



## The Diagnostic Threshold of Bitewing Radiographs for the Treatment of Proximal Caries

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### ABSTRACT

**Introduction:** Systematically review the English literature for the best available evidence of the relation between the depth proximal caries identified on bitewing radiographs and the probability of lesion cavitation requiring restorative intervention. **Methods:** A search of the English scientific literature using MEDLINE, EMBASE, SCOPUS, Web of Science, and the Cochrane Library databases and using MESH terms such as dental caries, bitewing, and radiography was performed. Only in vivo study designs on human permanent posterior teeth using bitewing radiographs and direct visual inspection published in the last ten years were included. The articles were reviewed against a checklist for assessing a diagnostic or predictive test. **Results:** Only two articles met the inclusion criteria and were included in this systematic review. There was marked variation in the sensitivity and specificity of bitewing radiographs between the two studies. **Conclusion:** There is still controversy regarding the relation between caries lesion cavitation and lesion depth as determined by bitewing radiographs. However, the prevalence of caries in the population seems to be an important factor to consider.

**Keywords:** Dental caries, Tooth demineralization, Tooth diseases, Stomatognathic diseases, Bitewing, Radiography, Diagnostic imaging

### INTRODUCTION

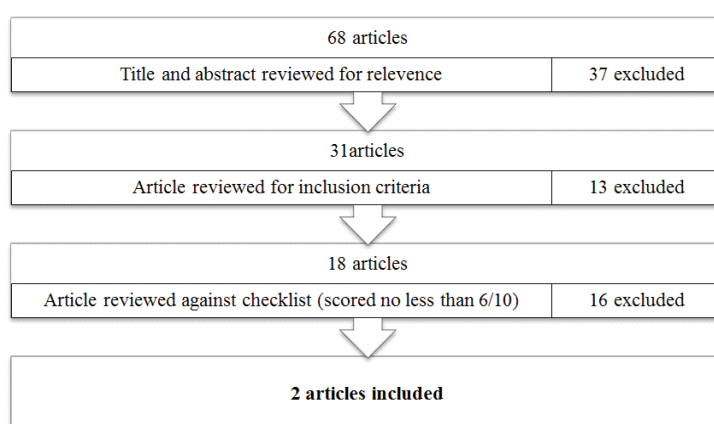
Caries diagnosis is dependent on many factors and one of the most important factors is radiographic findings. This is especially true for proximal carious lesions that are difficult to detect clinically. Bitewing radiographs are considered the standard of practice for detecting proximal carious lesions [1]. They are used not only to determine the presence or absence of a carious lesion but also to determine its depth. This in turn significantly influences the decision for treatment and management planning generally including preventive measures.

Cavitation is agreed upon as the point of no return that requires restorative intervention. However, determining cavitation especially for proximal carious lesions can be challenging both clinically and radiographically. Worldwide studies estimate that 40%-100% of carious lesions that display outer dentin radiolucencies are cavitated [2]. Nevertheless, it is well established that the depth of carious lesions is usually underestimated radiographically. In addition, great variation exists among dentists when they interpret bitewing radiographs [3]. This all translates to potentially false positive and false negative results of bitewing radiograph used for proximal carious determination.

Currently, there is no diagnostic threshold for bitewing radiographs for the treatment of detected proximal carious lesions. In addition, the treatment threshold may differ from one population to another according to the prevalence of caries in each population [1,4]. Therefore, this study aimed to systematically review the English literature for the best available evidence of the relation between the depth proximal caries identified on bitewing radiographs and the probability of lesion cavitation requiring restorative intervention. Establishing this relationship is important to determine a diagnostic threshold on which treatment decisions can be made.

## METHODS

A search of the English scientific literature using the MEDLINE, EMBASE, SCOPUS, Web of Science, and the Cochrane Library databases and using MESH terms such as dental caries, tooth demineralization, tooth diseases, stomatognathic diseases, bitewing, radiography, diagnostic imaging, diagnostic techniques, the diagnosis was performed. Reference lists and systematic review articles were also searched for relevant articles. Inclusion criteria included: original peer-reviewed articles published in the last 10 years, human subjects, posterior permanent teeth, *in vivo* study design, using bitewing radiographs and direct visual inspection, reported results as sensitivity and specificity, or reported sufficient data for these to be calculated. The process of article review and inclusion is detailed in Figure 1. The selected articles were reviewed against the “Checklist for assessing a diagnostic or predictive test” (Table 1) [5]. The highest score an article can achieve using this checklist is 10 but 6/10 was the cut-off value for including articles in this systematic review. After article selection, the relevant data was extracted as detailed in Table 2.



