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Comparison of radiographic and clinical diagnosis of approximal and occlusal dental caries in a young adult population

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Abstract – *Objectives:* The aims of the study were: (1) to determine if bitewing radiographs provided additional diagnostic yield for occlusal and approximal dental caries in adults aged between 17 and 30 years of age when compared with a clinical examination only, (2) how this translated into the measurement of dental caries experience, and (3) to determine the influence of water fluoridation on the diagnosis of dental caries in occlusal and approximal surfaces by clinical examination alone and by radiographic examination. *Methods:* Between November 2002 and March 2003 a total of 879 subjects aged 17–30 years had a clinical examination using visual and tactile criteria. Subsequent to this examination, bitewing radiographs were taken and viewed separately and blind. Approximal and occlusal surfaces of molars and premolars were examined on the radiographs. *Results:* Between 22.9–32.9% of approximal caries and 75.9–82.9% of occlusal caries was detected by clinical examination, while 93.1–97.1% of approximal caries and 33.1–42.6% of occlusal caries was detected by radiographic examination. In addition, while only 0.97% of clinically sound approximal surfaces and 0.83% of clinically sound occlusal surfaces were diagnosed with dentine caries on the radiographs, 67.1–77.1% of approximal caries was detected by radiographs alone, an additional diagnostic yield of 204–336%. The DS score increased 45–46% and the DMFS score increased 6–11% from the clinical examination with the addition of the radiographic information ($P < 0.001$). *Conclusions:* The prevalence of approximal and occlusal caries was underestimated when clinical means only were employed. There was a significant increase in DS and DMFS scores from the clinical examination only when radiographic information was added across all age groups ($P < 0.001$). This study confirms the value of bitewing radiographs in caries diagnosis.

Key words: bitewing radiographs; caries diagnosis; DMFS; epidemiology

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The accurate diagnosis of occlusal and approximal dental caries is important in both the clinical and epidemiological setting, yet the literature indicates that caries diagnosis by clinical examination has become more difficult. It has been widely reported that the prevalence of occlusal caries is significantly underestimated by visual examination alone, with up to 50% of clinically sound occlusal surfaces diagnosed radiographically with caries (1–3). Although several studies have indicated that fluoride may be responsible for this increase in hidden occlusal caries by slowing lesion progression and facilitating enamel remineralization (3, 4), others have reported no evidence of this effect (2). Furthermore, it appears that the onset of occlusal caries has been delayed beyond the previously recognized peak period immediately post-eruption (5). Although bitewing radiographs have long been

considered important for the diagnosis of approximal dental caries, there has been considerable debate regarding their usefulness in aiding the diagnosis of occlusal caries, especially in populations with high caries prevalence. Many early studies found little value in using bitewing radiographs for diagnosing occlusal caries (6, 7). However, more recently Weerheijm et al. (1) found 26–50% of clinically sound surfaces showed evidence of dental caries on bitewing radiographs, and proposed that bitewing radiographs should be considered for routine use in epidemiological surveys.

Clinical diagnosis of approximal caries is arguably more problematic. Poorterman et al. (8) reported that the extra diagnostic yield of bitewings varied between 163% and 700% for approximal dentine caries diagnosis of untreated surfaces, with a subsequent increase in the DMFS score between 1% and 12% for subjects aged between 14 and 54 years of age. They argued that bitewings were important in the clinical setting, but questioned their value in epidemiology. Several studies have shown approximately 10% of approximal surfaces judged to be clinically sound were diagnosed with dentine caries using bitewing radiographs (9, 10).

Although it is generally accepted that a clinical examination only will fail to diagnose all approximal and occlusal carious lesions, some studies have questioned the necessity of bitewing radiographs for epidemiological studies of dental caries in populations with low caries experience. In these populations, it is argued that radiographs contributed little additional information to the clinical examination (9, 11). In Australia, there has been a substantial decline in caries experience in young adults over the past 30 years, with a previous study of Army recruits in 1996 reporting mean DMFT scores of 3.59 and 4.63 for subjects aged 17–20 and 21–25 years, and 19% of 17–20-year-old subjects reporting DMFT = 0 (12). Therefore, it has become necessary to evaluate the additional diagnostic yield of bitewing radiographs for oral epidemiology in a contemporary Australian young adult population.

The aims of the present study were: (1) to determine if bitewing radiographs provided additional diagnostic yield for occlusal and approximal dental caries in adults aged between 17 and 30 years of age compared with a clinical examination only, (2) how this translated into the measurement of dental caries experience using the DS and DMFS indices, and (3) to examine the diagnosis of dental caries in occlusal and approximal surfaces by clinical examination alone and by radiographic examination, in subjects from fluoridated and nonfluoridated areas.

