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An *in-vivo* comparison of X-ray film and CBCT in the diagnosis of proximal caries in deciduous teeth

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Abstract
The aim of this study: Compare film x-ray and CBCT radiographs clinically in the diagnosis of proximal caries in deciduous teeth.
Materials and Methods: Samples consist of (20) primary teeth affected by proximal caries. After taking radiographic images of the samples according to their radiographic groups, subsequent clinical caries excavation is done, and the resulting depth is measured using a Vernier caliper.
Results: The clinical study concluded superiority of x-ray film over CBCT imaging in detecting proximal carious lesion depth; whereas, both radiographic methods were effective in the diagnosis of proximal caries.
Conclusions: X-ray film radiograph is more successful and reliable than CBCT radiography in the clinical detection of proximal caries depth in deciduous teeth; we do not recommend the use of CBCT in children's in order to detect proximal caries only. The importance of using x-ray radiographs for proximal caries diagnosis.

Keywords: Diagnosis, X-ray film, proximal caries, CBCT, vivo study, and deciduous caries

1. Introduction
Interproximal caries lesions develop between the contacting proximal surfaces of two adjacent teeth. They first appear clinically as opaque regions and are caused by the loss of enamel translucency at the outermost enamel between the contact point and the top of the free gingival margin [1]. In order to increase the frequency of detection of proximal caries, the authors have recommended that visual and clinical examination be combined with bitewing radiography [2]. The distribution and severity of dental caries vary in different parts of the world and within the same country or region [3]. Decayed teeth are harmful to children's growth and development and can severely jeopardize their health [4]. Therefore, clinical examination should always be supplemented with radiographic examination [5].
Among the various methods used today in the diagnosis of caries, intraoral bitewing radiography (IO BW) is the most frequently used examination for the detection of proximal carious lesions [6], and it is more accurate than periapical radiography in the diagnosis of proximal caries [7]. The relatively recent introduction of digital dental radiographic imaging has so far failed to demonstrate any increase in caries detection rates [8-9]. Also, many studies show that CBCT caries detection rates are approximately equivalent to intraoral modalities for non-restored teeth [9-10]. On the other hand, obtaining the image for CBCT still has advantages when compared with conventional x-rays, because it eliminates most of the problems related to image distortion and superimposition of structures [11].
The aim of this study is to clinically compare the accuracy of x-ray film and CBCT radiographs in the detection of proximal caries on deciduous teeth. The study included five different tests: visual examination, visual inspection with probe, x-ray film radiographic examination, CBCT radiographic examination and direct clinical caries measurement.

1.1 Ethical Statement
This study was performed in accordance with the provision of the declaration of Helsinki. The protocol was conducted under internally accepted ethical standards and it was approved by Hama University council in the decision number (56) session number (2).

Teeth that were included in this study were chosen after intraoral examination of a child's teeth, a written, signed form was obtained from every child's parent. All of child's patients were reviewers of the department of pediatric dentistry at Hama University. All figures that included patient faces or records were approved to be taken and added to this publication study-paper from the child's parent.

2. Materials and Methods

Samples consisted of (20) deciduous teeth, affected by proximal lesion. Sample divided into two groups (10 teeth in each group): (1) X-ray film Radiographs, (2) CBCT Radiographs. All proximal caries types were included in this study, after clinical assessment confirms conservative treatment need. Caries that penetrated into the pulp chamber and teeth with extensive carious extension were excluded from this study.

2.1. Clinical Examination

Teeth were cleaned with pumice powder to remove the bacterial plaque and food residue, ensuring a better ability to perform clinical examination. Children's teeth were undergoing visual examination, in addition to probe inspection, as shown in figure (1); also, the full treatment plan was assisted.

