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Pattern of dental caries experience on tooth surfaces in an adult population

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Abstract – *Objectives:* To determine the pattern of caries experience across teeth and surfaces in an adult population depending on age and exposure to water fluoridation. *Methods:* Between November 2002 and March 2003 a total of 973 subjects aged 17–51 years had a clinical examination using visual and tactile criteria. Subsequent to this examination, bitewing radiographs were taken and viewed separately. Approximal and occlusal surfaces of molars and premolars were examined on the radiographs. *Results:* Caries experience was relatively low, with mean DMFS scores of 3.21, 5.12, 9.61, 13.04 and 24.35 for subjects aged 17–20, 21–25, 26–30, 31–35 and 36–51 years respectively. The first molar teeth had the greatest caries experience, and occlusal surfaces had more caries experience than approximal surfaces. Subjects with a lifetime exposure to fluoridated drinking water had significantly lower caries experience than those who had no exposure to fluoridated drinking water. *Conclusion:* This study showed that caries prevalence, although relatively low in the study population, was found predominantly in occlusal surfaces, with an increasing prevalence in approximal surfaces of posterior teeth in older subjects. Subjects with a lifetime exposure to fluoridated drinking water had a lower level of caries experience than those with no exposure to fluoridated drinking water, and this was more noticeable in approximal surfaces than occlusal surfaces.

Key words: adult; dental caries susceptibility; epidemiology; fluoridation; prevalence

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The susceptibility of different tooth surfaces to dental caries is markedly different, with the pit and fissure (occlusal) surfaces the most susceptible and the smooth (labial and lingual) surfaces the least susceptible (1, 2). Carlos and Gittelsohn (3) were among the first to report on the susceptibility of different teeth to caries attack in a nonfluoridated population. They found that the susceptibility to caries was low in the first posteruptive year, which rose rapidly to the maximum rate 2–3 years post-eruption. They suggested that teeth could be grouped according to the order of susceptibility, from greatest to least, as follows: lower first and second molars, upper first molars; upper second molars; upper first premolars, upper and lower second premolars; upper incisors; upper canines, lower first premolars; and lower incisors, lower canines. These findings have been replicated in a more recent study of caries susceptibility in American children and young adults, with mandibular second molars the most susceptible teeth, followed by maxillary first and second molars and mandibular first molars; maxillary and mandibular second premolars; maxillary and mandibular first premolars; maxillary central and lateral incisors; and maxillary and mandibular canines and mandibular central and lateral incisors being the least susceptible teeth (4). Berman and Slack (5) found that occlusal caries was a problem in the initial years after tooth eruption, and that approximal caries became more prevalent than occlusal caries after 14 years of age. They also observed that occlusal surfaces that were sound 6 years after eruption were likely to remain so.

However, there is a growing body of evidence to suggest that dental caries is being delayed, with the

period of susceptibility moving well past adolescence into young adulthood. Ripa et al. (6) reported that American schoolchildren in the 1980s developed occlusal caries later than those in the 1970s. One quarter of US Navy personnel under 26 years of age attending a routine examination had new occlusal caries (7). Richardson and McIntyre (8) found that more teeth had experienced occlusal than approximal caries in a group of Royal Air Force recruits, although untreated approximal caries was more prevalent than untreated occlusal caries, and was the predominant site for new carious lesions over the 5-year study period. The level of caries in premolars was low in that study, with the distal surfaces of these teeth more than twice as susceptible as the mesial surface, and a decade or more after tooth eruption, occlusal and proximal caries was still a significant problem. In a longitudinal study of young adults 14–25 years of age, it was found that occlusal surfaces on molars and premolars accounted for 60% of the total DMFS score (9). Mejare et al. (10) reported that the first permanent molar is the most caries-susceptible tooth, with the occlusal, mesial and distal surfaces of these teeth accounting for more than 60% of all restored surfaces at the age of 21 years. Stenlund et al. (11), in a longitudinal examination of approximal surfaces of posterior teeth in Swedish children and young adults aged 11–22 years, found that the distal surfaces of the first molar teeth were the most susceptible to caries. This is consistent with an earlier study prior to the widespread use of fluoride, in which the distal surface of the first molar was found to be more susceptible to caries than the mesial surface of the second molar (12).

One of the possible explanations for this shift in the susceptibility of tooth surfaces to dental caries is fluoride in various forms, although the importance of water fluoridation may have been reduced because of its availability from other sources (13, 14). It has also been reported that fluoride has a more beneficial effect on smooth and proximal tooth surfaces, and has less of an effect on occlusal and pit and fissure surfaces (15, 16). Backer Dirks et al. (17) showed that water fluoridation reduced caries experience by 86–87% in free smooth surfaces, 73–75% in proximal surfaces and only 36–39% in occlusal surfaces. The susceptibility of pit and fissure surfaces has become more obvious with the widespread use of fluorides.

