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DIAGNOSTIC ACCURACY OF CONE BEAM COMPUTED TOMOGRAPHY USING GRAY SCALE VALUES IN DETECTING CARIES

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ABSTRACT:
AIM:The aim of this research was to evaluate the diagnostic accuracy of Cone beam computed tomography(CBCT) using gray scale value in detecting caries. The first objective was to measure the remaining dentin thickness (RDT) using intraoral periapical radiographs, CBCT, sectioning of tooth and compare the same. The second objective was to derive at the grayscale values of normal enamel, normal dentin, affected dentin and infected dentin by comparing the CBCT images with the sectioned tooth.

MATERIALS AND METHODS: 10 human permanent premolars and molars with dental caries not involving pulp was collected. The inclusion criterion did not include age, gender, or the reason for extraction. All the teeth were subjected to radiographic evaluation using Radio Visio Graphy (RVG), CBCT and stereomicroscopic evaluation of the sectioned tooth. The remaining dentin thickness was measured by all the three methods. Gray scale value of normal enamel, normal dentin, affected dentin and infected dentin was recorded using CBCT.

RESULTS: Statistical analysis using unpaired t-test showed remaining dentin thickness using CBCT and stereomicroscopic analysis to be statistically significant ($p<0.05$). The gray scale range was ranging from -50 to –200 in infected dentin and 200 to 600 in affected dentin, while that of normal enamel was 3450 to 3800 and normal dentin was 1900 to 2200.

CONCLUSION: Based on the gray scale values,CBCT can be considered as an accurate tool for use in the diagnosis of caries.

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INTRODUCTION:

Caries diagnosis is a critical component in the prevention and management of lesions, but it is a challenging process in dentistry.(Bader & Shugars, 2004).(Bader et al., 2001)Because of the morphology of pits and fissures causing plaque aggregation, occlusal surfaces are most affected by caries in children and adults.(Sheehy et al., 2001)(Rodrigues et al., 2009)An increase in the number of initial caries lesions and a general decline in caries prevalence is seen in the past two decades.(Marthaler, 2004). But, however the use of fluorides and other remineralising agents owing to their potential of superficial remineralisation have decreased the number of caries and increased the incidence of incipient caries, owing to the delay in cavitation.(Fejerskov & Kidd, 2009; Stewart et al., 1953). Changes in occlusal and lesion morphology can result in the presence of occlusal dentine caries under fissures that appear intact to the naked eye.(Diniz et al., 2009; Jablonski-Momeni et al., 2008)

In view of these developments in caries trend and the significant advances that have been made in the field of caries identification / diagnosis and caries prevention, visual and tactile methods of diagnosis of caries are insufficient in caries diagnosis. Moreover, the use of a probe in incipient lesions can cause trauma to the surface of the affected tooth.

To increase the degree of diagnosis of occlusal caries, researchers recommend that visual observation be combined with other diagnostic aids such as radiography, laser or light fluorescence–based techniques, electrical impedance measurements, and ultrasound.Radiographic examinations are the most popular and the only technology that is used in most dental practises to improve caries diagnosis.

Traditional intraoral periapical and bitewing radiographs are well-known and commonly used, and when done correctly, they provide excellent images for the majority of dental radiographic needs.(Mandal & Bhowmik, 2017; White & Pharoah, 2008)The primary task is to supplement the clinical tests by providing information on the internal anatomy of tissue and the teeth supporting to diagnose caries, periodontal bone degradation, periapical disorders and a range of other dental and osseous conditions.(White & Pharoah, 2008)

Over the past decade, many dental practises have replaced film with modern imaging technology for a number of reasons, including reduced levels of radiation exposure, better image delivery, and improved patient education/perceptions.(Kantor, 2005; Makdissi & Pawar, 2013; Stelt & Van Der Stelt, 2005) The most popular digital imaging systems employ either charge-coupled device (CCD) or complementary metal oxide semiconductor (CMOS) sensors, or photostimulable phosphor (PSP) plates, also known as storage phosphor plates.(Dzingle et al., 2001; Wakoh & Kuroyanagi, 2001) Both of these devices can provide 2-dimensional (2D) data about dental tissues and diseases. (American Dental Association Council on Scientific Affairs, 2006)

