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COMPARING THE ACCURACY OF CBCT IMAGING IN DIAGNOSIS OF RECURRENT CARIES UNDER PORCELAIN-FUSED TO METAL CROWNS VERSUS ZIRCONIA CROWNS: AN IN VITRO STUDY

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ABSTRACT

State of problem. The diagnosis of recurrent caries beneath a fixed dental prosthesis using dental radiographs is challenging without removal of the prosthesis. The material of the fixed dental prosthesis is considered one of the factors affecting the accuracy of the radiograph.

Purpose. The purpose of this study is to compare the accuracy of using cone-beam computed tomography images of recurrent dental caries beneath crowns fabricated from porcelain fused to metal and zirconia.

Materials and methods. Ten carious human molars were collected for this research. The same selected teeth were used in 3 groups (n=10). Group CO (n=10) (control group) (teeth imaged with CBCT without any crown), Group ZR (n=10) (teeth imaged with teeth covered with zirconia crown), and Group MC (n=10) (teeth imaged with teeth covered with porcelain fused to metal crown). The CBCT machine was used for imaging the specimens. With the use of 3D OnDemand software, the horizontal surface area of the carious lesion was measured at the same level (near the tooth's CEJ) in each of the three groups.

Results. The mean surface area measurements of caries in groups ZR (7.74 mm^2) and MC (6.47mm^2) were statistically significantly lower than those of group CO (9.98 mm^2) ($P<.05$). While there was no significant difference between surface area measurements of caries in both groups, ZR and MC.

Conclusion. Using cone-beam computed tomography images can detect recurrent caries beneath both zirconia and porcelain-fused-to-metal crowns margins, but the accuracy of measurements was affected significantly by crowns.

KEYWORDS: CBCT, accuracy, PFM, zirconia, crowns

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INTRODUCTION

The most frequent cause of retreatment and replacement in restorative failures is secondary caries under restorations [1]. Early diagnosis of secondary caries is crucial for preventing significant hard tissue loss and improving the prognosis for a good treatment outcome [2-4]. Partial fixed dental prosthesis (FDP) and porcelain fused to metal (PFM) crowns are the preferred treatments for individuals who have lost both esthetics and functionality [5].

FDPs usually have a 10-year survival rate, and their failure is caused by caries [6–9]. Although the materials and methods for creating fixed restorations have evolved, the need to remove them still occurs, and secondary caries is the most frequent cause of this [10]. In order to prevent their failures, a variety of radiographic techniques, including periapical, bitewing, occlusal, and panoramic imaging, are utilized in conjunction with clinical evaluation to evaluate secondary caries next to restorations [11].

Three-dimensional (3D) radiography techniques are required because those existing methods only provide two-dimensional (2D) information. For instance, it would be challenging to identify any carious lesions using standard 2D radiography techniques if they were situated buccally or lingually beneath the restoration [12]. The superimposition of anatomic structures and the noteworthy ability of X-rays to penetrate high-atomic-number metals are two more issues with these radiography approaches[13,14]. The accuracy of traditional radiography procedures is greatly impacted by the radiopacity of materials, which is correlated with their amounts of X-ray absorption and scattering[15,16].

It is challenging to diagnose caries at the crown level of abutment teeth with light and dark streaks since most metals are radiopaque in conventional X-rays and in most radiographic pictures due to their high electron density [17]. The more metal objects and units there are, the more of these metal artifacts there are [18]. Any distortion or inaccuracy in the image that has nothing to do with the topic under study is called an artifact. Due to distortion of the metallic structure, every metallic object that is present in the scanned area may cause an artifact[19]. Beam hardening is the process by which a high-density item that has been scanned absorbs more low-energy photons than high-energy ones. The three most prevalent artifacts caused by beam hardening are cupping, hypodense halo, and streaks.

Clinicians can assess the region of interest in three planes using cone-beam computed tomography (CBCT), a promising radiography technique: axial, coronal, and sagittal. Reduced radiation dose and cost are two benefits of CBCT over medical CT [20]. In order to obtain a complete 3D volume of data, CBCT rotates the patient's head 180 degrees to 360 degrees using a cone-shaped X-ray beam centred on a 2D sensor. Various materials, including PFM, full metal, and full ceramic, are employed for fixed prostheses in order to meet the needs of today's practitioners. These materials vary depending on the qualities of the biomaterials and how the products are processed [21, 22].

