Original Article

Cone Beam Computed Tomography- An Effective Tool in Detecting Caries Under Fixed Dental Prostheses

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ABSTRACT

Introduction: Caries under restorations is the most common reason for re-treatment and replacement in restorative failures. To avoid failures of fixed dental prostheses, it is important to diagnose caries under it earlier. Without image degradation and metal artifacts, Cone Beam Computed Tomography (CBCT) can be the solution to detect caries without removing fixed dental prostheses.

Aim: The aim of this study was to determine the efficacy of CBCT in detecting caries under fixed dental prostheses.

Materials and Methods: Each specimen was scanned with CBCT for evaluation of secondary caries under fixed prostheses. Exposure parameters were 60 kVp and 3mA. Field of View (FOV) used was 8cm X 8cm. According to International Caries Detection and Assessment System (ICDAS) criteria, six Grade 6 carious extracted teeth were selected. All teeth were prepared with four different specimens - full metal, metal-ceramic, full ceramic and metal-acrylic crowns for each tooth. Each specimen was scanned by CBCT. T-test was performed for mean gray value differences between caries and noncaries regions of each material. Gray values were recorded and evaluated for different parameters using two-way analysis of variance.

Results: Significant differences were found with respect to material (full metal, metal-ceramic, full ceramic and metal-acrylic) and situation (caries/noncaries) (p<0.001). There were no significant differences with respect to location (anterior or posterior). Mean gray values of caries and noncaries regions were found to be different for each material.

Conclusion: CBCT can be used as a post-treatment diagnostic technique for detecting caries under fixed prostheses without removing it.

INTRODUCTION

Secondary caries under restorations is the most common reason for re-treatment and replacement in restorative failures [1]. To prevent severe destruction of hard tissue and also to enhance the prognosis for a successful treatment outcome, it is important to diagnose secondary caries earlier [2-4]. For patients with esthetic and functional loss, the treatment of choice is metal crowns and partial Fixed Dental Prostheses (FDP) [5]. The survival rate of FDP is usually of about 10 years and caries is the reason for their failure [6-9]. Even though there are evolution of the materials and techniques used to fabricate fixed restorations, the need to remove them still arises and the most common reason for this is secondary caries [10]. To diagnose secondary caries adjacent to restorations, various radiographic techniques are used such as peri-apical, bitewing, occlusal and panoramic imaging together with clinical examination in order to avoid their failures [11]. Since these radiographic techniques provide only two-dimensional (2D) information, there is a need for three-dimensional (3D) radiographic techniques. For example, if there is any carious lesion located buccally or lingually beneath the restoration, then it would be difficult to detect such conditions using routine 2D radiographic techniques [12]. Another problem with these radiographic techniques is the superimposition of anatomic structures as well as X-rays are notable to penetrate high-atomic-number metals [13,14]. As radiopacity of materials is related to their levels of absorption and scattering of X-rays it has a significant effect on the accuracy of conventional radiographic techniques [15,16]. Most of the metals are radiopaque in conventional X-rays and in most of the radiographic images because of their high electron density making it difficult to diagnose caries at the crown level of abutment teeth with light and dark streaks [17]. These metal artifacts increase in the presence of greater numbers of metal objects and/

or units [18]. An artifact is any distortion or error in the image that is unrelated to the subject being studied. Any metallic object if present in scanned area can produce artifact due to distortion of metallic structure [19]. The scanned high density object absorbs more low-energy photons than high-energy photons, which is called beam hardening. Cupping, hypodense halo and streaks are the most commonly occurring artifacts which are produced because of beam hardening.

CBCT is a promising radiographic technique which enables clinicians to evaluate the region of interest in three planes, axial, coronal and sagittal. Advantage of CBCT over medical CT is reduced radiation dose and reduced cost [20]. CBCT uses a cone shaped X-ray beam centered on a 2D sensor to scan a 180°-360° rotation around the patient's head to acquire a full 3D volume of data. As per the need of today's practitioners', various materials are used for fixed prostheses such as porcelain-fused-to-metal, full metal and full ceramic which differ according to the properties of the biomaterials as well as the processing of the products [21,22]. In this study, CBCT was used to detect caries under FDP of full metal, metal ceramic, full ceramic and metal acrylic. Because of the difficulties in detection of caries under fixed restorations due to the compression of structures in intraoral radiography and metal artifacts in CBCT, the aim of this study was to determine the efficacy of CBCT in detecting caries under fixed dental prostheses.

