ORIGINAL ARTICLE

Detection of Caries under Fixed Prosthodontic Restorations Using Cone-beam CT: A Meta-analysis

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Abstract

Background: Secondary caries is the most common cause of failure of fixed prosthodontic restorations and radiography is often depended upon for the detection of caries under these restorations. Current radiographic techniques are specific, but they lack sensitivity. The inherent limitations in two-dimensional radiography led to the development of computed tomographic imaging techniques. Hence, this review aims to compile the available evidence on the utility of cone-beam computed tomography (CBCT) for detecting caries under fixed restorations.

Materials and methods: Electronic databases were screened for eligible studies using an appropriate search strategy. Full-texts were obtained and necessary data were extracted. The risk of bias of included studies was assessed using New Castle Ottawa Scale. The mean gray values obtained on CBCT were recorded on a Forest Plot using RevMan 5 in Non-Cochrane mode. Mean difference with 95% confidence interval was used as the effect estimate of the mean gray values. Heterogeneity was assessed using chi-square and I^2 tests

Results: Three studies were included. Although there was significant heterogeneity between the studies as observed using the I^2 values, a statistically significant difference in mean gray values between caries and dentin was observed when CBCT was used under lithium disilicate, zirconia, and metal-ceramic restorations. This indicates that caries can be diagnosed with accuracy under these restorations without the need for removing the restoration. The problem of metal artifacts in CBCT can be reduced if the field of view is small.

Conclusion: The results seem to indicate considering CBCT as a possible option if secondary caries is suspected, and in patients with high caries risk. If appropriately used with clinical judgment in high caries risk patients, a possible tooth loss could be prevented.

Keywords: Cone-beam computed tomography, Fixed restoration, Secondary caries.

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Introduction

Dental cone-beam computed tomography (CBCT) is used when intraoral and periapical dental X-rays are inconspicuous in representing the exact picture of a three-dimensional dentoalveolar structure. It is an evolution from conventional computed tomography with the advantage of low radiation exposure, higher contrast images, rapid scan time, and lower cost.[1] Although digital intraoral imaging has been a breakthrough, image geometry has always been a concern, including that in panoramic technology.[2] Historically, the use of CBCT has been primarily limited to the temporomandibular joint, implant site examination, and other maxillofacial applications with previous studies reporting no consistency in the system used, technical device properties, setting, and other parameters of the CBCT system.[3] The 10-year survival rate of fixed prosthodontic restorations has been reported to be around 85–95% depending on the material (metal, ceramic) and the type of restoration (crowns, veneers, bridges, inlays, onlays),[4–7] and secondary caries has been identified as the most common cause of failure.[8] The two-dimensional radiographic methods have demonstrated low sensitivity, higher specificity, and high intraoperator variability for the detection of secondary caries under restorations. In addition to this, metal restorations are radiopaque making it further challenging.[1] Early detection of caries under these restorations could possibly help in initiating strategies that can prevent tooth loss. Considering the disadvantages of two-dimensional intraoral radiographs, CBCT has been tried in various studies to detect caries underneath fixed restorations. This meta-analysis is aimed to address the use of CBCT to detect secondary caries under fixed prosthodontic restorations.

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Materials and Methods

Information and Search Strategy

The protocol for this review was registered with the International prospective register of systematic reviews (PROSPERO) with the registration number CRD42016053739. The review protocol can be accessed at https://www.crd.york.ac.uk/PROSPERO/register_new_review.asp.

A literature search was conducted using the search strategy: (((((cone-beam OR cone beam) computed tomography)) OR (CBCT OR CT)) AND (caries OR secondary caries)) AND (fixed prosthodontic restorations OR bridges OR FPD OR crowns). The keywords were also used in combinations for the search. The search was completed

on January 24, 2021. The primary database used was Medline (via PubMed), Cochrane central register of clinical trials (CENTRAL), and Database of Abstracts of Reviews of Effects (DARE). This search was further supplemented by hand searching of relevant references from review articles and other eligible studies. No limits were applied to the year of study but only studies published in the English language were included.

Eligibility Criteria

Randomized controlled trials, observational studies, prospective or retrospective studies, case reports, case series which are *in vivo* or *in vitro*, evaluating CBCT for the detection of caries under fixed restorations like crowns, bridges, veneers using ceramic, metal, or zirconia were included for the review.