Few studies have assessed the accuracy of CBCT in diagnosing recurrent caries under various fixed restorative materials, as far as the authors are aware. In this study, cavities beneath PFM and zirconia crowns have been detected using CBCT. The purpose of this study was to evaluate the diagnostic accuracy of CBCT for the detection of recurrent caries extension beneath the margin of both PFM restorations and zirconia crowns. This was done because caries under fixed restorations can be difficult to detect because of metal artifacts in CBCT and compression of structures in intraoral radiography. According to the null hypothesis, there will not be any significant differences in CBCT accuracy across groups.

MATERIALS AND METHODS

The Department of Oral Radiology, Faculty of Dentistry, Kafr El-Sheikh University, Kafr El-Sheikh, Egypt 2025, was the site of this in vitro investigation. The Kafr El-Sheikh Research Ethics Committee gave its approval (KESIRB200.583).

The G* Power software, version 3.1.9.2, was used to determine the sample size. Given $\alpha = 0.05$, effect size = 0.6, and test power = 0.8. Therefore, 30 (10 in each group) is the suggested sample size [23]. Throughout the cervical and middle thirds of the crown, 10 extracted carious permanent molars had extensive caries that reached the dentin and cavity walls. Due to significant cavities, all of the chosen teeth were extracted. Following extraction, the teeth were cleaned and stored at 37ºC for 24 hours in distilled water. CO, ZR, and MC were the three groups that used the same teeth. All teeth in group CO were imaged with CBCT without any restoration, all teeth in group ZR were imaged with zirconia crowns seated, and all teeth in group MC were scanned with PFM crowns seated.

All selected teeth were fixed to an acrylic block to facilitate its handling and placing it in the CBCT machine during imaging. Before teeth preparation, the caries cavity was filled with wax to a level in line with the anatomy of the crown. All teeth were prepared by a single operator (A T) with 1.5 mm occlusal reduction and 1.5 mm axial reduction following the anatomy.

All prepared samples were scanned by the same operator (A T) using a wireless intraoral scanner (Medit i700, MEDIT Corp., Seoul, Republic of Korea). The restorations were designed using a software program (DentalCAD 3.0 Galway 2021, exocad, Darmstadt, Germany) for both the ZR group and the MC that received the exported Standard Tessellation Language (STL) file. The design for zirconia was full anatomy and milled from monolithic zirconia (zolid, Amann Girrbach, Mäder, Österreich), while the metal was designed by cutting back a virtual layer for porcelain build-up (Kuraray Noritake Dental, Tokyo, Japan) after milling from Co-Cr alloy blocks (Ceramill Sintron, Amann Girrbach, Mäder, Österreich) as shown in Fig. 1.

Fig. (1) An example of prepared tooth and fabricated zirconia and PFM crowns

The wax was eliminated from the caries cavity by using hot water. A total of ten specimens were obtained; the same prepared teeth without any restorations were used for the CO group and imaged with CBCT once and covered with zirconia crowns and imaged with CBCT and finally covered with PFM for the MC group and imaged with CBCT.

Each specimen was then scanned with CBCT for evaluation of the secondary caries under different crown materials. The CBCT machine (Carestream C900, Carestream Health, NY, USA) was used for imaging the specimens. The conditions of exposure were 4 mA and 120 kVp. An 8cm × 8cm field of view (FOV) with a 1mm slice thickness and a 14-second exposure period was employed. The CBCT system automatically calculated the tube potential and tube current from scout views. With the use of 3D OnDemand Software (version 10.0.10.7510, Cybermed, Korea), the specimens' CBCT pictures were recreated. The cross-sectional pictures on axial, coronal, and tangential slices were assessed by a specialist oral and maxillofacial radiologist