MATERIALS AND METHODS

This in-vitro study was conducted at the Department of Oral Medicine and Radiology, MGV's KBH Dental College and Hospital, Nashik, India from October 2015 to December 2015. According to International Caries Detection and Assessment System (ICDAS) criteria [Table/Fig-1] [23], inclusion criteria of the study was six extracted carious permanent teeth (Tooth no. 11, 12, 23, 16, 26,

47) with Grade 6 caries that extended to dentin and the pulp cavity and cavity walls all along the cervical, middle and occlusal third of the crown. All the selected teeth were without any restoration and got extracted because of extensive caries and mobility. Extracted teeth were then cleaned and kept in distilled water for 24 hours at 37ºC. During teeth preparation, the caries cavity was filled with wax to a level in line with the preparation outline making it a full crown structure [Table/Fig-2]. Impression was taken with a silicon impression material and sent to a technician to fabricate a crown of full metal, metal ceramic, full ceramic and metal acrylic materials. From the caries cavity, the wax was removed by using hot water. A total of five crown specimens were obtained: One full metal (16), One metal ceramic (12), One full ceramic (11), One metal acrylic (47) and Two prepared teeth, One anterior (23) and One posterior (26) without any restorations as the control group
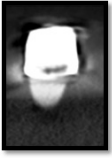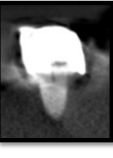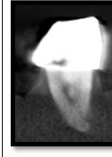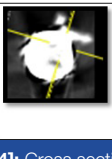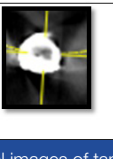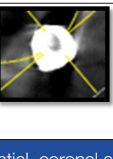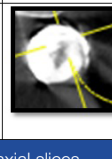
Code	Description	Pictorial Presentation
0	Sound tooth surfaces	
1	First visual change in enamel	
2	Distinct visual change in enamel	
3	Initial breakdown in enamel due to caries with no visible dentin	
4	Surface with underlying dark shadow from dentin	
5	Distinct cavity with visible dentin	
6	Extensive distinct cavity with visible dentin	

[Table/Fig-1]: International Caries Detection and Assessment System (ICDAS).

[Table/Fig-2]: The caries cavity was filled with wax making it a full crown structure.
[Table/Fig-3]: A cast with crowns of full metal, metal ceramic, full ceramic and metal acrylic materials.

[Table/Fig-3]. We inserted the cast with all crown specimens into water in order to imitate oral soft tissues. Each specimen was then scanned with CBCT for evaluation of the secondary caries under fixed prostheses. Orthophos XG model of Sirona CBCT machine was used for this study. 3D Exposure parameters were 60 kVp and 3mA. Field of View (FOV) used was 8cm X 8cm with 1mm slice thickness and exposure time of 14 seconds. Tube potential and tube current were automatically determined from scout views by the CBCT machine. The CBCT images of the specimens were reconstructed with Galileos Software [Table/Fig-4]. Two specialized oral and maxillofacial radiologists separately evaluated the cross-sectional images on axial, coronal and tangential slices. The ability of CBCT imaging to display differences in attenuation is related to the ability of the detector to reveal subtle contrast differences. This parameter is called the bit depth of the system and determines the number of shades of gray available to display the attenuation [19]. All gray values of caries and dentin were recorded from axial, coronal and tangential slices. The mean of these three gray values of caries and dentin was then calculated respectively for each image and considered as Mean Gray Value (MGV) at that site. All the obtained data was collected, tabulated and entered in MS excel and analyzed by using SPSS version 20.0.0 software. Pearson's correlation was used to assess inter-examiner reliability. Two-way ANOVA was used for statistical analysis. Independent sample t test was done for individual evaluation of caries and dentin differences.

Section	Metal Acrylic	Full Ceramic	Metal Ceramic	Full Metal
Tangential				
Coronal				
Axial				

[Table/Fig-4]: Cross sectional images of tangential, coronal and axial slices.

