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Original Article

Evaluation of the effect of amalgam fillings on the diagnosis of proximal caries using cone-beam computed tomography technique

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ABSTRACT

Background: Diagnosis of dental caries using cone-beam computed tomography (CBCT) may be hindered due to several introduced and inherent artifacts. The aim of this study was to evaluate the effect of amalgam fillings on the accuracy of diagnosis of proximal caries in CBCT.

Materials and Methods: In this *in vitro* study, 102 extracted human teeth (mandibular and maxillary molars and premolars) were used. Six molars were chosen for mesio-occluso-distal amalgam restorations. Before obtaining the CBCT images, the 96 remaining teeth were stabilized in dental sockets of six dry human skulls in a way that the proximal contacts re-established. Thereafter, six of the molar teeth were replaced by the amalgam-restored teeth and the second group of images was then obtained. All images were evaluated by two independent observers in the panorama view and the presence or absence of caries was recorded. For histopathologic investigations, the teeth were cut and assessed by an oral pathologist using a stereomicroscope. The McNemar test was used for comparison between CBCT assessments and histopathologic evaluations ($P < 0.05$ was considered statistically significant). In addition, the receiver operating characteristics curve was utilized to evaluate the diagnostic accuracy in different sections of imaging.

Results: The result sensitivity and specificity of CBCT imaging in the first group of images before placement of the restored teeth were 0.96 and 0.36, respectively. In the second group of images after placement of the restored teeth, these values were 0.78 and 0.18, respectively. Moreover, statistical analysis showed that there is a good agreement in interproximal caries diagnosis between histopathologic and CBCT imaging findings without placement of amalgam restorations ($P < 0.001$). However, this agreement does not exist after amalgam restorations ($P = 0.84$).

Conclusion: Diagnosis of proximal caries using CBCT is not an efficient method where there are amalgam restorations adjacent to the suspected teeth.

Key Words: Cone-beam computed tomography, dental amalgam, dental caries, radiography

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INTRODUCTION

Cone-beam computed tomography (CBCT) is prone to several inherent and introduced artifacts which may cause difficulty in the interpretation of images. "Beam hardening" and "Scatter" artifacts occur when metallic objects exist in the field of imaging.

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X-ray photons that are diffracted from their original path after interaction with the metallic object cause the scattering phenomenon. As an X-ray beam passes through an object, lower energy photons are absorbed in preference to higher energy photons. Beam hardening leads to two types of artifacts: (1) Distortion of metallic structures as a result of differential absorption, known as a cupping artifact, and (2) Streaks and dark bands, which occur between two dense objects, create extinction or missing value artifacts.[1]

Amalgam restorations can be responsible for such artifacts when CBCT images of the dentition and adjacent structures are obtained. These artifacts can interfere with diagnostic evaluations such as the diagnosis of dental caries.[2,3]

Utilizing digital radiographic modalities, including CBCT leads to better diagnosis in various fields of dentistry such as endodontics and restorative dentistry[4-7] and in accordance with other advancements in the field of dentistry, reduces the complications of dental treatments.[8,9] Seker *et al*. study[10] and Kayipmaz *et al*.[11] found that the accuracy of CBCT imaging in occlusal, proximal, and recurrent dental caries is better than the plain radiographs and digital radiographs (phosphor storage plates [PSPs]). On the other hand, Zhang *et al*.[12] have reported that the accuracy of diagnosis of three-dimensional (3D) systems such as ProMax and Kodak 9000 has no significant differences with conventional intraoral PSPs in noncavitated carious lesions detection. Therefore, they do not suggest using CBCT in caries detection. Pauwels *et al*.[13] study concluded that regions in the vicinity of metal rods were moderately or severely affected by artifacts, particularly in the area between the rods.

Esmaeili *et al*.[14] and Isman *et al*.[15] studies noted that artifacts produced by metallic objects such as orthodontic brackets, which occur due to beam-hardening phenomenon, occur in all computed tomography (CT) and CBCT imaging systems and lead to issues in the diagnostic process.

Furthermore, when a patient has a CBCT image for other purposes if CBCT can be also useful in diagnosing caries, the individual no longer requires plain radiographs, and therefore, this can be useful for reducing patients' radiation according to as low as reasonably achievable principle, which states that a minimum amount of radiation must be given to the patient. Moreover, due to the controversial results of previous studies about using CBCT for detecting caries and the effect of metal artifacts on diagnosing process, one important question arises: Are CBCT images reliable for caries detection, especially when they are next to a metal restoration?