Intraoral imaging continues to provide the highest spatial resolution of any imaging technique. However, it is 2-D representation of 3-D structuresh. The third dimensional spatial information is lost.(Luczaj-Cepowicz et al., 2019)

CBCT has achieved widespread recognition in dentistry in the last five years, despite its origins

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dating to around two decades.(Ludlow et al., 2006; Ludlow & Ivanovic, 2008) The only difference between intraoral and panoramic imaging is that it produces high-quality, thin-slice images.(Ludlow et al., 2006) Cone-beam CT devices, as opposed to traditional CT machines, emit an x-ray beam shaped like a cone, rather than a fan. (Kurzweg et al., 2017)Since the laser occupies the whole area of interest, the x-ray source only has to make one loop through the patient's head or less when capturing images(Kurzweg et al., 2017; Lofthag-Hansen et al., 2007). CBCT provides 3-dimensional (3D) data at a reduced cost and with lower absorbed doses than standard CT in medical radiology.(Iikubo et al., 2009) CBCT in clinical dental practise has many possible benefits over traditional tomography, including simpler image processing, higher image precision, lower efficient radiation exposures, shorter scan times, and greater cost-effectiveness.("Endodontic Uses of Cone-Beam Computed Tomography," 2011; McClammy, 2014; Patel et al., 2007)(White & Pharoah, 2008)

Earlier caries study of the CBCT was based mostly on the identification of proximal caries.(Akdeniz et al., 2006)(Tsuchida et al., 2007)(Haiter-Neto et al., 2008)There is a paucity of evidence on the detection of occlusal caries in conjunction with proximal caries, as well as the impact of grey scale values on caries detection.(Rai et al., 2022) Previously our team had a rich experience in working on various research projects across multiple disciplines; (Azeem & Sureshbabu, 2018; Felicita, 2017; Felicita et al., 2012; A. R. Jain, 2017; Krishnan & Lakshmi, 2013; Kumar et al., 2006; Mp, 2017; Patturaja, 2016; Rao & Kumar, 2018; Sekar et al., 2019; Sivamurthy & Sundari, 2016)

The aim of this research was to evaluate the use of an intraoral digital CCD sensor and CBCT images in the identification of occlusal caries in vitro. The first objective was to measure the remaining dentin thickness (RDT) using intraoral periapical radiographs, CBCT, sectioning of tooth and compare the same. The second objective was to derive at the grayscale values of normal enamel, normal dentin, affected dentin and infected dentin by comparing the CBCT images with the sectioned tooth.

MATERIALS AND METHODS:

Following a visual and radiographic preliminary examination,, 10 permanent premolars and molars with no restorations were chosen for extraction for a variety of reasons, including periodontitis, alveolar bone deterioration, ectopic localization, pericoronitis, and orthodontic sign. The inclusion criterion did not include age, gender, or the reason for extraction.

Individual teeth were cleaned and stored in a 2% thymol solution. Visual inspection followed by histological analysis revealed that three of the ten teeth included were sound and seven had occlusal caries. Direct optical intraoral sensor imaging, CBCT examination, and histopathological sections were performed on each tooth.

Intraoral images were recorded bucco-lingually for each tooth in ortho-radial projection, with a 20 cm focus-receptor distance and 0.04 seconds image-exposure time, for 10 images. In vitro intraoral imaging was performed using an AMS-6010E. A 8 mA x-ray 70 kVp and unit are used, as well as a 2 million pixel X-ray Max CCD direct optical intraoral sensor with a resolution of 24 lp/mm.A no 2 sensors was used, having a sensor size of 43*32* 5 mm and an

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active area of 37 27mm. Dental Imaging Software, Version 7.0.3, was used to record and save all images.(CS Imaging Software).Observer consensus was used to assess image settings based on the visibility of enamel, dentine, and pulp.The remaining dentin thickness was measured for each sample and was recorded in mm.