RESULTS

MGVs of caries versus healthy dentin of control group i.e. 23 and 26 were 1089 ± 129.8 versus 2397.5 ± 118.13 of caries and 1193 ± 131.91 versus 2415.7 ± 120.27 of dentin respectively. MGVs of caries of full metal, metal ceramic, full ceramic and metal acrylic are 2440 ± 207.25, 2352.7 ± 249.04, 2012 ± 216.64 and 2055 ± 84.113 respectively. MGVs of healthy dentin of full metal, metal ceramic, full ceramic and metal acrylic are 2820.3 ± 125.94, 2731 ± 174.07, 2933.7 ± 93.388 and 2568.7 ± 169.19 respectively. Means and standard deviations of MGVs are listed in [Table/Fig-5].

Two-way analysis of variance showed significant differences with respect to material (full metal, metal ceramic, full ceramic, metal acrylic) ($p < 0.001$); and situation (caries or noncaries) ($p < 0.007$), whereas no significant difference was found with respect to location (anterior/posterior) [Table/Fig-6]. MGVs for caries and healthy dentin regions were found to differ significantly between four different materials ($p < 0.001$) [Table/Fig-7].

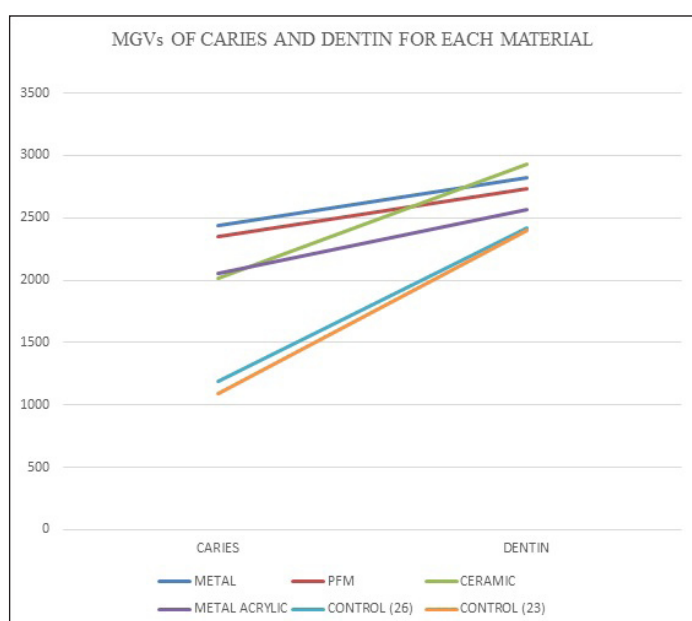| MATERIAL	CARIES	DENTIN
Full Metal	2440 ± 207.25	2820.3 ± 125.94*
Metal Ceramic	2352.7 ± 249.04	2731 ± 174.07*
Full Ceramic	2012 ± 216.64	2933.7 ± 93.388*
Metal Acrylic	2055 ± 84.113	2568.7 ± 169.19*
Control (23)	1089 ± 129.8	2397.5 ± 118.13*
Control (26)	1193 ± 131.91	2415.7 ± 120.27*

[Table/Fig-5]: Mean gray values of the material tested for caries and dentin.
Independent sample t test
*Statistically significant difference at p < 0.05

PARAMETERS	SUM OF SQUARES	df	MEAN SQUARE	F	p-value
Anterior/ Posterior	9004.8	2	4502.4	3.814	0.1901
Metal/PFM/ Ceramic/ Metal Acrylic	409158	3	136386	25.299	0.0012
Caries/Dentin	35467	2	17734	3.174	0.0079

[Table/Fig-6]: Two-way analysis of variance for different parameters.
a) Metal - full metal, b) PFM - porcelain fused to metal (metal ceramic), c) Ceramic - full ceramic

[Table/Fig-7]: Mean gray values of caries and dentin for each material.
a) Metal - full metal, b) PFM - porcelain fused to metal (metal ceramic), c) Ceramic - full ceramic

DISCUSSION

There are very few scientific researches on the detection of different types of caries at different levels beneath different types of FDP using CBCT. In this study, we assessed teeth with full metal, metal ceramic, full ceramic, metal acrylic and compared with teeth without restorations at different levels and for different types of caries. In a previous study, researchers evaluated the caries under a single crown of lithium disilicate ceramic crown, zirconia ceramic crown, and metal ceramic crown using CBCT and determined significant differences between the caries and dentin images [5]. In the present study, we increased the numbers of specimens i.e., we used four different specimens of full metal, metal ceramic, full ceramic and metal acrylic in order to increase the sensitivity of the data. Even with the increased numbers and different types of specimens, the results were found to be similar to the findings of Bilgin et al., [5]. Murat et al., [11] made standardized artificial carious lesions instead of using natural carious teeth. They prepared specimens to imitate caries cavitation at the cervical third under various types of restorations of composite resin, amalgam, complete metal crown, and thermoplastic polymer. They assessed the performance of intraoral film and digital radiography and two different CBCT systems for the visibility of artificial buccal recurrent caries lesions under various restorative materials. They found