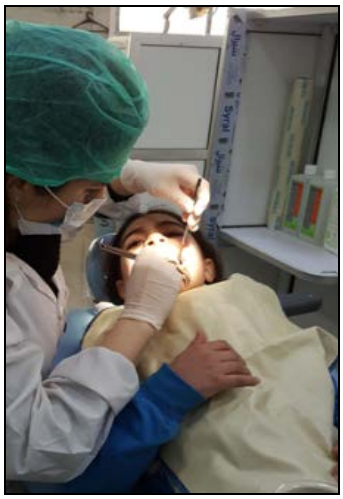

Fig 1: Intraoral clinical examination (Author's).

The child's parent was confirmed about treatment plan needs; teeth that were chosen for the study were discussed also; Goals of the study were explained and a written consent form with signature were obtained from the child's parent, written form clearly mentioned the teeth included in this study.

2.2. Taking radiographs

An empirical study consisted of (4) teeth samples (2 for each group) were made before initiation of the study samples; helping to set standards and verify critical methods and steps to be followed.

Group no. (1), Kodak (E-Speed) films were used for taking intraoral radiographs by (Xgenus® ac\dc de Gotzen). An EEZEE-grip (Snap-A-Ray) Intraoral film holder was used. Intraoral films were processed by the automatic film processor.

Group no. (2), CBCT radiographs, taken by Vatech (Mod. PHT-30LFO), under the supervision of a radiologist.

Radiographic considerations for x-ray film group was (kVp=70, mA=8) and the exposure time was (0.350 sec); CBCT radiographic consideration were (kVp = 80, mA = 10, exposure time = 11 sec), FOV (Field of View) = 5 x 5 for each child.

- Children included in CBCT study group were chosen to have at minimum 5 proximal caries in deciduous teeth, to minimize many intraoral repetitive x-rays.

2.3. Clinical intraoral steps

Sufficient anesthesia was performed; adequate isolation was obtained using the rubber dam. Proximal caries were excavated clinically using both hand held and low-speed excavators, until reaching non-affected hard tissue.

Cavity preparation was done in two stages, caries excavation stage followed by a cavity outline preparation form stage, where retention and resistance form were obtained in the preparation; caries extension was calculated between those two stages.

The depth of the lesion in both study groups was assisted by measuring lesion-depth with two points to calibrate between, mesial or distal lesion surface and deepest point of caries extension towards the pulp; measurements were taken intraorally using an inside caliper [12], (Figure 2). Millimeter values recorded by Vernier Caliper considered to be the true depth-value of the lesion.

Fig 2: Intraoral measurements using inside caliper (Author's).

Arithmetic mean was calculated from the repeated measured, to obtain the most accurate numerical millimeter value of the lesion depth.

Next, second stage of cavity preparation took a part; resistance and retention form were added in cavity preparation, according to G.V Black's principles; Amalgam restoration with an adequate calcium hydroxide lining (base and catalyst paste) was applied to all prepared teeth samples.

2.4. Diagnosis of radiographs and radiographic measurements

View box was used to view x-ray films; whereas CBCT radiograph was shown on a laptop screen with (Inter® Core ™ i3 CPU) precision characters, using (Ez3D2009) imaging software. Both x-ray film and CBCT radiographs were managed under upper dim light in off light room.

- The researcher had undergone training course in theoretical and practical uses of the CBCT software program in (Damascus University, Syria) before making any diagnosis or measurements in the CBCT-Group samples.

Proximal caries on x-ray film were diagnosed under (×4) magnification using handheld magnifying glass, Outside Caliper was used to obtain the radiological depth of the proximal lesion directly from the radiograph [13-14], figure (3).

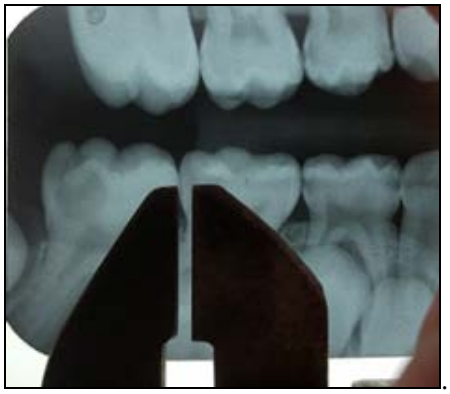

Fig 3: Proximal caries depth measurement on x-ray film (Author's).