Inclusion Criteria

- Participants—*In vivo* or *in vitro* studies evaluating caries in natural teeth coded using International Caries Detection and Assessment System (ICDAS), under permanent ceramic, metal, or porcelain fused to metal (PFM) fixed prosthetic restoration of any type.
- Intervention—CBCT to detect caries under fixed prosthodontic restorations and expressed as mean gray values.
- Comparison—CBCT system images using any field of view to detect normal enamel or dentin expressed as mean gray values.
- Outcome—Differences in mean gray value as detected by cone-beam tomography between caries and enamel or dentin.

Study Procedure

All the authors independently screened the above-mentioned databases for studies and independently reviewed abstracts for suitability. Full-texts were obtained for all eligible studies. References of these full-length papers were also screened. A pretested data extraction form was created and both the authors independently extracted the following data from each eligible study: trial site, year, trial methods, participants, interventions, and outcomes. A disagreement between the authors was resolved through discussion. The present meta-analysis was conducted and presented in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[9] The quality of the included studies was assessed using the New Castle Ottawa scale for nonrandomized studies.[10] The heterogeneity between the studies in direct comparison was assessed using chi-square and I^2 tests for direct comparison meta-analysis. The random-effects model was used for both direct and mixed treatment network meta-analysis. Mean difference at 95% confidence interval was used as the effect estimate. The meta-analysis was carried out using RevMan 5.0 tool in non-Cochrane mode.[11]

Results

Search Results

A total of 14 studies were identified after the title and abstract screening, of which only one was found eligible on the title and abstract screening. Two more papers were identified on further screening of the related literature. The full-length text was obtained for all three papers and all three were found eligible[12–14] to be included for the final review.

Key Features of Included Studies

All three studies were *in vitro* studies on fixed prosthodontic restorations fabricated on extracted natural teeth with caries graded using ICDAS. Out of the three studies, one was a pilot study,[12] which was later continued and published.[13] The PRISMA flow diagram is presented in Flowchart 1. All three studies evaluated the detection of caries under full metal, metal-ceramic, and all-ceramic restorations compared to natural dentin. Additionally, full metal and metal acrylic were also studied in Vedpathak et al.[14] The key features of each study are depicted in Table 1. The outcome measure was mean gray values of caries and dentin under restoration.

Study Results

The key results of all the included studies show a statistically significant difference in mean gray values between caries and dentin under lithium disilicate (Fig. 1), zirconia (Fig. 2), and metal-ceramic (Fig. 3) restorations as depicted using the Forest Plot. Though caries under metal restorations are difficult to diagnose due to the common occurrence of artifacts, the results from Vedpathak et al.[11] showed that CBCT is a reliable and valuable guide to detect caries under metal restorations with minimum artifacts, if the field of view (FOV) is small. There was significant heterogeneity