that CBCT outperformed intraoral radiography in detection of artificial buccal recurrent caries under restorations. In the present study, extracted teeth with ICDAS Grade 6 caries that extended to dentin, including the pulp cavity and cavity walls all along the cervical, middle, and occlusal third of the crown were used and we evaluated caries detection under the four different crown systems using CBCT. Nummikoski et al., observed that the radiopacity of restorative materials, which depends on the atomic number, has a primary effect on the ability to detect caries in the cervical zone [16]. The present study showed that, with advanced digital radiographic techniques, the middle portion of the tooth under a fixed restoration could be diagnosed in addition to the cervical zone. As the number of metal restorations in the oral cavity increases, metal artifacts and image degradation (as light streaks) increases [11,18]. However, although metal restorations hinder the visualization of caries under fixed restorations, the present study showed that caries under all four types of restorations can be detected and characterized. Many authors described that radiopacity of the restorative materials aids in detection of caries in cervical zone. This radiopacity is associated with atomic number of the material. However, the high atomic number leads to degrade the image [11,16,18]. Thus it has been suggested that by reducing field size or modifying the patient position would help to avoid the scanning region susceptible to beam hardening [24-27]. In this study, we used small FOV i.e., 8cm X 8cm which in turn avoided the chances of metal artifacts. Our study also indicates that with the help of CBCT with smaller FOV, it would be possible to detect even middle and cervical portion of tooth beneath fixed dental prosthesis.

LIMITATION

One of the limitations of this study was that only a single crown unit was evaluated for CBCT diagnosis. Future studies should be undertaken to evaluate CBCT for the detection of caries by using a greater number of metal units. Another limitation was that the specimens were not fixed using luting cement, which can also affect radiopacity. This should motivate other researchers to review previous CBCT scans in order to determine the possibility of detecting caries with FDPs under different conditions.

CONCLUSION

CBCT enables the detection of ICDAS Grade 6 caries under the crowns of all four materials investigated. Ceramic crowns allowed more effective detection of secondary caries as compared to other three materials. The radiopacity of the restorative material have a significant effect on accuracy with conventional but not with advanced three dimensional radiographic techniques. Efforts are needed to improve CBCT reconstruction algorithms, with a target on reducing artifacts induced by dense dental materials so that we can get an enhanced image quality at low radiation doses. CBCT scans taken for other reasons can be used as a post-treatment diagnostic technique for detecting caries under fixed dental prostheses. Since the routine 2D radiographic techniques cannot detect caries under fixed metallic dental prostheses, there is a need for CBCT (3D) radiographic techniques to detect such carious lesions. Moreover, it is a solution for diagnosing secondary caries without the removal of fixed prosthesis. Also chances of tooth fracture during fixed dental prosthesis removal can be avoided with less discomfort to patients. Further studies should be carried out to evaluate caries lower than ICDAS Grade 6 along with larger sample size and multiple unit prostheses.

REFERENCES

[1] Mamai-Homata E, Margaritis V, Koletsi-Kounari H, Oulis C, Polychronopoulou A, Topitsoglou V, et al. Tooth loss and oral rehabilitation in Greek middle-aged adults and senior citizens. *Int J Prosthodont*. 2012;25:173-79.

[2] Arnold WH, Sonkol T, Zoellner A, Gaengler P. Comparative study of in vitro caries-like lesions and natural caries lesions at crown margins. *Jr Prosthodont*. 2007;16(6):445-51.

[3] Ando M, Gonzalez-Cabezas C, Isaacs RL, Eckert GJ, Stookey GK. Evaluation of several techniques for the detection of secondary caries adjacent to amalgam restorations. *Caries Research*. 2004;38(4):350-56.

[4] Okida RC, Mandarino F, Sundfeld RH, de Alexandre RS, Sundefeld ML. In vitro evaluation of secondary caries formation around restoration. *Bulletin of Tokyo Dental College*. 2008;49(3):121-28.