Longitudinal mesiodistal cross sections (1mm thickness) were taken for each sample; radiographic depths of proximal carious lesion on CBCT radiographs were obtained by software ruler caliper [17-18]; as shown in Figure (4), many measurements were taken of many cross sectional images for each sample, and the chosen depth value was the deepest referring measure.

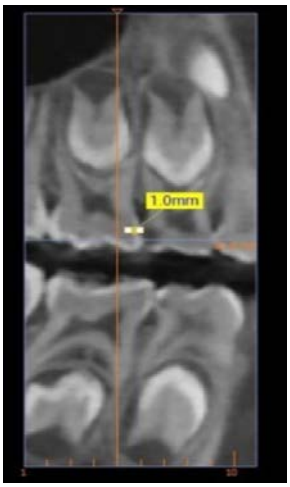

Fig 4: Measuring CBCT radiographic lesion depth (Author's)

The proximal caries depth on radiographs -in both groups- obtained by demonstrating two points to calibrate between, an outer mesial or distal enamel-surface point and the deepest point of carious extent toward the pulp chamber.

2.5. Analyzing measurements and results

Clinical and radiographic proximal lesion depths were calibrated in millimeter (mm); all numerical values were converted into standard values according to a scale. Values were scaled based on a previous studies of enamel [15] and dentine [15] thickness in the middle third of the crown in deciduous teeth; Radiographic and clinical standard value scale: (0)- caries enclose to enamel, (1)- caries reach the DEJ and (2)- caries within the dentine.

Radiographic standard values compared with clinical standard values, considering the clinical standard values as the gold standard.

3. Results

The study contains 20 deciduous teeth, they were distributed at table (1).

Table 1: Samples distribution based on the tooth type and radiographic technique.

Distribution of samples	Conventional x-ray film	CBCT	Sum
Upper first deciduous molar	4	3	7
Upper second deciduous molar	1	1	2
Lower first deciduous molar	1	2	3
Lower second deciduous molar	4	4	8
Sum	10	10	20

According to the direct clinical evaluation, there was only one lesion enclose to enamel and 9 caries within the dentine in the CBCT group samples; two caries enclose to enamel, and one reaching the dentinoenamel junction (DEJ) and 7 caries within the dentine in the x-ray film group samples, as viewed in table (2); the validity of the different radiographic images is viewed in table (3).

Table 2: Repeats of both clinical and radiological evaluation in clinical study groups.

Radiographic Technique	Radiographic evaluation	Direct clinical measurement			Sum
		Enamel	Dentinoenamel junction (DEJ)	Dentine	
CBCT	Enclose to enamel	0	0	1	1
	DEJ	0	0	0	0
	Dentine	1	0	8	9
Sum		1	0	9	10
Conventional x-ray	Enclose to enamel	2	0	0	2
	DEJ	0	1	0	1
	Dentine	0	0	7	7
Sum		2	1	7	10

Table 3: Clinical diagnostic validity of radiographic images.

Diagnosis Validity		CBCT	Conventional
Not Valid	Frequency	2	0
	Percentage	20.0%	0.0%
Valid	Frequency	8	10
	Percentage	80.0%	100.0%
Sum	Frequency	10	10
	Percentage	100.0%	100.0%

Fisher's exact test was conducted to study the difference in radiographies diagnostic validity ratios between study groups; the test did not show a statistically significant difference between the study groups, viewed in table (4).

Table 4: Fisher's exact test values.

Diagnostic validity differences	The value of the test	Indication of differences
Fisher's Exact Test	0.473	Not significant

The Kappa compatibility factor was calculated to determine the extent of compatibilities of the degrees of diagnosis between radiographs and direct clinical examination of the study groups. The test did not show a statistically significant difference between the direct clinical examination and CBCT ($p = 0.725$). While there was a significant statistical agreement between conventional film radiographs and direct clinical examination ($p<0.0005$), the degree of compatibility was very good ($\kappa w = 1.000$), (Table-5).