Flowchart 1: PRISMA flow diagram

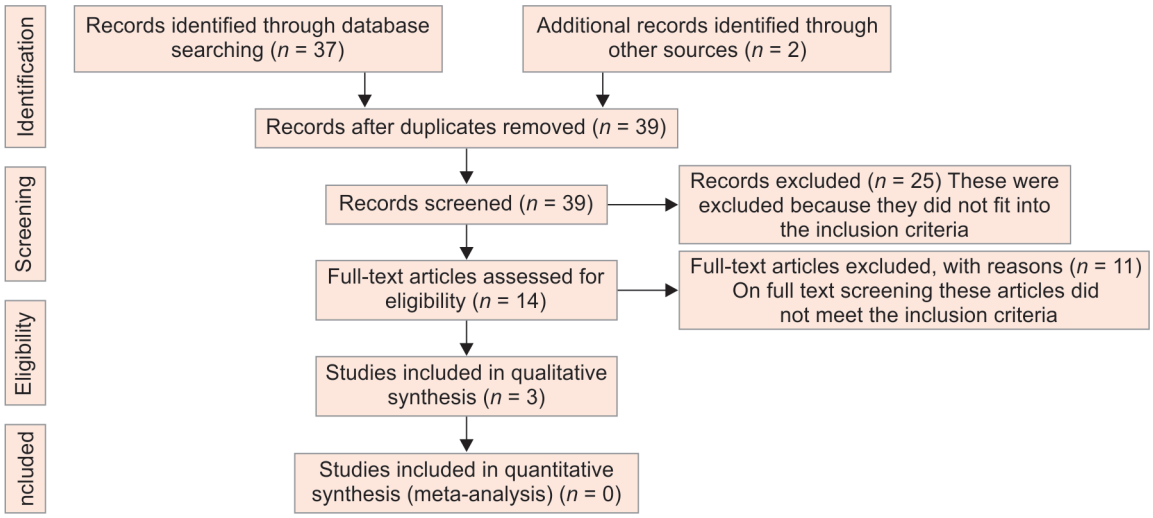

Table 1: Key features of included studies

Author and year of study	*Classification of caries and the type of restoration studied*	*Key study parameters*	*Outcome measures (mean gray values)*			*Key results*
			Type of crown	*Intervention group (caries)*	*Control group (dentin)*	
Bilgin 2014	One tooth with ICDAS 6 caries under lithium disilicate, zirconia, and metal-ceramic bridge	CBCT NewTom scanner was used to scan the tooth without and with crowns with exposure parameters being constant. 8 × 8 cm field of view with high-resolution denture scan mode with 36 seconds scanning time and 7.3 seconds exposure time The axial slice thickness was 0.1 mm with a pixel size of 0.1 mm. Images of axial slices were evaluated using photo editing software to determine mean gray values	Lithium disilicate Zirconia Metal ceramic	25.29 ± 0.57 69.36 ± 1.50 37.39 ± 1.76	144.04 ± 2.46 140.9 ± 1.15 106.39 ± 2.27	• Zirconia crown with caries had the highest opacity • A significant difference was observed between caries and dentin under all three restorations
Aglarci 2015	Eight teeth with ICDAS ≥3 under lithium disilicate, zirconia, and metal-ceramic bridge	CBCT NewTom scanner was used to scan the tooth without and with crowns with exposure parameters being constant. 8 × 8 cm field of view with high-resolution denture scan mode with 36 seconds scanning time and 7.3 seconds exposure time The axial slice thickness was 0.1 mm with a pixel size of 0.1 mm. Images of axial slices were evaluated using photo editing software to determine mean gray values	Lithium disilicate Zirconia Metal ceramic	10.68 ± 2.68 85.93 ± 34.71 56.22 ± 30.02	71.67 ± 3.21 143.41 ± 28.06 120.81 ± 23.04	• A significant difference was observed between caries and dentin under all three restorations
Vedpathak 2016	Six teeth with ICDAS 6 under metal-ceramic, full ceramic, full metal, and metal acrylic	Orthophos XG model of Sirona CBCT machine with exposure parameters 60 kVp and 3 mA. The field of view was 8×8 with a 1 mm slice thickness and exposure time of 14 seconds. The images were reconstructed using Galileo's software to determine to mean gray values	Lithium disilicate Metal ceramic Full metal	2012 ± 216.64 2352 ± 249.04 2440 ± 207.25	2933 ± 93.3 2731 ± 174.07 2820.3 ± 125.94	• In addition to metal-ceramic and all-ceramic restorations, caries under full metal restorations were also studied • Although metal restorations had greater chances of producing artifacts, caries could still be detected especially in the cervical region • A significant difference was observed between caries and dentin under all restorations

between the included studies from the I^2 values (Figs 1 to 3). The overall quality of included studies was considered moderate to high (Table 2).

Discussion

The present review is an attempt to evaluate the available evidence on the use of CBCT to detect caries under fixed prosthodontic restorations. The key results from the review indicate significant differences in the mean gray values between dentin and caries, which suggests that CBCT could accurately detect secondary caries under these restorations.

The broad category of fixed prosthodontic restorative materials includes metal and ceramic which are used as crowns, bridges, veneers, inlays, and onlays, and their modifications.[15] The most common cause of failure of these restorations is secondary caries[8] which leads to loss of tooth and the restoration as well. Early detection of caries under these restorations using radiographs could serve as a guide to initiate preventive strategies and avoid adverse outcomes to both the tooth and the restoration. Intraoral radiographs are accessible, economical, less radiation exposure, and offer high specificity. However, they lack sensitivity with greater inter- and intraoperator variability.[1–3] Careful clinical examination can be used for occlusal, facial, and lingual surface caries. However, for proximal and secondary caries, radiographs are the only available tool for detection. A study by Terry et al. in 2016[16] indicate that the percentage of non-readable proximal caries was 4.1, 18.3, and 51.5% with the use of intraoral bitewings (BWs), extraoral panoramic BWs, and standard panoramic images, respectively. This indicates the disadvantages of panoramic radiographic techniques as well. The differences may be attributed to various factors such as depth of caries, tooth position, and restoration if any, superimposition of adjacent structures, artifacts, X-ray beam saturation and angulation, and other patient factors.[17]

