Original Article

Evaluation of image quality of bitewing radiographs taken by UITM dental students.

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Abstract

Objectives: To evaluate the quality of bitewing radiograph taken by Universiti Teknologi MARA (UiTM) dental students during daily clinical practices and to evaluate the difference in caries lesions found on bitewing radiographs and clinical examination.

Materials and method: 120 patients who attended the undergraduate dental clinic for dental examination were included in this study. The inclusion criteria were patients within the age range of 17-45 years old, possessing at least three sets of posterior teeth, with bitewing radiographs taken by undergraduate dental students. The number of caries lesions detected by clinical examination, bitewing radiographs, and a combination of both methods were recorded. The quality of 240 bitewing radiographs was classified into three categories; excellent, acceptable, and unacceptable. The frequency of radiographic errors; foreshortening/elongation, horizontal overlapping, inadequate film coverage, non-ideal centering and inadequate contrast and density were also evaluated.

Results: The quality of bitewing radiographs are mostly accepted to be used as a diagnostic tool and one of the factors which commonly affected the quality of the bitewing is the overlapping of adjacent teeth. The highest number of caries lesions were detected radiographically (74%) compared with 25% caries by clinical examination. The majority of radiographs (71%, n=171) were deemed to be of acceptable quality, 39(16%) were excellent, and 30(13%) were diagnostically unacceptable. “Horizontal overlap” was the most common error detected on the radiographs (n=139, 57.9%), followed by “non-ideal centering” (n=93, 38.8%), “inadequate contrast” (n=46, 19.2%) and “inadequate film coverage” (n=24,10%). The highest number of caries lesions were detected radiographically (74%) compared with 25% caries by clinical examination.

Conclusion: The quality of the majority of bitewing radiographs taken by undergraduate dental students in this institution is acceptable. However, given that more than half of the radiographs possessed horizontal overlapping error, caries diagnosis may have been underestimated. Further training and periodic audits are required to reduce the percentage of errors in bitewing radiographs amongst undergraduate dental students.

Keywords: Bitewing radiograph, undergraduate dental students, caries, horizontal overlapping, radiographic diagnosis

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Introduction

The dental literature is rife with numerous published guidelines and position statements outlining recommendations for promoting safety and effectiveness of

diagnostic oral radiography (Hewitt et al. 1989; Horner 1994; Espelid et al. 2003; American Dental Association 2006; Callaghan et al. 2007; Hart et al. 2009). There is good evidence that initial posterior bitewing radiographs are required for all new dentate patients over five years of age with posterior teeth (Horner et al. 2004; Goodwin et al. 2017). This procedure is required as an adjunct to clinical examination for the detection of caries on both the approximal and occlusal surfaces of the teeth (Pitts 1996). Bitewing radiography remains the recommended method of choice for caries diagnosis and treatment planning in most circumstances.

A good quality bitewing radiograph with minimal errors not only reduces the need for re-exposures, but also forms an essential part of caries diagnosis. The relationship between film/sensor, cone and tooth projects a consistent parallel orientation and reliable interpretation. Radiography involves, not only identifying the presence and nature of pathoses but also characterizing and differentiating normal structure. Various studies support the importance of using visual and clinical examination in combination with bitewing radiographs to increase detection of interproximal caries (Scarfe et al. 1994; Muhammed et al 1982). The use of film holders and beam-aiming devices have been shown to have several potential advantages in facilitating the procedure of taking a proper radiography by minimizing improper positioning or bending of the film and maintaining the relationship of film to the considered structures. Despite the evolution of dental radiology, the transition from conventional to digital radiography has not reflected an increase in image quality. Only a small percentage of dental radiography has achieved a satisfactory level of image quality (Svenson et al. 1994; Emanuel et al. 2003). Ideally, 90% of radiographs should be of diagnostically acceptable standard or above, although minor errors that do not alter the diagnostic value are excusable (Emanuel 2003). This maintains the principles of ALARA (As Low as Reasonably Achievable) and therefore reduces the total amount of radiation attributable from dental sources. This study aimed to evaluate the quality of bitewing radiographs taken by Universiti Teknologi MARA (UiTM) undergraduate dental students and to evaluate the difference in caries lesions found on bitewing radiographs and clinical examination.