[5] Bilgin MS, Aglarci OS, Erdem A. Post-treatment diagnosis of caries under fixed restorations: A pilot study. *J Prosthet Dent*. 2014;112:1364-69.

[6] Lemke HUVM, Inamuson K, Farman A. CARS '98 Computer Assisted Radiology and Surgery. Amsterdam: Elsevier; 2007:792-797.

[7] Tan K, Pjetursson BE, Lang NP, Chan ES. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. *Clin Oral Implants Res*. 2004;15:654-66.

[8] Creugers NH, Kayser AF, van't Hof MA. A meta-analysis of durability data on conventional fixed bridges. *Community Dent Oral Epidemiol.* 1994;22:448-52.

[9] Scurria MS, Bader JD, Shugars DA. Meta-analysis of fixed partial denture survival: Prostheses and abutments. *J Prosthet Dent.* 1998;79:459-64.

[10] Sharma A, Rahul GR, Poduval ST, Shetty K. Removal of failed crown and bridge. *J Clin Exp Dent.* 2012;4:167-72.

[11] Murat S, Kamburoglu K, Isayev A, Kursun S, Yuksel S. Visibility of artificial buccal recurrent caries under restorations using different radiographic techniques. *Oper Dent.* 2013;38:197-207.

[12] Kandemir S. The radiographic investigation of the visibility of secondary caries adjacent to the gingiva in Class II amalgam restorations. *Quintessence International.* 1997;28(6):387-92.

[13] Farman AG, Farman TT. A comparison of 18 different X-ray detectors currently used in dentistry. *Oral Surg Oral Med Oral Pathol Oral Radiology Endod*. 2005;99:485-89.

[14] Kamburoglu K, Ilker Cebeci AR, Grondahl HG. Effectiveness of limited cone-beam computed tomography in the detection of horizontal root fracture. *Dent Traumatol.* 2009;25:256-61.

[15] Okuda Y, Noda M, Kono H, Miyamoto M, Sato H, Ban S, et al. Radio-opacity of core materials for all-ceramic restorations. *Dent Mater J.* 2010;29:35-40.

[16] Nummikoski PV, Martinez TS, Matteson SR, McDavid WD, Dove SB. Digital subtraction radiography in artificial recurrent caries detection. *Dentomaxillofac Radiol.* 1992;21:59-64.

[17] Chandler HH, Bowen RL, Paffenbarger GC. Physical properties of a radiopaque denture base material. *J Biomed Mater Re*s. 1971;5:335-57.

[18] Tohnak S, Mehnert AJ, Mahoney M, Crozier S. Dental CT metal artifact reduction based on sequential substitution. *Dentomaxillofac Radiol*. 2011;40:184-90.

[19] White SC, Pharoah MJ. Oral radiology. Principles and interpretation. 7th ed. St. Louis Missouri: Mosby;2014:187-91.

[20] Schulze RK, Berndt D, d'Hoedt B. On cone-beam computed tomography artifacts induced by titanium implant*s. Clin Oral Implants Res.* 2010;21:100-07.

[21] Esmaeili F, Johari M, Haddadi P, Vatankhah M. Beam hardening artifacts: Comparison between two cone beam computed tomography scanners. *J Dent Res Dent Clin Dent Prospects*. 2012;6:49-53.

[22] Vasconcelos KF, Nicolielo LF, Nascimento MC, Haiter Neto F, Boscolo FN, Van Dessel J, et al. Artifact expression associated with several cone-beam computed tomographic machines when imaging root filled teeth. *Int Endod J*. 2015;48(10):994-1000.

[23] Ismail AI, Sohn W, Tellez M, Willem JM, Betz J, Lepkowski J et al. Risk indicators for dental caries using the International Caries Detection and Assessment System (ICDAS). *Community Dent Oral Epidemio*l. 2008;36:55-68.

[24] Abramovitch K, Rice DD. Basic principles of cone beam computed tomography. *Dent Clin North Am*. 2014;58:463-84.

[25] White SC. Cone beam imaging in dentistry. *Health Physics*. 2008;95(5):628-37.

[26] Wassell RW, Walls AW, Steele JG. Crowns and extra-coronal restorations: Materials selection. *Br Dent J*. 2002;192:199-202:205-211.

[27] Höland W, Schweiger M, Watzke R, Peschke A, Kappert H. Ceramics as biomaterials for dental restoration. *Expert Rev Med Devices*. 2008;5:729-45.

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