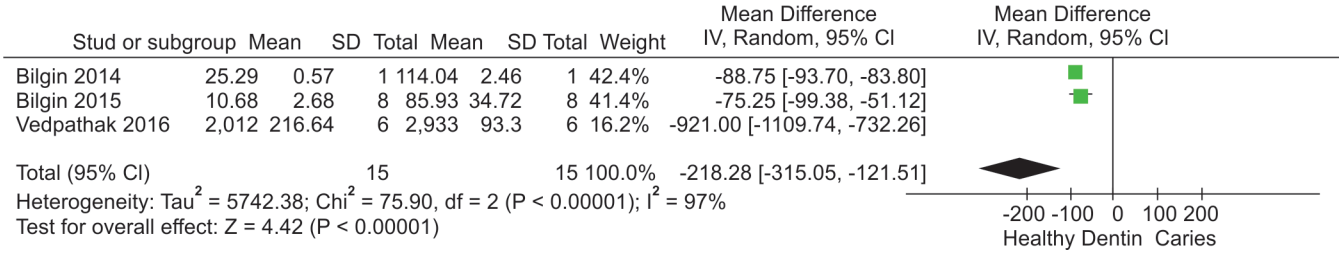

Fig. 1: Forest plot for mean gray values under lithium disilicate restorations

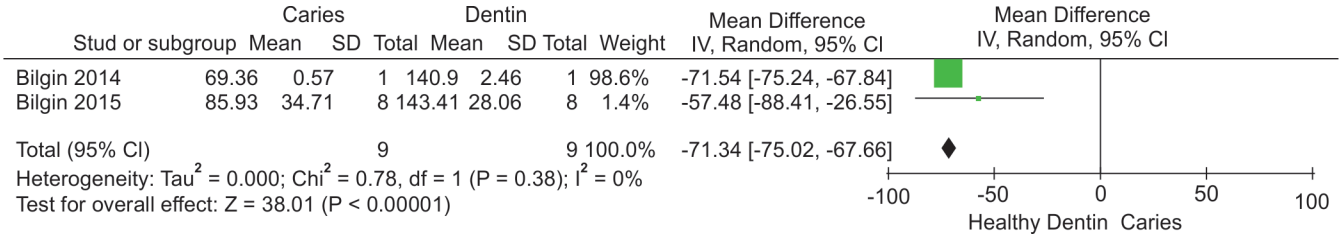

Fig. 2: Forest plot for mean gray values under zirconia restorations

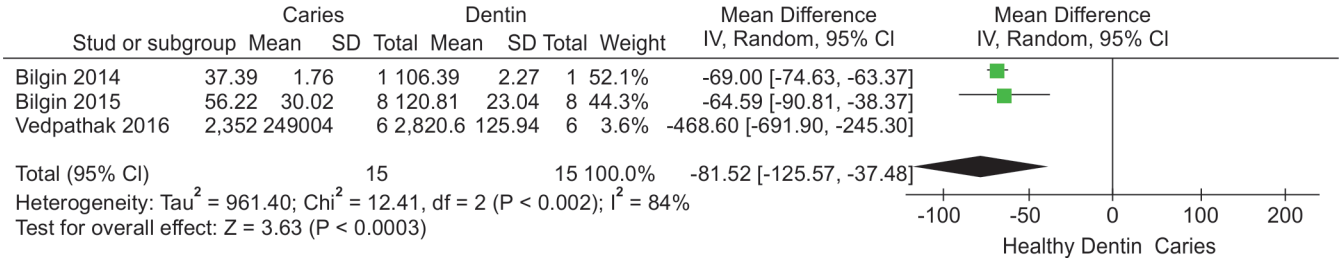

Fig. 3: Forest plot for mean gray values under metal ceramic restorations

Table 2: Risk of bias using new castle ottawa scale

Study ID	*Is the case definition adequate*	*Representativeness of case*	*Selection of controls*	*Definition of control*	*Comparability of cohorts*	*Outcome assessment*	*Same method of ascertainment of case and control*	*Non-response rate*	*Overall quality*
Bilgin 2014	★		★	★		★	★		Moderate
Aglarci 2015	★		★	★	★	★	★		High
Vedpathak 2016	★	★	★	★	★	★	★		High