Materials and Method

Study design

This is a prospective cross-sectional study assessing bitewing records within the Faculty of Dentistry, Universiti Teknologi MARA (UiTM) over a 7-month period from June to December 2017. All UiTM undergraduate dental students are required to complete 49 hours of face-to-face comprehensive didactic module series on Oral and Maxillofacial Radiology. The topics involved range from radiation physics and protection, to techniques and interpretation of diagnostic images, and are taught over the course of both pre-clinical and clinical years. The students are also provided with ICDAS training, which encompasses a minimum of 50 hours of face-to-face comprehensive didactic module series. This module is comprised of various topics including ICDAS charting, treatment planning, and deep caries management. Ultimately, the students are required to pass an ICDAS calibration test prior to proceeding to their clinical years. Ethics approval was obtained from the UiTM Research Committee (600-IRMI (5/1/6)-REC/105/17).

During their clinical training, the undergraduate dental students are allowed to prescribe and take intraoral radiographs pending approval by their clinical supervisors, which normally comprises of either trained general dentists or specialists. The criteria for prescribing bitewing radiographs are based on recommendations by the American Dental Association (ADA 2012), which includes new, dentate and partially edentulous adult patients. Recall patients with and without increased caries risk were recommended to have their bitewings taken at 6-18- and 24-36-months intervals respectively.

Sample size calculation

To assess the quality of bitewing radiographs, a minimum sample size for number of bitewing radiographs was calculated using PS software for two proportions. The significance level was set at $\alpha = 0.05$ with a statistical power of 80% and $p_0=0.1$ $p_1=0.7$. A minimum sample size of 240 bitewing radiographs were derived from the sample size calculation.

Inclusion criteria

New patients who attended UiTM Dental Centre between June and December 2017 to be seen by Year 3-5 undergraduate dental students were entered into the study. The inclusion criteria were:

- The patients' age ranges from 17 to 45 years old
- The patient must present with a minimum of three completely occluding pair of posterior teeth
- Bitewing radiographs were taken by undergraduate dental students of UiTM Dental Faculty between June 2017 to December 2017

Exclusion criteria

- Bitewing radiographs assisted or taken by non-undergraduate dental students. This includes postgraduate students, dental officers, radiographers and specialists.
- Patients with mixed dentition

Data collection

Subjects were chosen among the patients that were treated by UiTM dental undergraduates from year 3 until year 5. Clinical examination was conducted by these undergraduate dental students, and teeth were charted according to The International Caries Detection and Assessment System (ICDAS). The operators (the undergraduate dental students) were briefed by the examiners (R.L.H and R.S) prior to performing clinical examination on their patients. Subject's teeth were cleaned with a toothbrush or prophylaxis cup, and clinical examination was done on dried teeth surfaces using mouth mirror and ball-ended explorer. Caries charting was entered by the researchers into a pro forma, specifically to record the number of caries lesions present clinically. If all inclusion criteria were met, the examiners noted down the subject's record number for bitewing radiograph assessment at a later time. The bitewing radiographs were taken by corresponding operators using an EzSensor Classic CMOS sensor (Vatech,Korea) , positioned with the aid of a paralleling device (XCP-DS® Digital Sensors Holder, Dentsply, USA). Radiation exposure was generated with an X-MIND DC™ (Acteon, France) x-ray machine, which is maintained by a resident radiographer and calibrated twice yearly. The bitewing radiographs were stored on the EasyDentV4@ viewer software version 4.1.4.5 (Vatech, Hwaseong, Korea). If the subject did not meet the inclusion criteria (e.g: no indication for bitewing radiographs or insufficient number of

teeth), the examiners continued to approach the next available subjects until 240 bitewing radiographs were obtained. In total, 180 subjects were clinically examined, 120 of which met the inclusion criteria, providing 240 bitewing radiographs.