**Figure 1** The stepwise process of selecting and reviewing the articles

**Table 1** Checklist for assessing a diagnostic or predictive test

1. Was the study ethical?
2. Is the test clearly described (including the cut-off values)?
3. Was the test evaluated against a valid gold standard?
4. Were the test results and disease status determined independently?
5. Was the test evaluated using patients with a range of severity of disease?
6. Was the test evaluated among patients with diseases that might be confused with, or are closely related to, the disease of interest?
7. Is the test performance reported using sensitivity/specificity, likelihood ratios, or ROC curves? (Note: If predictive values, only, are reported, was the background prevalence of disease similar to that of your patients)
8. Is the effect of moving the cut-off point reported?
9. Does this test give better results than the current or standard test?
10. Is the test likely to be acceptable to patients?

**Table 2** Evidence table summarizing the results of the two articles included in this systematic review

References	Sample size	Test	Gold standard	Results	Conclusion
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[6]	53 subjects Mean age 24.6 years  338 proximal surfaces	4 observers  Criteria: 0=sound 1=outer 1/2 E 2=inner 1/2 E 3=outer 1/3 D 4=inner 2/3 D	Direct visual inspection after 3 days of tooth separation by same observers  Criteria: 0=sound 1= non-cavitated 2=cavitated	Sensitivity=80.3% Specificity=26.5%	The visual-tactile method alone was superior with regards to reaching the correct management decisions
[7]	34 subjects 17 M, 17 F Mean age 36.76 years  79 proximal surfaces	2 observers  Criteria: Cavitated Not cavitated	Direct visual inspection after 3 days of tooth separation by a different observer  Criteria: Cavitated Not cavitated	Sensitivity=44% Specificity=85.5%	CBCT was more accurate in detecting cavitation in proximal surfaces than bitewing radiographs

## RESULTS

Only two studies were found to meet our inclusion criteria (Table 2). Unfortunately, this precluded us from proceeding with a meta-analysis of the available data. The first study by Baelum, et al. was conducted in Denmark in 2012 to examine the effect of combining various caries diagnosis methods (visual-tactile and bitewing radiographs) on the management decision in a population with low caries risk [6]. The observers were asked to determine the depth of the carious lesion using two criteria; the first dictated that any lesion in dentin was considered cavitated, while the second set of criteria dictated that only carious lesions in the inner 2/3 of dentin were considered cavitated. Visual inspection was done by the same four observers. According to both sets of radiographic criteria, the sensitivity of bitewing radiographs was 80.3% and the specificity was only 26.5% [6].

The second study by Sansare, et al. aimed to examine the diagnostic accuracy of Cone Beam Computed Tomography (CBCT) in comparison to bitewing radiographs to detect cavitated proximal carious lesions [7]. Two observers examined both sets of images (CBCT and bitewing radiographs) but at different times and they were only asked to decide if the proximal carious lesion was cavitated or not. Another observer compiled the findings from the visual examination. The results indicate that bitewing radiographs have a sensitivity of 44% and a specificity of 85.5%. In contrast, CBCT had a greater sensitivity of 77% and a slightly lower specificity of 77% than bitewing radiographs [7].

## DISCUSSION

Non-cavitated carious lesions can now be arrested and re-mineralized using preventive measures [3]. This has prompted guidelines to recommend preventive measures for non-cavitated lesions before any restorative treatment is attempted [1]. While clinical examination can establish the state of carious lesions of the occlusal and smooth surfaces, proximal surfaces that are clinically inaccessible are challenging [1]. Therefore, bitewing radiographs remain the most reliable diagnostic method for proximal caries [8]. However, establishing the relation between caries detectability radiographically and its clinical state remains an area of great debate and controversy.

Only two articles met the inclusion criteria and were included in this systematic review. There was marked variation in the sensitivity and specificity of bitewing radiographs between the two studies. This is most likely due to the difference in caries prevalence between the two populations studied. In the Baelum, et al. study, the reported high sensitivity but low specificity may potentially lead to false-positive results especially in a population where caries are not prevalent [6]. However, the combination of visual-tactile and bitewing radiographs increased the sensitivity to 97.4% and the specificity to 34.5% which is why the authors considered data from the radiographic examinations only useful to supplement properly collected visual-tactile data. The authors also called for a review of the practice of screening for proximal caries using bitewing radiographs. In the Sansare study, the sensitivity was much less while the specificity was much greater than the Baelum study [6,7]. Unfortunately, the study population was not stated and, therefore, the caries risk was not known. Also, it would have been beneficial to examine whether the differences in sensitivity and specificity between the two imaging modalities (CBCT and bitewing radiographs) were statistically significant or not. Despite these promising findings, those authors were quick to state that CBCT should not be used as a routine

diagnostic examination for proximal caries detection because of the risk of radiation exposure that outweighs the benefits of increased diagnostic accuracy.