This study aimed to evaluate the effect of amalgam restorations on adjacent teeth for detecting proximal caries using CBCT.

MATERIALS AND METHODS

In this *in vitro* study, 102 extracted human permanent posterior teeth (46 premolars and 52 molars) with or without apparent caries were randomly selected. The teeth were extracted due to orthodontics or periodontal problems. All procedures followed were under the Ethical Standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. All procedures performed in the present study were approved by the Ethical Committee of Isfahan University of Medical Sciences (#IR.MUI.RESEARCH.REC.1395.3.247). The present study was funded by Isfahan University of Medical Sciences (395,247) and was performed as a partial requirement for obtaining DDS degree. Any debris and calculus were removed and all teeth were disinfected with 2% hypochlorite solution for 20 min and then stored in normal saline. Six molar teeth were selected and mesio-occluso-distal (MOD) cavities were prepared on them. Then, they were restored with amalgam. The gingival floor of the cavity was placed 2 mm coronal to the cementoenamel junction (CEJ) and the crown of the tooth was sectioned to separate the root and crown 2 mm apical to the CEJ.

The 96 remaining teeth were divided into six groups using the block technique with six blocks with a size of 16 by utilizing the random allocation software 2.0 (Mahmood Saghaei, Isfahan, Iran). Each group included both mandibular and maxillary posterior teeth. The crowns of the teeth were placed in red wax (Polywax, Tehran, Iran) so that the proximal contacts were reestablished. Then, the teeth were mounted on six dry human skulls in their respective dental socket. The teeth were mounted in a way that each group of teeth was placed in their sockets and the appropriate occlusion was established between jaws by MS. Furthermore, the MS glued and fixed the cranium and the mandible to maintain this position [Figure 1].

Figure 1: Frequency percentage of diagnosis of caries level by histopathological findings.

In the next step, each group was examined by a CBCT unit (Soredex, Helsinki, Finland), with fixed exposure parameters of 89 kVp, 7 mA, and 12.6 s.

Then, one molar tooth of each skull was replaced by an amalgam-restored molar tooth. Therefore, all six groups had one restored tooth. CBCT examination with the same exposure condition was carried out for all groups for the second time.

Volumetric CBCT data were reconstructed utilizing On-demand software (On-demand, 3D Dental 1.0.9.1343, USA) and independently examined by two experienced dental radiologists each with 6 years of experience in the radiology field. Both observers assessed the images, in random order, in a dimmed room on the same computer with a 22″ monitor (32-bit, 1440 × 6900 pixels, LG, Seoul, Korea) with a distance from viewer to monitor of approximately 60 cm.

The observers assessed the proximal surface in the panorama view (mesiodistal plane of the tooth). They were asked to state whether they could identify caries, using a five-step confidence scale:

1. Caries definitely present
2. Caries probably present
3. Unsure if caries is present or absent
4. Caries probably do not present
5. Caries definitely do not present.

All the examinations were performed independently twice, with a 2-week interval to minimize the effect of memory and assess the intra-examiner reliability.

Then, for histopathologic examination, the teeth were sectioned to 0.4 mm thickness slices parallel to the long axis of the teeth in the mesiodistal plane. One pathologist examined each section using a stereomicroscope (Trinocular zoom, SMP200) in ×15 magnitudes. Any demineralized white spots or any yellow-brownish discoloration in enamel or dentin was recorded as a carious lesion. Among all slices of a single tooth, the slice, in which the carious lesion has the greatest depth was chosen to score as below:

- 0: Without caries on the proximal surface
- 1: Proximal caries limited to enamel
- 2: Proximal caries extending through dentinoenamel junction or occlusal half of the dentine
- 3: Proximal caries extending to the pulpal half of dentin.

Statistical Package for the Social Sciences (SPSS, version 16, IBM, Armonk, NY, USA) was used for statistical analysis.

Sensitivity, specificity, positive predictive values (PPV), negative predictive values (NPV), false positive ratio (FPR), and false negative ratio (FNR) were computed for each observer in sections before and after amalgam restoration and the mean value of each parameter was reported.

Results of radiologic observations and histopathologic findings were compared with McNemar analysis test to evaluate the accuracy of caries detection in radiographic sections ($P < 0.05$ was considered statistically significant).

RESULTS

The histopathologic findings of the proximal surface of the 96 teeth are presented in Figure 1.