There were 2 parts in the data collection process:

1. Assessment of quality of bitewing radiographs
2. Comparison of caries detection between clinical examination and bitewing radiographs

Assessment of quality of bitewing radiographs

The quality of bitewing radiographs was evaluated according to a modified version of the "Quality Standards for Bitewing Radiography" table published in the European Guidelines on Radiation Protection in Dental Radiology 2004 (Horner et al. 2004). Each bitewing radiograph was assessed based on three main categories of operator-induced errors; image geometry, anatomical coverage, and density and contrast. Specifically, presence of the following radiographic errors was identified:

- **Foreshortening or elongation:** A vertical angulation error resulting in images appearing shorter or longer than the actual object.
- **Horizontal overlapping:** A horizontal angulation error resulting in overlapping of proximal surfaces
- **Inadequacy of film coverage:** Any radiograph that did not cover the mesial surface of the most posterior erupted tooth.
- **Non-ideal centering:** Maxillary and mandibular alveolar bone crests not visible, and the maxilla and mandible are imaged unequally
- **Inadequacy of contrast and density**: Inadequate contrast and density to allow distinguishment between enamel and dentine even after image manipulation of software

Any errors that were not defined in the assessment, were assigned as "Others". Then, each bitewing radiograph was further classified into three categories of 'excellent', 'acceptable' and 'unacceptable' based on their image quality (Table 1). The number of radiographic exposures was also recorded.

Excellent	Acceptable	Unacceptable
No fault	Some fault but not affecting image interpretation	Fault leading to radiograph being unsuitable for interpretation

Table 1: Criteria Standard For Bitewing Radiograph Based On European Guidelines On Radiation Protection In Dental Radiology 2004(Keith Horner et al. 2004).

Comparison of proximal caries detection by clinical and radiographic methods

For this part of the study, the following data were obtained:

- **Total caries detected clinically:** Total number of occlusal and proximal caries lesions recorded during clinical examination by undergraduate dental students
- **Total caries detected radiographically:** Total number of occlusal and proximal caries lesions visible on bitewing radiographs as recorded by examiners
- **Total caries detected clinically and radiographically**: Total number of caries lesions that were confirmed via

both clinical and radiographic examination

Clinical method:
The data for "total caries detected clinically" were obtained from the pro forma filled by the examiners.

Radiographic method:
For this part of the study, the number of caries lesions detected on bitewing radiographs were recorded into a pro forma. Caries lesion detection on the bitewing was performed according to the ICDAS/ICCMS™ radiographic scoring system. Caries was defined as any lesion seen radiographically that fits the RA 1 to RC 6 score.
RA 1: Radiolucency in the outer ½ enamel
RA 2: Radiolucency in the inner ½ of the enamel +/- enamel-dentine junction (EDJ)
RA 3: Radiolucency limited to the outer 1/3 of dentine
RB 4: Radiolucency reaching the middle 1/3 of dentine
RC 5: Radiolucency reaching inner 1/3 of dentine
RC 6: Radiolucency into the pulp

Radiographic calibration

Two independent examiners (R.L.H and R.S) were calibrated by two observers, both of which were experienced endodontists. Forty-eight images were selected and viewed in a room with fixed ambient lighting. Calibration was performed in similar set-ups on two separate occasions, separated by a 14-day interval. The first examiner (R.L.H) assessed all bitewing radiographs whereas the second examiner (R.S) interpreted about 20% of the radiograph to determine interobserver agreement. Cohen's kappa was used as a measure of reliability proving a good agreement (%=0.709) between observers.

Statistical analyses

The quality of bitewing radiographs, and the data for caries detection between clinical examination and bitewing radiographs were expressed as frequencies and percentages. The intra-group difference for each radiographic error was assessed for statistical significance using chi-square test. Data analysis was done using SPSS (version 23.0 for Windows, SPSS Inc, Chicago, USA).