A third study that we would have liked to include in this systematic review was another by Sensare, et al. [4]. This study aimed to examine the relationship between proximal caries depth radiographically and lesion cavitation in a population with a high caries risk. Unfortunately, the authors did not report sensitivity and specificity results, nor was there enough data for us to calculate these two outcomes. Nevertheless, the authors asked 5 observers to examine the bitewing radiographs of 126 proximal surfaces and score the carious lesion depth as 0=sound, 1=lesion in enamel, 2=lesion in outer 1/3 of dentin, and 3=lesion in inner 2/3 of dentin. Then after wearing orthodontic teeth separators for three days, the proximal surfaces were examined by two different observers and were scored as cavitated or not [7]. They found that 7.1%-32% of proximal surfaces that were scored as sound radiographically were cavitated. Of the proximal surfaces that were scored as having caries in enamel, 25.6%-38.3% were cavitated. Of the proximal surfaces that were scored as having caries in the outer 1/3 of dentin, 83.3%-100% were cavitated. Of the proximal surfaces that were scored as having caries in the inner 2/3 of dentin, 96.4%-100% were cavitated. This led the authors to conclude that a high percentage of proximal carious lesions that were radiographic “not deep” were cavitated and necessitated operative treatment in this population with high caries prevalence. They also set the treatment threshold for proximal lesions at a depth between enamel and outer dentin radiographically in order not to miss a significant number of cavitated lesions. These conclusions were based on the claims that the caries prevalence was higher in their studied population; the access to fluoride was limited, the disease activity and the cavitation threshold may be different among different populations [7]. The authors called for reviewed global standards but perhaps what is needed are customized national guidelines for the diagnosis and treatment of proximal caries.

When acquiring bitewing radiographs for the indication of proximal caries detection, two factors need to be taken into consideration. The first factor is the radiation dose to the patient, which in turn is dependent on several other factors including the choice of the image receptor. The use of conventional film-based and digital image receptors for the detection of carious lesions has been extensive studies and the consensus is that there is no difference between the two image receptors with regards to diagnostic accuracy. However, digital image receptors are more sensitive to radiation requiring shorter exposure times, which in turn results in less patient movement, less image blur, and most importantly less radiation exposure for the patient [1]. Estimates of the effective radiation dose to the patient from intraoral radiographs using digital image receptors range are between 1  $\mu$ Sv-8  $\mu$ Sv [9]. Radiation dose to the patient is also influenced by the use of image receptor holders and beam aiming devices. These two have resulted in a significant reduction in patient radiation exposure because of the reduction in the number of remakes [8]. The second factor to consider is cost. Despite its popularity very little has been published on the cost-effectiveness of bitewing radiographs for the detection of proximal caries. The cost of a diagnostic examination is based not only on the diagnostic accuracy of the examination but also on the treatment outcome and the prevalence of the disease to be detected in the population [1,10]. A cost-effective analysis by Schwendicke, et al. considered all these factors and concluded that for occlusal caries, the combining of visual-tactile examination or radiographic examination with micro-invasive treatment was the most cost-effective in a population with low caries prevalence [10]. In contrast, combining radiographic examination with micro-invasive treatment was the most cost-effective for a population with high caries prevalence [10]. Wenzel in a review concluded that customizing the radiographic examination was more cost-effective than standardizing the examination for all patients [1].

The interpretation of bitewing radiographs is another important factor to consider. It depends not only on the expertise of the observer but also on the viewing conditions and the classification system adopted. In an *in vitro* study by Hajizadeh, the ability of four groups of observers (dental students, dentists, restorative dentistry specialists, and oral radiology specialists) to categorize proximal lesions according to the International Caries Detection and Assessment System (ICDAS) was compared [11]. Although no statistical differences were found, they noted that oral radiologists had the highest diagnostic accuracy. They also found that decision errors were more common with carious lesions classified as ICDAS 1 and 2 followed by 3, 4, and 5 [11]. Much research is still needed in this area to explore the influence of the years of experience not only the clinical specialty and the viewing conditions on the diagnostic outcome.

The relation between proximal caries depth radiographically and the likelihood of cavitation has been extensively studied in the 1980s and 1990s [12,13]. The results, however, have been controversial and no definitive conclusion has

been reached. Yet studies to examine this relationship seem to have ceased. This seems perplexing considering bitewing radiographs are still heavily relied upon for the detection of proximal caries and their findings play a major role in the management decision. It is generally agreed upon that the deeper the carious lesion, the more likely it is cavitated with lesion extending into the inner half of dentin, most likely to be cavitated [14-20]. The grey area of controversy seems to be the outer third or half of the dentin [1]. Nevertheless, treatment guidelines have been established for “western countries” presumed to have low caries risk. These guidelines recommend definitive restorative treatment for lesions involving the inner 1/3 of dentin but leave the operative decision to the dentists for carious lesions involving the outer 2/3 of dentin [1,21].

### CONCLUSION

There is still controversy regarding the relation between caries lesion cavitation and lesion depth as determined by bitewing radiographs. However, the prevalence of caries in the population seems to be an important factor to consider.

### Clinical Significance

Because the diagnosis and management decision of proximal carious lesions relies so heavily on the findings of bitewing radiographs, the relation between the two must be fully understood so that treatment thresholds can be put in place to facilitate the decision for the practicing dentist. This systematic review provides an overview of the current literature on this matter and explores the areas where much research is still needed.

### DECLARATIONS

#### Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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