A CareStream Cone-beam CT Scanner (CareStream 9600) with a cylindrical volume of reconstruction up to 21.1 14.2 cm and an amorphous silicon flat-panel image detector (24.4 19.5 cm) are used to collect CBCT images. The images were taken at 3.8 mA and 120 kVp . They were then rebuilt at 0.2-mm (high-resolution), 0.2-mm (ultra-resolution),0.3-mm (low-resolution) voxel scales.Voxel size of a minimum of 75 µm; having a gray scale range of 16384 - 14 bits. Multiplanar reconstructions and axial scans were obtained on a local workstation using the CS 3D dental imaging programme in compliance with the instructions given by the manufacturer . Reconstructed volumetric data is mesiodistally sectioned. Three gray scale reference points were selected in each normal enamel,dentin and the body of the carious lesion and the mean gray scale value was calculated. Remaining dentin thickness was measured using RVG,CBCT and its accuracy was compared using histopathological sections of the samples.

Each tooth was encased in a block of acrylic. The status of caries was histologically validated by sectioning each tooth parallel to the long axis of the crown serially and then measured with a hard tissue microtome (LEICA-SP-1600). One of the study authors investigated both sides of each segment with a stereomicroscope (Stemi 2000; Carl Zeiss, Jena, Germany), recording each tooth as either having a carious lesion or sound tooth structure.Histological examination showed three sound teeth (no enamel demineralization) and seven teeth with occlusal and proximal caries (one superficial enamel lesion, one deep enamel lesion, two superficial dentine lesions, and three deep dentine lesions), which was characterised as a demineralized white or yellowish-brown discoloured region in the enamel or dentine. And the remaining dentin thickness was measured in mm.Two observers separately assessed and recorded the remaining dentin thickness.Statistical Analysis was done to compare the remaining dentin thickness measures using Rvg, CBCT and stereomicroscopic analysis.Independent t test was done.

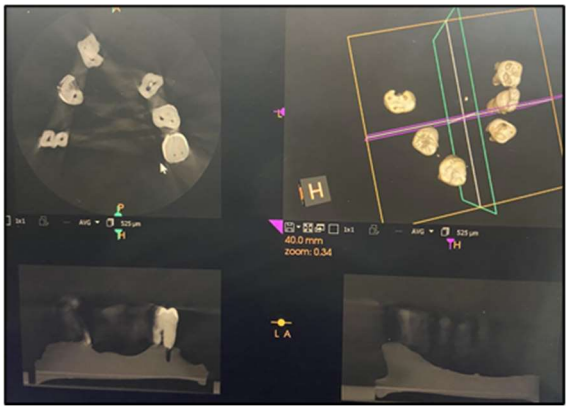

Fig 1: CBCT Analysis of samples

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Fig 2- RVG Analysis of samples

Fig 3-Samples mounted on acrylic for microtome sectioning

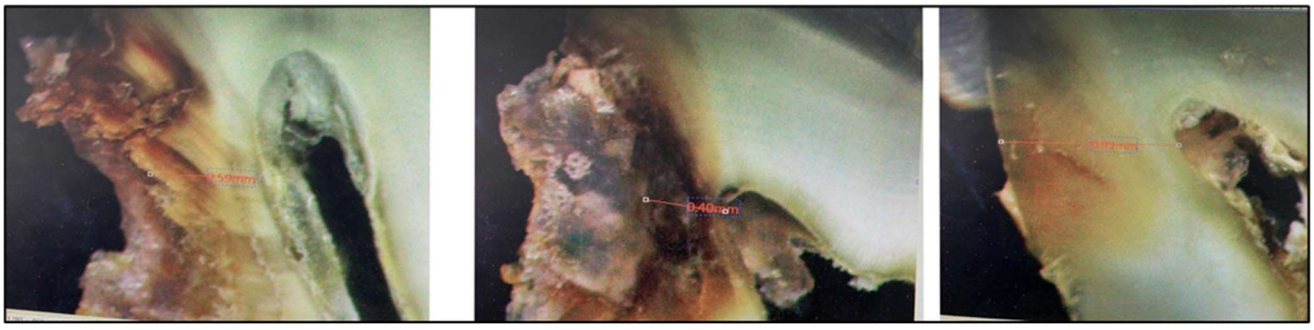

Fig 4-Stereo Microscopic analysis of samples, measuring the remaining dentin thickness.