Results

When 240 bitewing radiographs were analyzed based on their quality, 171(71%) of the bitewing radiographs were deemed to be of acceptable quality, 39(16%) were excellent, and 30(13%) were deemed diagnostically unacceptable (Figure 1). Of all the radiographs assessed, 90%(n=216) were taken without re-exposures. The remaining radiographs were taken with one (0.4%), two (8.4%), three (0.8%) and four (0.4%) re-exposures.

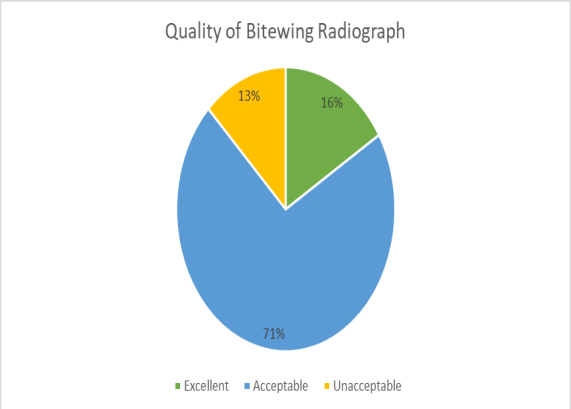

Figure 1: Quality of bitewing radiograph

Errors affecting the quality of the bitewing radiographs were shown in table 2. "Horizontal overlap" was the most common error detected on the radiographs (n=139,

57.9%), followed by "non-ideal centering" (n=93, 38.8%), "inadequate contrast" (n=46, 19.2%) and "inadequate film coverage" (n=24,10%). There intra-group difference for each error was statistically significant (p=0.05). No foreshortening or elongation errors were reported in any radiographs.

The number of caries lesions detected radiographically (64.6%) was almost three-fold the amount diagnosed clinically (22.4%) (Table 3).

	Errors affecting quality of bitewing radiograph											
	Shorten-ing or elonga-tion		**Horizontal overlap**		**Inadequate film cover-age**		**Non-ideal centering**		**Inadequate contrast and density**		**Others**	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
n	0	240	139	101	24	216	93	147	46	194	4	236
Percent%	0	100	57.9	42.1	10.0	90.0	38.8	61.2	19.2	80.8	1.7	98.3

Table 2: Factors affecting quality of bitewing radiograph

Total caries detected clinically		**Total caries detected ra-diographically**		**Total caries detected clinically and radiographically**	
n	Percentage	n	Percentage	n	Percentage
55	22.4	159	64.6	32	13.0

Table 3: Total caries detection by clinical examination and bitewing analysis

Discussions

To aid correct patient diagnosis, an acceptable quality of radiograph is needed. The quality of a radiograph depends on a series of processes: positioning of the film or sensor within the patient's mouth; positioning of the x-ray tube; exposure factor setting; and the development of the exposed film. A fault or inadequacy in any of these processes will affect the image quality. In our study, radiographs were taken using a digital system, which allows post-exposure image manipulation, in addition to greater, if not equal dose reduction compared with conventional film radiography (Berkhout et al 2004). Furthermore, digital radiography also eliminates processing errors which has been noted as the most significant contributor to repeat exposures in conventional film radiography (Button et al 1999;Yakoumakis et al 2001). This subsequently helps to reduce the number of unacceptable radiographs (Wenzel et al 2010), as evidenced in our results.

In the present study, the percentage of unacceptable radiographs (13%) corroborates with findings reported in a previous study conducted in the same institution (Yusof et al 2017). In the previous study, 15.1% of bitewing radiographs required re-exposure, the majority (56.7%) of which was due to operator errors. Upon comparison with other studies of similar objective, our percentage of unacceptable radiograph

(13%) is within the reported range of 5.5-36.8% (de Vries et al 1990; Kidd et al 1992; Machiulskiene et al 1999).