Perfect intra-observer agreement was found for the first and second observer (κ values ranging from 0.895 to 0.936), as well as inter-observer agreement (κ values ranging from 0.857 to 0.931).

Due to strong intra-observer agreement, further calculations were based on the first readings of each observer.

The placement of amalgam fillings caused a decrease in sensitivity, specificity, PPV, and NPV. However, the FPR was significantly increased after the placement of amalgam restorations. The FNR was not significantly different between the two sets of images [Table 1].

The frequency percentage of diagnosis of caries level before and after amalgam filling by CBCT and histopathological findings are shown in Figures 2 and 3.

Table 1: Sensitivity value, specificity value, positive predictive values, negative predictive values, false positive ratio, false negative ratio, of radiographic evaluation before and after amalgam restorations

CBCT	Specificity (%)	Sensitivity (%)	FPR (%)	FNR (%)	PPV (%)	NPV (%)
Before amalgam restored tooth placement	77.5	96.4	22.5	21.4	85.7	93.9
After amalgam restored tooth placement	37.5	78.6	62.5	21.4	63.8	55.6

PPV: Positive predictive values; NPV: Negative predictive values; FPR: False positive ratio; FNR: False negative ratio; CBCT: Cone-beam computed tomography

In Figure 4, the surface below the receiver operating characteristic curve before and after amalgam filling is shown. The surface of the above curve before placement of amalgam fillings was 0.93 ± 0.032 which is statistically significant ($P < 0.001$). After the placement of amalgam restorations, the surface below the curve decreased to 0.69 ± 0.06. However, the surface of the curve is still significant ($P = 0.001$) but its area decreased.

Chi-square test on the abovementioned data also showed that the diagnostic value criteria of CBCT after amalgam restoration significantly decreased ($P = 0.023$).

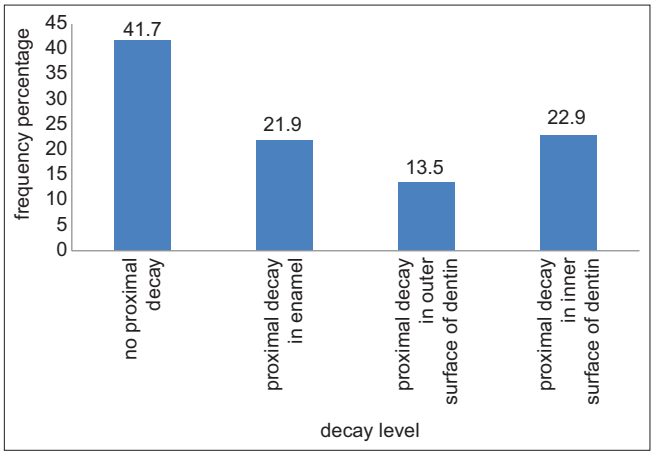

Figure 2: Frequency percentage of diagnosis of caries level by histopathological findings.

DISCUSSION

In the present study, no significant difference existed between pathologic diagnosis and radiographic diagnosis of dental caries before amalgam restoration placement. However, placement of MOD amalgam restorations significantly decreased sensitivity, specificity, and PPV and NPV for caries detection. This finding confirmed that CBCT imaging is less accurate in the diagnosis of proximal caries adjacent to amalgam restorations compared to nonrestored teeth.

Different studies show different results regarding the accuracy of CBCT images for caries detection.

In one study, Zhang *et al.*[12] evaluated the accuracy of proximal caries detection by CBCT, film, and phosphor plates. They used ProMa × 3D, Kodak 9000 3D imaging, phosphor plates, and film, and the gold standard was the histologic examination. The results of their study showed that to detect subtle noncavitated proximal caries, the detection accuracy with the CBCT images was a little better than chance performance and was similar to that with phosphor plate – and film-based intraoral images. Their findings are according to this study. Haiter-Neto *et al.*[16] reported that the sensitivity of Accuitomo and NewTom was 21% and 13%–18%, respectively, in field of view of 6″, 9″, and 12″. The low value in this study may be explained by subtle