Table 5: Kappa compatibility coefficient between radiographic and clinical examination of the study groups.

Radiographic technique	Kappa Value	P value	The confidence interval (95%) for Kappa values	
			Maximum	Minimum
CBCT	-0.071	0.725	0.030	-0.173
Conventional	1.000	0.000	1.000	1.000

Due to the small sample size, the sensitivity and specificity of caries types of each radiographic group was not calculated.

4. Discussion

Through research in the medical literature within the available conditions, we did not find similar *in vivo* studies in assessing the accuracy of conventional and CBCT imaging in the detection of proximal caries on deciduous teeth, which made this clinical study unique.

Accurate intra-oral measurements can be made using Depth gauge, Vernier caliper, or gingival probes (WHO-Probe) [12]. In this study, Vernier caliper tool was used for measuring proximal lesion depth in both clinical manner and film x-ray radiography, as in a previous study [14]; whereas another study used this technique to determine radiographic lesion depth only [13]. The CBCT software's millimeter ruler caliper was used for determining the radiographic depth of the proximal lesion [18].

In the manner of clinical proximal lesion depth detection, a previous study used histological validation; radiographs were taken before deciduous tooth extraction [20]. On other studies, proximal lesion depth was valued by specialist observers [21], or they were diagnosed without remarking lesion extension [19-22].

Although, similar radiographic techniques (conventional x-ray film and CBCT) were both compared clinically in a similar previous study [19]; except of that study were done on permanent teeth only.

Radiological diagnosis is considered to be valid when the radiographs standard value simulates the clinical standard value of the lesion depth. This study concluded the superiority of the x-ray film radiographs over CBCT imaging in the detection of proximal lesion depths; our result matches with a previous study [14].

When calculating the Kappa compatibility coefficient, the resulted value for conventional x-ray radiography and direct clinical examination was close to 0.000 value, thus conclude that the compatibility was high; While the value of the CBCT technique was greater than 0.05 value, and this confirms the lack of compatibility between the radiographic results and direct clinical examination in detecting degrees of proximal caries depths; This can be explained by, the lack of that CBCT cross sectional radiograph in the two dimensional plane (2D) might accurately correspond to the three dimensional (3D) spread of the carious lesions. Therefore, several cross-sectional images were managed to obtain an average millimeter-value that could consider the maximum radiographic extension of the proximal lesion.

On the other hand, conventional radiography was reliably accurate than CBCT radiographs in detecting proximal caries depths; This might result from, the ease of adapting film-radiograph within the children mouth's, also being more accepted by the child, and ease of taking bitewing images; Which aids the x-ray beam to pass through the interdental spaces, thus increasing the accuracy of proximal caries diagnosis. In addition to obtaining (2D) radiograph of the (3D) carious lesion extension, which ease the evaluation of the extent and depth of the proximal lesion, when good diagnostic films are available.

Our current study also concluded that the both radiographic methods were effective in proximal caries diagnosis; No significant statistical difference was found between the two methods. This result did not coincide with previous clinical study [19]; which found the superiority of CBCT technique over the x-ray film; this might be due to the application of tooth separators 3 days before taking radiographs, in addition to their samples being of permanent teeth.

5. Conclusion

X-ray film radiograph is more successful and reliable than CBCT radiographs in the clinical detection of proximal caries depth in deciduous teeth; we do not recommend the use of CBCT in children's in order to detect proximal caries only. Also, the use of radiographic diagnosis regardless of its type considered of great importance in proximal caries diagnosis.

In conclusion, this study is unique in that it is the first study to examine the diagnosis of proximal caries in primary teeth with only clinical validation, using x-ray film and CBCT radiographs, with power and fully clinical examination methods and measurements.

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