The number of unacceptable radiographs in our study not only averages the range reported in previous studies, but also compares with proposed achievable audit standards in general dentistry settings. The European Guidelines on Radiation Protection in Dental Radiology (Horner et al. 2004) acknowledges that no level of "unacceptable radiographs' should be tolerated and recommended that a fraction of no more than 10% of unacceptable radiographs should be targeted for. However, with an already low percentage of unacceptable radiographs in our study, undergraduate students should not be resting on their laurels. But instead, periodic audits should be conducted, focusing on the reasons and how to overcome errors, ultimately achieving a 50% reduction in unacceptable films at consecutive audit sessions (White et al. 1994). Re-training can also be proposed in an attempt to bring the percentage of rejected radiographs down to as low as possible.

Horizontal overlapping is a common error reported in bitewing radiographs (Marthaler et al.1966; Haugejorden 1974; Sewerin 1981; Yusuf et al. 2017). It is an error that occurs due to failure of directing the positioning indicator device (PID) through the proximal surfaces of the teeth, giving rise to an image of horizontally overlapping contact points. A high number of overlapping error raises an issue in that, the number of actual caries lesions could have been underestimated. Shaw & Murray (1971) acknowledged this shortcoming, and categorised various overlaps based on their extent. In their study, the diagnostic threshold identified approximal caries only when it has reached the inner half of enamel , ultimately underdiagnosing early enamel caries lesion. Conversely, setting a higher threshold for caries diagnosis to include enamel caries can also result in an overestimation of caries diagnosis. Rimmer et al. (1991) reported an increase of DMFT score from 1.7 to 4.7 when the diagnostic threshold for radiographic caries detection included all grades of caries lesion , as opposed to those involving dentine only.

In our study , the percentage of overlapping in radiographs is higher compared with that found in another study. Mourshed et al. (1971) analysed intraoral radiographs taken by undergraduate dental students and found that incorrect horizontal angulation manifesting as horizontal overlapping were present in 20.6% (652/ 3173) of radiographs. This percentage however, was calculated based on the total of periapical and bitewing radiographs. In another study, Haugejordan **(**1974) demonstrated that caries lesions extending beyond moderate overlaps could still be assessed despite the high number of overlapping present (30-40 %) in posterior teeth. This is perhaps a reassuring finding considering that although horizontal overlapping is not desirable, it is an error that cannot be consistently avoided even in the experienced hands of radiographers (Sewerin 1981).

"Inadequate contrast and density" was the third most common radiographic error (19.2%) in this study. For this parameter, a bitewing radiograph is noted as having "inadequate contrast" when post-exposure manipulation of the imaging software fails to allow discrimination between enamel and dentine. With the advent of digital radiography, this error should not occur unless if it is attributed to faulty exposure setting factors. Nonetheless, this observation highlights the need to reiterate the importance of confirming exposure

settings before radiograph taking amongst the undergraduate dental students.

In our study, the number of caries lesions detected via bitewing radiographs was three times that by clinical examination. This result corroborates with findings in another study which reported a three-fold increase of caries lesions detected with bitewing radiographs (de Vries 1990). However, an even larger difference has been documented. Poorterman et al. (1999) noted that, from a total of 1372 caries lesions, only 10.8% were detected clinically, of which, approximately eight times as many lesions were found radiographically (89.2%). In contrast, Machiulskiene et al. (1999) reported no significant difference between the mean number of cavitated caries lesion involving the dentine as detected by clinical (n= 2.09) or radiographic (n=2.94) method. Although the difference in caries detection in our study may pose some questions on the precision of clinical caries detection amongst the undergraduate dental students, it must be borne in mind that there are limitations to radiographic examinations. This includes the fact that radiographs cannot discriminate between cavitated and non cavitated lesions (Nielsen et al 1996), let alone allow differentiation of active and arrested lesions. In fact, only 35-79% of radiolucencies in the one third or outer half of the dentine presents with cavitation clinically (Pitts & Rimmer 1992; Akpata et al. 1996; Hintze et al. 1998).

