures.[22,23]

Lascala *et al.* showed that real distance in skull sites (except for the structures located at the skull base) in CBCT images is reliable.[24] Patcas *et al.* also found that the CBCT is a little more reliable than multi-detector CT for linear measurements.[25] In the present study, linear measurements were compared between three artifact removal states, without any comparison to actual size. It should be noted that effect of artifact removal option can be considered in the diagnosis of root fractures in next studies. Effect of this option either in different radiation condition or in different areas of imaging field can be studied.

CONCLUSION

According to our results, we can conclude that applying of artifact removal options did not exert any changes in large anatomical structures (mental foramen and mandibular canal) observation, but the visibility of delicate anatomical structures (lamina dura) got more difficult. Applying the artifact removal option also did not change the linear measurements of bone.

Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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