Materials and methods

Subjects

This study reports on data from a cross-sectional study of Australian Army recruits between November 2002 and March 2003. During this period, a total of 1036 recruits were examined, with 973 giving informed written consent to participate in the study. Of these, 879 recruits were aged 17–30 years, and the data from these subjects are reported here. Each recruit had a clinical examination using visual and tactile criteria. Bitewing radiographs were taken and viewed separately from the clinical examination. The examination and bitewing radiographs were part of the normal Army procedure for an initial dental examination. The recruits completed a sociodemographic questionnaire that also provided detailed information on lifetime exposure to water fluoridation.

Examination and questionnaire

The recruits were examined by one of three calibrated examiners in a dental clinic, using a plane mouth mirror and sickle probe with the aid of a dental chair light. The sickle probe was used to remove debris, check restoration margins and detect cavitation. A pair of posterior bitewing radiographs, positioned using adhesive tabs, was taken of all recruits using Kodak Ultra-Speed D Size 2 films and a Philips Dens-o-mat X-ray unit. Radiographs were examined separately from the clinical examination by a single examiner (MH). The clinical data was recorded separately from the radiographic data, and without prior viewing of the radiographs. The clinical diagnostic criteria for dental caries were visually apparent cavitation, discolouration showing through enamel or visual evidence of recurrent caries. Dental caries was assessed from the radiographs at both the enamel and dentine level for approximal surfaces, and at the dentine level for occlusal surfaces, using the following codes: 1 – radiolucency in outer half of enamel; 2 – radiolucency in inner half of enamel; 3 – radiolucency just penetrating into dentine;

4 – radiolucency in outer half of dentine; and 5 – radiolucency in inner half of dentine (13). Radiographic caries is reported in this paper for codes 3, 4 and 5 (D_3 threshold). Radiographs were used to assess tooth surfaces from the distal surface of the second molar to the mesial surface of the first premolar. In all cases, radiographs were viewed on a light box using a ×2 magnification viewer. Inter-examiner reliability for the clinical examination was tested by comparison to the chief investigator (MH) with a total of 20 blind re-examinations for each examiner, with κ scores of 0.70 and 0.87 reported. Twenty repeat blind examinations were conducted by each examiner on four occasions, approximately 2 h after the initial examination, to measure intra-examiner reliability for the clinical examination, with κ scores of 0.87, 0.90 and 0.93, and 30 radiographs were re-examined blind 1 day apart on six occasions throughout the study period to determine intra-examiner reliability for the radiographic examination at the dentine caries threshold, with a κ score of 0.90.

Subjects completed a questionnaire prior to examination to elicit sociodemographic data and lifetime exposure to water fluoridation. Both the clinical and radiographic examinations were conducted blind to the questionnaire data, and examination of the radiographs was conducted blind to the clinical examination. Lifetime exposure to fluoridated drinking water was calculated using data obtained from state health departments. Subjects were classified as either having a lifetime exposure (100%), no lifetime exposure (0%) or a partial lifetime exposure to fluoridated drinking water. Only those subjects with a lifetime or no lifetime exposure were included in the analysis of the effect of water fluoridation on caries diagnosis.

Statistics

Caries prevalence is reported for approximal and occlusal surfaces, from the distal of the second molar to the mesial of the first premolar. Differences in the proportions of surfaces with clinically undetected caries between age groups, surface types and lifetime exposure to water fluoridation were measured using Pearson's chi-square analysis.

Ethics

The study was approved by the Australian Defence Human Research Ethics Committee and The University of Melbourne Human Research Ethics Committee. Participation in the study was voluntary, and informed written consent was obtained from all the participants.

Results

The sample population had a low level of caries experience, with mean DMFT scores ranging from 2.43 to 5.47 based on both clinical and radiographic examination (Table 1). The level of untreated caries (DS) across all tooth surfaces was also low, ranging from 1.08 to 1.77 surfaces.

Figure 1 shows the relationship between the number of approximal caries lesions detected by clinical and radiographic examination across the age groups. The majority of caries lesions were detected radiographically, with between 2.9% and 6.9% of lesions detected by clinical examination only, and between 22.9% and 32.9% of lesions detected by clinical examination. Caries prevalence (DS) increased significantly with increasing age ($\chi^2 = 54.91$, $P < 0.001$), and the proportion of lesions detected solely by radiographic examination decreased with increasing age, although this was not statistically significant ($\chi^2 = 2.71$, $P = 0.258$). More than three times as many additional approximal lesions were detected by radiographs for subjects aged 17–25 years, and more than twice as many from the radiographs in subjects aged 26–30 years.