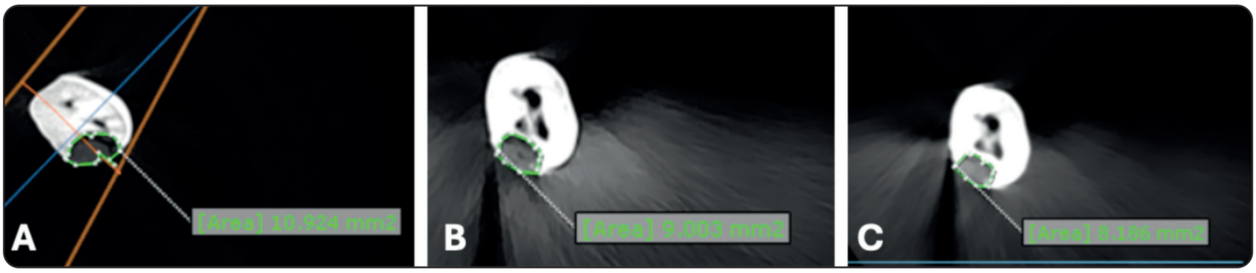

Fig. (2) (A-C) A. An example of the measurement of caries surface area at CEJ without any restoration, B. An example of the measurement of caries surface area at CEJ with a zirconia crown on the tooth, C. An example of the measurement of caries surface area at CEJ with PFM crown on the tooth.

(N H). As seen in Figs. 2(A-C), the horizontal surface area of the carious lesion was measured on the axial image at the same level (near the tooth's CEJ) in each of the three groups. All the obtained data were collected and tabulated.

All statistical measures were performed through the statistical package for social studies (SPSS) version 23 for Windows. For the normality test of data, the Shapiro-Wilk test was performed. Differences in means between treatment groups were investigated by one-way ANOVA. The Tukey HSD test is used to identify which of the pairs of treatments are significantly different from each other. The arithmetic mean is an average description of the central tendency of the results. The standard deviation is a mean of dispersion of the results. The level of significance for all statistical tests was set at a *P*-value < 0.05.

RESULTS

Table 1 showed the descriptive data of mean ± standard deviation for surface area measurement of caries in each group.

Table 2 showed that there was a significant difference between three groups in surface area measurements of caries using CBCT (*P*<.05). In pairwise comparison,

Table 3 revealed that mean surface area measurements of caries in groups ZR (7.74 mm^2) and MC (6.47 mm^2) were statistically significantly lower than those of group CO (9.98 mm^2) (*P*<.05). While there was no significant difference between surface area measurements of caries in both groups, ZR and MC, as shown in Fig. 3.

TABLE (1) Descriptive statistics of surface area in mm^2 of caries among the different experimental groups.

Study Groups	Surface area of caries	
	Mean	Standard Deviation
Group CO	9.98	1.56
Group ZR	7.74	1.36
Group MC	6.47	1.25

TABLE (2) One-way ANOVA Table for surface area in mm^2 of caries among the different experimental groups.

Source	Surface area of caries				
	Sum of Squares	DF	Mean Square	F Statistic	P-value
Between groups	63.17	2	31.59	16.16	<0.05
Within groups	52.76	27	1.95		
Total	115.93	29			

TABLE (3) Tukey HSD results for surface area in mm^2 of caries among the different experimental groups.

Treatments pair	Surface area of caries		
	Tukey HSD Q statistic	Tukey HSD P-value	Tukey HSD interference
CO vs ZR	5.07	0.00365	P < .05 (significant)
CO vs MC	7.94	0.00002	P < .05 (significant)
ZR vs MC	2.87	0.12395	insignificant

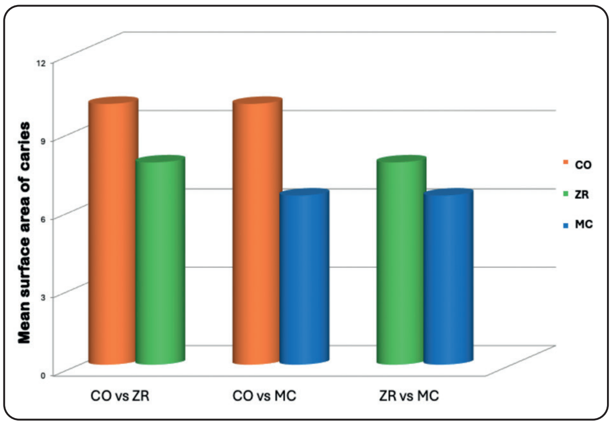

Fig. (3) The means values of surface area of caries among the different experimental groups.