As regards caries under fixed restorations, the presence of metal makes it almost impossible to detect caries using the conventional intraoral radiographic technique because of the radiopacity. It has been reported that as the number of metal restorations increase, metal artifacts and image degradation also increases[18] A study conducted by Murat et al.[19] on the use of CBCT to detect caries imitating lesions on the tooth under restorations identified CBCT as a better diagnostic tool when compared with intraoral radiographic technique. A higher interobserver agreement was also obtained with CBCT.

Earlier attempts at three-dimensional (3-D) imaging used variations of tomosynthesis, the most notable one is the turned aperture computed tomography (TACT). This was followed by volume tomographic machines which are based on the statistical inversion principle. A stack of 256 cross-sectional images was produced within a limited volume of 6 × 6 cm.[20] However, by the end of the 20th-century CBCT apparently became the most accepted 3-D imaging technique with radiation exposure paralleling a panoramic radiograph or a full mouth intraoral radiographic technique.[1]

Dental CBCT rotates around the patient, capturing data using a cone-shaped X-ray beam. These data are used to reconstruct a 3-D image of the structure studied. The advantages are it is fast, noninvasive, and provides 3-D information, rather than the two-dimensional (2-D) information provided by a conventional X-ray image. The image is produced by absorption of X-ray photon energy by the materials located between the X-ray source and the detector and represented as attenuation value. This value depends on the density of the material. Denser materials absorb more energy, resulting in greater attenuation values. These attenuation values are then converted into mean gray values or voxel values in a digital image during slice reconstruction. It is also to note that these attenuation values are reported as Hounsfield Units in a CT machine.[21] Studies in the past comparing Hounsfield Units and voxel values from CBCT and conventional CT showed a linear relationship suggesting that CBCT could be used with predictable results.[22]

Although the radiation doses from these devices are lower than conventional CT, dental CBCT typically delivers more radiation than conventional dental intraoral X-rays. Concerns about radiation exposure are greater for patients more sensitive to radiation like pregnant women and children. It is advised that the rationale for use is well discussed with the patient and/or parent to ensure a clear understanding of benefits and risks.[12]

Considering the advantages of CBCT, studies evaluated the reliability of CBCT in diagnosing caries under fixed prosthodontic restorations fabricated with ceramic, metal ceramic, all-metal, zirconia, and metal acrylic.[4,5,7] Three studies were identified from electronic databases and all studies showed a statistically significant difference between caries and dentin under zirconia, lithium disilicate, and metal-ceramic restorations. All metal and metal acrylic was studied only in one study.[5] The results also suggest that when the FOV is smaller, CBCT is a better alternative. Collimation of the X-ray beam by adjustment of the FOV limits the radiation to the region of interest which helps in yielding better images and avoiding unnecessary exposure. This depends upon the detector size and shape, beam projection geometry, and the ability to collimate or not. It is always desirable to limit the field size to the smallest volume that can accommodate the region of interest.[13]

Though results from individual studies showed CBCT to be promising in the diagnosis of caries under all metal and metal acrylic restorations, it is still inconclusive because of lack of sufficient evidence in the form of randomized controlled trials with a larger sample size. All studies included were *in vivo*, with a small sample size, which is a limitation. Metal artifact reducing softwares like metal deletion technique (MDT) or metal artifact reduction (MAR) are available which can reduce the metal artifacts that are commonly seen during crown imaging. However, studies indicate that although softwares decreases metal artifacts and increases diagnostic confidence, there is a greater tendency that the software introduces new artifacts that can obscure pertinent structures, interfering with the diagnostic accuracy.[23] However, these softwares were not used in the included studies. Future studies should include the effect of using these softwares in reducing metal artifacts in CBCT. The study by Vedpathak et al. suggests the use of the smallest FOV. However, they used a FOV of 8 × 8. A 4 × 4 FOV could have been preferred. Though there is no conclusive evidence from available literature, this review suggests that CBCT could be used as an alternative caries detection tool in patients with high caries risk and those with multiple restorations. This review is a basis on which future randomized controlled trials can be planned with the factors that are mentioned above.

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