Approximal caries prevalence in subjects with no lifetime exposure to fluoridated drinking water was twice that of subjects with a lifetime exposure to fluoridated drinking water ($\chi^2 = 20.00$, $P < 0.001$), however, there was no significant difference in the proportion of additional lesions detected by radiographic means (Fig. 2).

The data on occlusal surfaces followed a different pattern, with more than three quarters of caries lesions detected clinically, and only an additional 20.7–31.7% of lesions detected with radiographs across all age groups (Fig. 3). Radiographs detected an additional 27.6% of occlusal lesions in subjects with a lifetime exposure to fluoridated water

Table 1. Number of participants and mean DMFT and DMFS scores for all teeth

Age (years)	*n*	Mean DMFT (SD)	Mean DMFS (SD)
17–20	525	2.43 (2.82)	3.21 (4.74)
21–25	238	3.44 (3.61)	5.12 (6.77)
26–30	116	5.47 (4.58)	9.61 (10.89)

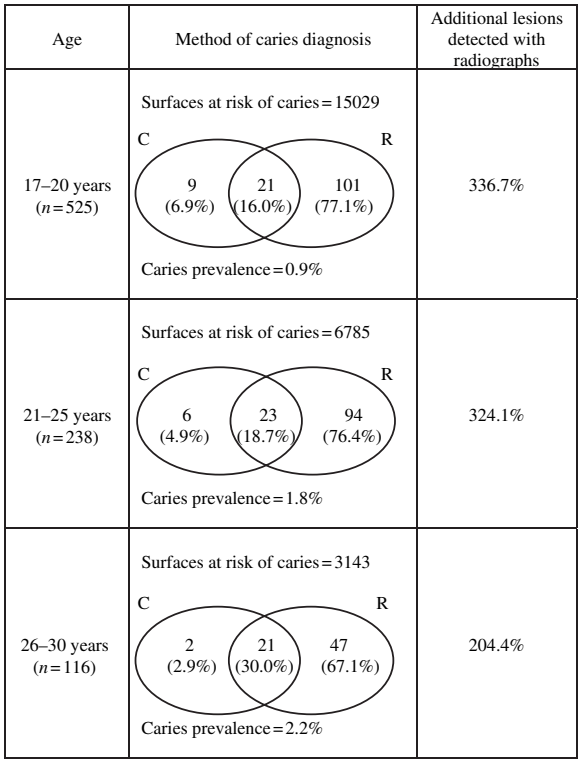

Fig. 1. Relationship between the number of approximal caries lesions detected by clinical (C) and radiographic (R) examination by age group.

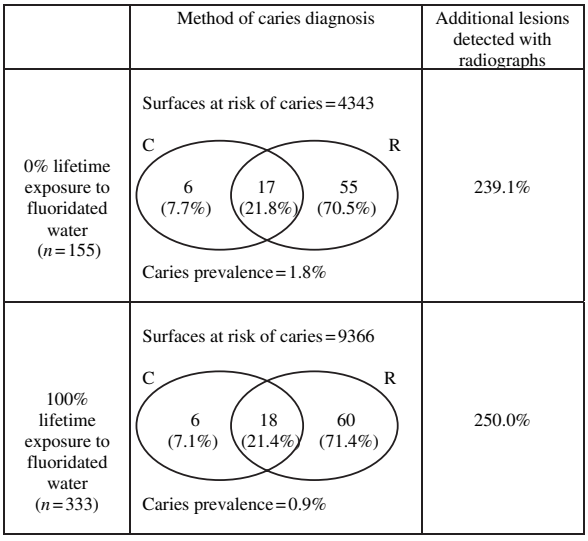

Fig. 2. Relationship between the number of approximal caries lesions detected by clinical (C) and radiographic (R) examination by water fluoridation exposure.

compared with 19.2% for subjects with no lifetime exposure to fluoridated water (Fig. 4). However, this difference was not statistically significant ($\chi^2 = 1.12$, $P = 0.290$).