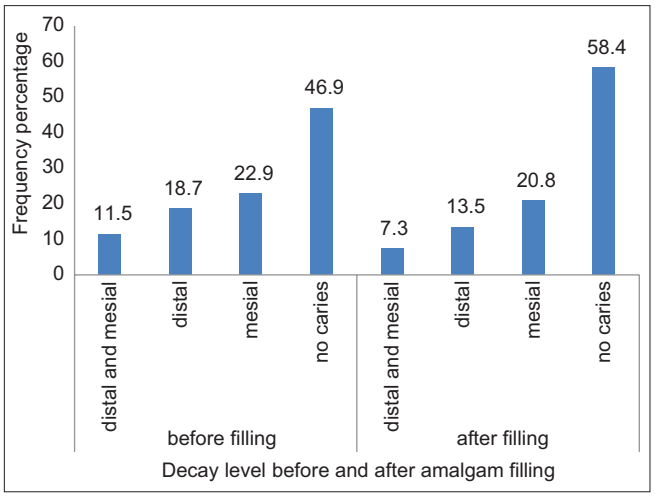

Figure 3: Frequency percentage of diagnosis of caries level before and after amalgam filling by CBCT. CBCT: Cone-beam computed tomography.

caries in teeth samples besides the high percentage of sound to carious surfaces. The low sensitivity value in the present study also would be explained by this reason. Furthermore, the results of their study showed that the NewTom 3G CBCT had a lower diagnostic accuracy for the detection of caries lesions than intraoral modalities and the 3DX Accuitomo CBCT. In an investigation which had been done by Kamburoğlu *et al.*,[17] no differences had been found between different methods of caries detection such

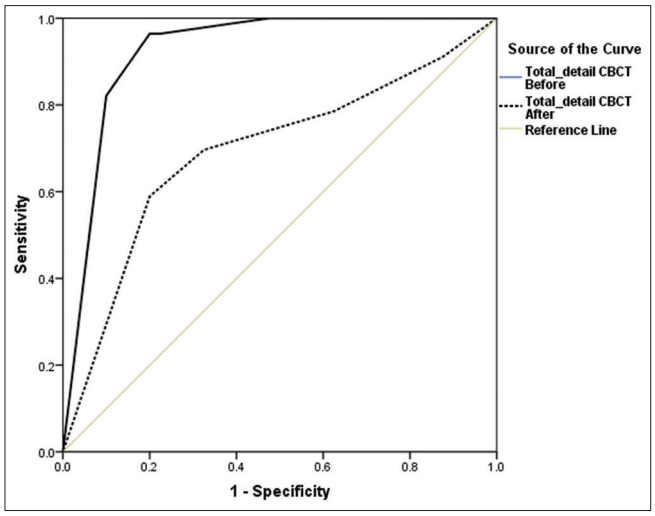

Figure 4: ROC curve for the diagnosis of proximal caries before and after amalgam filling. ROC: Receiver operating characteristic, CBCT: Cone-beam computed tomography.

as intraoral radiographs, intraoral digital radiographs charged coupled device (CCD), and 3D imaging modalities (Accuitomo and Iluma CBCT imaging systems).

In an *in vitro* study, Tarım Ertas *et al*.[18] compared the diagnostic accuracy of different methods in detecting occlusal caries lesions. In their study, CBCT exhibited better performance in detecting deep occlusal caries than other imaging modalities. Another study performed by Sansare *et al*.[19] showed that CBCT is a more accurate method in the diagnosis of cavitated proximal caries compared to bitewing radiography. Moreover, it is expressed in this study that CBCTs taken for other purposes can also be used for cavitated caries.

In a study by Qu *et al*.,[20] AZ-values for five types of CBCT systems were very close together (about 0.5), indicating that CBCT is not a suitable tool for diagnosis of primary proximal caries, that these results are in agreement with the result of this study.

Nabha *et al*.[21] showed that metallic substances such as amalgam create an artifact in 3D imaging which, in turn, cause problems for dental diagnostic purposes. This study also showed that MOD amalgam restorations create the most artifacts in CBCT images.

In a recent study by Kulczyk *et al*.,[22] it was shown that specificity, sensitivity, PPV, and NPV for the diagnosis of caries adjacent to amalgam restorations are 0.64, 47.27, 0.0, and 33.56, respectively. These figures indicate inadequate accuracy of CBCT in the diagnosis of caries which complies with the results of the present study.

Performing the imaging procedure in an optimum *in vitro* condition without motion blur and surrounding soft tissue, which makes the imaging and diagnosis process difficult and misleading in caries detection. In reality, this was the limitation of this study. The authors suggest performing further studies in a clinical environment with a higher number of samples.

CONCLUSION

CBCT imaging is not efficient enough to detect proximal caries adjacent to amalgam restorations.

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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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