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Figure 5 (a-c)- Complex image depicting various modalities of measuring RDT-Rvg of the sample, b-CBCT analysis of the sample, c-Sample subjected to stereomicroscopic analysis

RESULTS:

Based on the independent t test statistics comparing CBCT and stereomicroscopic analysis, there was a significant effect of caries level (P.003). Even a large median influence of the modality of imaging (P.002) indicated that the discrepancy between the image modes depended on the degree of caries.

SAMPLE NO	RVG	CBCT	STEREOMICROSCOPIC ANALYSIS
S1	1.2mm	0.97mm	0.98mm
S2	0.9mm	0.34mm	0.27mm
S3	2.1mm	0.33mm	0.39mm
S4	1.3mm	0.44mm	0.41mm
S5	0.6mm	0.12mm	0.17mm
S6	1.3mm	0.79mm	0.75mm
S7	1.4mm	1.05mm	1.07mm
S8	1.1mm	0.77mm	0.79mm
S9	0.9mm	0.92mm	0.98mm

Table 1- Remaining Dentin Thickness values measured using RVG.CBCT and stereomicroscopic analysis

Mean	1.000	1.710

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Std Deviation	0.000	0.003205

Table 2- Statistical analysis using unpaired t-test showed remaining dentin thickness using CBCT and stereomicroscopic analysis to be statistically significant (p<0.05)

	GRAY SCALE VALUES	AVERAGE
NORMAL ENAMEL	3450 to 3800	3500
NORMAL DENTIN	1900 to 2200	2100
AFFECTED DENTIN	200 to 600	400
INFECTED DENTIN	-50 to -200	-150

Table 3- Gray scale values for healthy enamel, dentin,affected and infected dentin

In the calculated gray scale values; average gray scales are as follows, normal enamel:3500, normal dentin:2100, affected dentin:400 and infected dentin: -150. The gray scale range was ranging from -50 to –200 was seen in infected dentin and 200 to 600 in affected dentin, while that of normal enamel was 3450 to 3800 and normal dentin is 1900 to 2200.

Kappa values for intraobserver agreement ranged from 0.817 to 0.984. Given the very high intraobserver Kappa coefficients, which indicate excellent intraobserver agreement, interobserver Kappa coefficient calculations were focused solely on the first readings. Among various observers, Kappa values for interobserver agreement ranged from 0.800 to 0.907. In general, both the CBCT and intraoral images showed strong interobserver agreement. Since the consensus between observers was so strong, it was sufficient to test the results with just one observer, who was chosen at random.

DISCUSSION:

Since CBCT is a novel imaging technique, its diagnostic ability for some imaging functions is not known. This is especially valid for the most recent CBCT units.The present study compared the ability to detect carious lesions using RVG and CBCT images. Statistically significant results (P .01) were found between histological and limited CBCT measurements, histological

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and film measurements, whereas no significant differences (P .05) were found between histological and film measurements when the remaining dentin thickness was measured. A range for the Gray scale values for each sound enamel, dentin and affected and infected dentin was created in hope that it can be used as a diagnostic tool in caries detection in the future, which would in turn enhance the treatment outcome.Observer performance,mouse sensitivity, reference point selection and device capability were all discovered to be critical factors in assessing the measurements of caries lesions.(Kamburoğlu et al., 2010)