DISCUSSION

The accuracy of CBCT images with PFM and zirconia crown artifacts for the identification of caries at crown margins that extend beneath the crown was compared in this in vitro investigation. One significant benefit of CBCT is its capacity to offer three-dimensional imaging without requiring the removal of fixed prostheses. This non-invasive method reduces the possibility of prosthesis removal-related problems, like harm to the surrounding teeth and periodontal ligament. Very little scientific study has been done on the use of CBCT to identify caries and its extension beneath various crown types. For the sake of standardization, the authors of this study evaluated teeth with PFM and zirconia crowns and contrasted them with teeth that were unrestored at the same level.

For dental diagnostics, CBCT is regarded as a reliable three-dimensional imaging technique. Planning for dental implant procedures, diagnosing and scheduling procedures to treat impacted teeth and maxillofacial pathologies, detecting bone and dental abnormalities, managing dental and maxillofacial trauma, identifying temporomandibular joint disorders, and orthodontic planning are all included in its classic indication [24, 25]. The diagnostic use of CBCT has been examined more recently for the detection of marginal discrepancies in restorations and dental caries, among other conditions [26, 27]. The previously acquired images can be utilized to evaluate certain dental conditions, even though their original indication might not have been for these uses.

The development of artifacts, which are characterized as any picture distortion that is absent from the object being analyzed, is one of the drawbacks of CBCT that could account for its low sensitivity and accuracy rates for the diagnosis of caries extension [28, 29]. Metal or high-density materials are the primary source of artifacts due to radiation beam hardening, which enhances x-ray absorption [29]. The development of hypodense bands, hyperdense streaks, and deformed objects consequently modifies the final image, jeopardizing the diagnosis in the vicinity [30–32].

The teeth that were extracted for this investigation had Grade 6 caries according to the International Caries Detection and Assessment System (ICDAS), which included the pulp cavity and cavity walls throughout the cervical, middle, and occlusal third of the crown. By using the same tooth to fabricate both PFM and zirconia crowns, standardization was achieved. Instead of using genuine carious teeth, Murat et al. [34] and Bilgin et al. [33] created standardized artificial carious lesions. Furthermore, the current study's accuracy assessment relies on measuring the caries surface area in a fixed horizontal cross section, which differs from earlier evaluation scales used in earlier research, such as gray values [23, 34].

The current study's findings demonstrated that the precision of caries dimension measurements in CBCT is influenced by PFM and zirconia crowns. The caries surface area measurements at the same level in the zirconia crown (7.74 mm^2) and PFM (6.47 mm^2) were significantly smaller than the control group's (9.98 mm^2) dimension ($P<.001$), while the zirconia crown's caries surface area measurements were smaller than the PFM's but not significantly different. The null hypothesis was thus partially rejected.

In comparison to the size of cavities for the same tooth at the same level without a crown, the surface area of caries was reduced by both zirconia and PFM crowns with a statistically significant difference. The capacity to detect caries in the cervical zone is mostly impacted by the radiopacity of restorative materials, which is dependent on the atomic number [23]. This outcome is in line with a study by Bilgin et al. [33], in which they used CBCT to assess the caries under a single crown of PFM, zirconia, and lithium disilicate ceramic crowns and found a substantial difference between the caries images. Vedpathak et al., [23] on the other hand, came to the conclusion that CBCT can be utilized as a post-treatment diagnostic method to find cavities beneath fixed prostheses without taking them out.

One of the limitations of this study was that it was an in vitro study, which is different from an oral situation in that CBCT images can be affected by other parameters. Another limitation: only a single crown unit was evaluated for CBCT diagnosis, and the specimens were not fixed using luting cement, which can also affect radiopacity. Future studies are recommended to evaluate CBCT for the detection of caries and accuracy of measurements by using a greater number of units with and without artifacts.

CONCLUSION

Within limitation of the present study

- CBCT images can detect recurrent caries beneath both zirconia crown and PFM crown margins.
- The measurements of caries surface area were affected significantly by zirconia and PFM crowns.

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