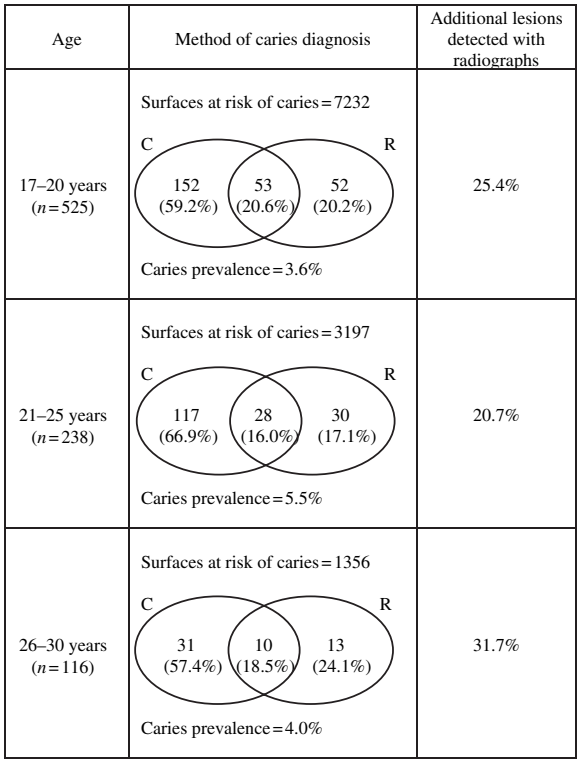

Fig. 3. Relationship between the number of occlusal caries lesions detected by clinical (C) and radiographic (R) examination by age group.

The percentage of approximal and occlusal surfaces with clinically undetected caries lesions by age group are shown in Table 2. There was a significant difference ($P < 0.001$) found in approximal surfaces across age groups, although this amounted to only 0.67–1.51% of clinically sound surfaces. There was a similar proportion of clinically undetected occlusal caries lesions across all age groups, with no statistically significant differences evident.

Approximal surfaces that had no lifetime exposure to fluoridated drinking water were found to have twice the percentage of clinically undetected caries than those with a lifetime exposure to fluoridated drinking water ($P < 0.001$), but differences were not evident on occlusal surfaces (Table 3).

There was a significant difference between the mean DS and DMFS scores reported from clinical examination alone compared to those obtained with the addition of bitewing radiographs (Table 4). The mean number of decayed surfaces (DS) increased 45–46% from the clinical examination with the aid of bitewing radiographs. The mean DMFS scores subsequently increased 6–11%, giving correction factors of 1.06–1.11 to adjust the clinical DMFS score.

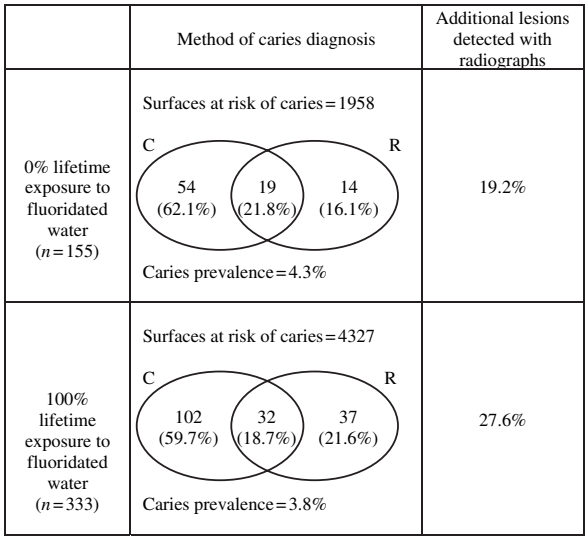

Fig. 4. Relationship between the number of occlusal caries lesions detected by clinical (C) and radiographic (R) examination by water fluoridation exposure.

Table 3. Percentage of approximal and occlusal surfaces with clinically undetected dentine caries, stratified by water fluoridation exposure

	Exposure to water fluoridation			
	Approximal[a]		Occlusal[b]	
	0%	100%	0%	100%
n	4398	9426	1972	4364
1	4343	9366	1958	4327
2	55	60	14	37
3	1.25%	0.64%	0.71%	0.85%

n = Total number of clinically sound surfaces; 1 = clinically and radiographically sound; 2 = clinically sound and radiographically carious; 3 = percentage clinically undetected dentine caries; ES = effect size.
[a] $\chi^2 = 13.71$, $P < 0.001$; ES = 0.03.
[b] $\chi^2 = 0.32$, $P = 0.569$; ES = −0.01.