Since the introduction of the “lesion behavior” rather than the “lesion progression” concept, the way clinicians view the role of radiographs in caries management has been altered (Pitts & Rimmer 1992). Armed with the knowledge that carious process is a dynamic nature that exhibits interchanging phases of demineralization and remineralization, various radiographic prescribing guidelines have since shifted their focus on monitoring caries lesion behavior, allowing clinicians to manage caries by preventive rather than interventive treatment (Pitts & Kidd 1992; Jenson et al 2007; American Dental Association 2012; Horner & Eaton 2013).

The European Guidelines on Radiation Protection in Dental Radiology (Horner et al 2004) indicates that, for a bitewing radiograph to have “adequate film coverage”, the image must display distal surfaces of the canines to the mesial surfaces of the most posterior erupted teeth. However, issues of adequate film coverage with digital sensors has been raised previously. Bahrami et al. (2003) reported that fewer images produced with charge-coupled device (CCD) displayed canine and premolar surfaces than those by photostimulable phosphor plates (PSP), and this difference was statistically significant ($p<0.05$). This limitation is attributed to the much bulkier and rigid nature of the CCD (compared with PSP and conventional film), thus requiring the sensor to be pushed further posteriorly to compensate for the patient’s jaw anatomy and to reduce patient discomfort. In fact, conventional film and PSP plate were rated as the most comfortable receptors, demonstrating statistical significance of difference in visual analog scores (VAS) against CCD sensors ($p<0.05$). For that reason, we modified the criteria for film coverage to include the mesial aspect of the most posterior erupted teeth to the most anterior points. In a majority of the bitewings assessed in this study, the general observation was that the anterior limit of the images often includes the mesial aspect of first premolars, and not as much the canine. However, this observation was not quantified, paving more room for improvement in future

studies alike.

In a systematic review that assessed the additional value of bitewing radiographs to clinical caries detection, data derived from seven studies included in the meta-analysis reported an increase of between 1.7 to 10% of extra approximal caries lesions detected with bitewings (Bloemendal et al 2004). This was observed when dentine was considered a diagnostic threshold i.e: enamel caries was not taken into account radiographically. When enamel caries (in addition to dentin) was included, the percentage increase of extra approximal caries detection rose to 13.6% (de Vries 1990). In our study, enamel was considered a diagnostic threshold i.e: enamel caries was included in the assessment, and 104(42.3%) additional caries lesions were detected with bitewing radiographs. The higher percentage in our study may be attributed to two reasons. Firstly, our study analyzed clinical and radiographic records performed by undergraduate dental students, whereby the experience in clinical caries detection varies based on their level of study and is inherently limited compared with that of general dental practitioners. In addition, our study included lesions as minor as incipient caries in the enamel during collection of radiographic data. These lesions are not as easily detected clinically, which explains the higher percentage of extra caries lesions detected radiographically compared to other studies (de Vries et al. 1990; Hintze et al. 1993; Machiulskiene et al. 1999; Poorterman et al. 1999,)

This study was conducted to assess the quality of bitewing radiographs taken by undergraduate dental students of UiTM, in addition to comparing the number of caries lesions detected by clinical and radiographic methods. The result shows overlapping as the most frequent error, reflecting the lack of attention paid by the operator during tube head positioning, and perpetuating the importance of retraining. There are several limitations to this study. Firstly, the lack of dichotomization of data prevented us from assessing the difference between occlusal and proximal caries detected. Furthermore, intra-observer agreement was not calculated, thus putting into the question the examiner reliability. Should this study be repeated in the future, several changes should be made. This includes defining the diagnostic threshold when assessing radiographs with horizontal overlap to make the study more relevant and comparable to previous studies. In addition, recording visual analog scores (VAS) by patients during radiograph -taking could provide additional information with regards to acceptance of the specific sensor, thus a reflection on patient's comfort in digital radiography.

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