According to the scientists, CBCT is a promising diagnostic and carious lesion monitoring tool with highly accurate caries depth measurements.(Kamburoğlu et al., 2010; White, 2008) The present study did not compare different CBCT systems; nevertheless, future research may be conducted to compare the precision of measurements of occlusal caries by various CBCT systems. In other studies done by researchers comparing caries lesions, there were no major variations between the two schemes. In a study which was analysed using 7 observers diagnosed initial intraoral proximal caries and CBCT 3D Accuitomo images (J Morita MFG. Corp). The mean for the 3D Accuitomo was 0.63 0.02 and the mean for the film were 0.63 0.03.(Jeon et al., 2020; Matsuda et al., 1995)(Jeon et al., 2020; Tsuchida et al., 2007) Based on these results, the authors suggested that mechanical improvements such as contrast enhancement, noise reduction and artefact reduction could enhance accuracy in detection of carious lesions.(Dove & McDavid, 1992; Tsuchida et al., 2007). Another research compared a local CBCT Sidexis sensor (Sirona Dental Systems, Bensheim) to traditional x-rays found no difference between the 2 technologies in the identification of proximal caries. However, in the assessment of caries lesion depth with CBCT observations saw that it worked better than with traditional X-rays.(Kalathingal et al., 2007) It is well known that digital intraoral radiography performs comparably to conventional IOPA in the detection of occlusal caries.(Wenzel, 1998) For this reason, the output of CBCT images was compared to that of intraoral digital images in this study. To our knowledge, the present study is the first in the literature to evaluate the relation between gray scale values and caries detection; however, a recent study did assess the effects of voxel size in the detection of simulated external root resorption and in caries detection using CBCT.(Liedke et al., 2009)(Kamburoğlu et al., 2010) Though CBCT is revolutionary and promising, effective doses of radiation remain higher than traditional intraoral and panoramic image. Moreover it is impractical to use CBCT in normal clinical practise.(Ludlow et al., 2006)(Hirsch et al., 2008) According to the principle of “as low as reasonably achievable,” radiographic examinations must be fully justified before they are performed and evidence-based selection criteria should be considered. The present study found that the CBCT is useful for the diagnosis of dentin caries.Although some studies have found no advantage of CBCT over film or phosphor plates for the diagnosis of caries. Another research found that the CBCT provided a greater radiation dosage to the patient (5-16 times more) than a conventional panoramic radiograph.(Mikic et al., 2022) For proximal caries, the advantages of CBCT do not predominate the radiation hazards since the dosage of a single intraoral radiograph is significantly smaller than that of a conventional panoramic radiograph. Moreover, the present in vitro analysis took place under ideal imaging conditions excluding movement of objects,

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metallic restorations, teeth-related tissues and other parameters which could complicate caries diagnosis. Especially the factors that cause cone beam hardening artefacts would complicate the caries detection process.Our institution is passionate about high quality evidence based research and has excelled in various fields.(R. K. Jain et al., 2014; Johnson et al., 2019; Keerthana & Thenmozhi, 2016; Lakshmi et al., 2015; Neelakantan et al., 2011)

One limitation of the study is that the equivalent soft tissue materials used were not equal in the current research. Intraoral radiographs and CBCT photographs were supplied with a 30-mm thick acrylic block and a water phantom. This may have set in motion a variation in the dispersion of radiation, which could have affected the image contrast resolution, while one analysis suggests that the precision of the proximal detection of caries from photographs produced from these two different materials does not vary.

In conclusion, proper knowledge about the patient selection would be very important to assess the condition and render the appropriate method of diagnosis that is needed. There is a strong correlation of gray scale value that is seen in these samples which can be attributed to the level of mineralisation of the tooth structure and therefore considered as a major diagnostic tool in caries detection. It is suggested that further studies should be carried out with other CBCT scanners and in vivo studies to extrapolate these results and its application clinically.

CONCLUSION: Based on the gray scale values,CBCT can be considered as an accurate tool for use in the diagnosis of caries. With the use of these grey scale values the differentiation between affected and infected dentin can be done,which will enhance the treatment outcome of the restorative procedures and move towards a more conservative approach.

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Conflicts of Interest

There are no conflicts of interest.

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