Table 4. Increase in DS and DMFS scores with the addition of radiographic diagnosis

	17–20 years	21–25 years	26–30 years
DS score			
Clinical	0.74	1.27	1.22
Combined	1.08	1.84	1.77
Difference	0.34	0.57	0.55
Paired *t*-test	$P < 0.001$	$P < 0.001$	$P < 0.001$
Correction factor	1.46	1.45	1.45
DMFS score			
Clinical	2.91	4.59	9.09
Combined	3.21	5.12	9.61
Difference	0.30	0.53	0.52
Paired *t*-test	$P < 0.001$	$P < 0.001$	$P < 0.001$
Correction factor	1.10	1.11	1.06

Discussion

This study found that there was substantial underestimation of the prevalence of approximal caries lesions, and to a lesser extent on occlusal surfaces, by clinical examination alone. Overall, clinical examination detected nearly 60% of all occlusal and approximal dentine caries on molars and premolars. However, more than two-thirds of the approximal dentinal caries lesions remained undetected by clinical examination alone. Obviously, this has important implications for the measurement of dental disease. First, this study confirms the value of bitewing radiographs for the detection of approximal caries in clinical practice. The relative decline in caries experience in the young adult population in Australia may have led clinicians to believe that bitewing radiographs are not required for many of these patients. However, it is apparent from this study that there were some subjects who appeared caries-free clinically but had radiographic carious lesions into dentine. Secondly, researchers conducting clinical trials of anti-caries agents should also consider the use of bitewing radiographs, to ensure a better detection of the

Table 2. Percentage of approximal and occlusal surfaces with clinically undetected dentine caries, stratified by age group

	Approximal[a]			Occlusal[b]		
	17–20 years	21–25 years	26–30 years	17–20 years	21–25 years	26–30 years
n	14999	6756	3120	7027	3052	1315
1	14898	6662	3073	6975	3022	1302
2	101	94	47	52	30	13
3	0.67%	1.39%	1.51%	0.74%	0.98%	0.99%

n = Total number of clinically sound surfaces; 1 = clinically and radiographically sound; 2 = clinically sound and radiographically carious; 3 = percentage clinically undetected dentine caries; ES, effect size.
[a] $\chi^2 = 35.46$, $P < 0.001$; ES = 0.04.
[b] $\chi^2 = 1.95$, $P = 0.377$; ES = 0.01.

level of dental caries. Finally, epidemiological surveys performed without bitewings in similar populations will underestimate the true caries prevalence using DMFS by approximately 10%. This is in contrast to previous studies which have concluded that in some populations, the omission of radiographs will not result in a substantial loss of information (9, 14).

The additional contribution of bitewing radiographs to the DMFS index is comparable to that reported by Poorterman et al. (8), although they examined only approximal surfaces with bitewing radiographs. They found a correction factor of 1.03–1.12 for subjects aged 17–34 years. This relatively small correction factor is likely to be due to the fact that untreated caries in approximal and occlusal surfaces of molar and premolar teeth is a small component of the DMFS index in this age group, with 64–82% of this index being due to missing and filled surfaces. Caries experience was relatively low in this population, and due to the practicalities of bitewing radiographs, the additional potential diagnostic value is available on only 48 of the 128 surfaces that comprise the DMFS index. It has previously been suggested that the correction factor is dependent on caries experience, age, fluoride exposure and the amount of previous restorative treatment (10). In the present study, a greater proportion of additional caries lesions were detected with radiographs on approximal surfaces in the youngest subjects compared with the older subjects. The low caries prevalence in this study, especially in the younger subjects, makes caries diagnosis more difficult. The proportion of additional lesions detected with radiographs was similar for subjects regardless of water fluoridation exposure for both approximal and occlusal surfaces, and although there was no difference in the proportion of clinically undetected occlusal caries lesions between these two groups, subjects with no lifetime exposure to fluoridated drinking water had twice the proportion of clinically undetected approximal dentinal caries lesions as subjects with a lifetime exposure to fluoridated drinking water ($P < 0.001$).

The percentage of clinically sound surfaces diagnosed with dentine caries radiographically was considerably lower in this study than has been reported previously, where approximately 10% of approximal surfaces were found to have caries radiographically (9, 10). Again, the low caries prevalence in the present study is probably an important contributing factor. The present study found that approximately one in every hundred clinically sound occlusal or approximal surface had a caries lesion extending into dentine radiographically. Although the additional information provided by radiographs resulted in a significant increase in mean DS and DMFS scores ($P < 0.001$), the DMFS scores only increased in the order of 6–11%. Oral epidemiological studies of caries experience that are based on clinical examination only will underestimate caries prevalence, however bitewing radiographs should not be considered necessary in studies in young Australian adults with low caries experience.

Nonetheless, this study confirmed that bitewing radiographs still provided significant diagnostic yield for approximal caries, with 67.1–77.1% of these lesions detected by radiographic examination alone, a diagnostic yield of 204–336%, and 17.1–24.1% of occlusal lesions detected by radiographic examination alone (diagnostic yield of 20.7–30.7%). This is important both in the context of the provision of clinical treatment of patients and in other fields of research, such as clinical trials of anti-caries agents.

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