The past 40 years has seen a dramatic decline in caries experience in adults in Australia, with a survey of Australian Army recruits in 1996 showing mean DMFS scores of 6.4, 9.1, 18.2 and 24.0 for subjects aged 17–20, 21–25, 26–30 and 31–35 years respectively (18). However, caries prevalence was still high, with only 19% of 17–20-year olds and 11% of 21–25-year olds reported to have DMFS = 0. It appears that occlusal and approximal dental caries are still a significant problem for present-day young adults in Australian from late adolescence until at least into their early twenties.

This paper reports the pattern of dental caries experience by tooth surface for a group of Australian Army recruits examined in 2002–2003, and compares the relative past susceptibility of different tooth surfaces to dental caries by age and water fluoridation exposure.

Materials and methods

The data used in this study were collected as part of a cross-sectional study of volunteer Australian Army recruits at the Army Recruit Training Centre, Kapooka between November 2002 and March 2003. As recruits presented for their initial dental examination, they were asked to participate in the study. A total of 973 of 1036 recruits consented to the use of their clinical data and completion of a questionnaire, a participation rate of 94%.

Clinical and radiographic examination

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 were taken of all subjects using Kodak Ultra-Speed D Size 2 films (Eastman Kodak Company, Rochester, NY, USA) and a Philips Dens-o-mat X-ray unit (Philips, Shelton, CT, USA). Adhesive tags were used to position the films. The radiographs were viewed separately from the clinical examination by a single examiner (MH). The clinical and radiographic data were recorded separately for each subject. The clinical diagnostic criteria for dental caries was visually apparent cavitation, discolouration showing through enamel or visual evidence of recurrent caries. Dental caries was recorded from the radiographs at 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 (10). Radiographic caries is reported in this paper for codes 3, 4 and 5 (D_3 threshold). Radiographs were used to assess the approximal surfaces from the distal surfaces of the second molar to the mesial surface of the first premolar. Radiographs were viewed on a light box using a ×2 magnification viewer. Interexaminer reliability for the clinical examination at the tooth surface level was tested by comparison to the chief investigator (MH) with a total of 20 blind re-examinations for each examiner, with reported kappa scores of 0.70 and 0.87. Intraexaminer reliability for the clinical examination at the tooth surface level was measured by 20 repeat blind examinations conducted by each examiner on four separate occasions, approximately 2 h after the initial examination, with kappa scores of 0.87, 0.90 and 0.93 for each of the examiners. Thirty pairs of radiographs were re-examined blind to the initial examination the following day, on six separate occasions, using the dentine caries (D_3 threshold) at the tooth surface level, with a kappa score of 0.90.

Questionnaire

Subjects completed a questionnaire prior to examination to elicit sociodemographic data and lifetime exposure to water fluoridation, using methods described previously for a similar study in 1996 (18). Socioeconomic status was determined by parental occupation using Australian Bureau of Statistics classifications. The socioeconomic groups are as follows: SES 1, managers and professionals; SES 2, associate professionals and tradespersons; SES 3, advanced and intermediate clerical and service; SES 4, intermediate production, elementary clerical and labourers. Lifetime exposure to fluoridated drinking water was calculated using data obtained from State Health Departments. Subjects were asked to list the places they had lived in since birth, and the years lived in each location. Subjects were classified according to the percentage of total lifetime spent living in with optimal levels of water fluoridation (either natural or artificial). Both the clinical and radiographic examinations were conducted blind to the questionnaire data, and the radiographic examination was conducted blind to the clinical examination.

Data analysis

Caries experience is reported as decayed and filled surfaces (DF) only for existing teeth to assess the pattern of caries experience, as there is no way of assessing the distribution of surface susceptibility for missing teeth (8). However, this was not considered to be a significant problem, because only 148 teeth (0.5%) were assessed as missing because of caries in the sample population of 973 recruits, mostly molars. The pattern of caries experience was symmetrical between the left and right side of the mouth for both maxillary and mandibular teeth, so the left and right surfaces were combined for each tooth. The prevalence of DF surfaces was calculated from the number of surfaces available for examination for five surfaces for molars and premolars (distal, occlusal, mesial, buccal and lingual), and four surfaces for canines and incisors (distal, mesial, buccal and lingual).

Caries experience was calculated using the DMFS index, based on combined clinical and radiographic findings. Bivariate Poisson regression was used for each dependent variable to determine if any had a significant effect on caries experience. Variables that were found to have an effect on caries experience were then used in the multivariable Poisson regression model. Models were calculated for caries experience for all surfaces (DMFS), approximal surfaces (DMFSP), occlusal surfaces (DMFSO) and smooth buccal and lingual surfaces (DMFSS). Results from the regression models were expressed as incidence rate ratios (IRR). Poisson regression was chosen as the distribution of caries experience more closely resembled the Poisson distribution than the normal distribution (19). Statistical analysis was performed using the statistical package Stata 5.0.

Ethics

Ethical approval for the study was obtained from 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

In subjects aged 17–20 years, most teeth surfaces displayed very low caries prevalence, apart from the occlusal surfaces of the first and second molars,

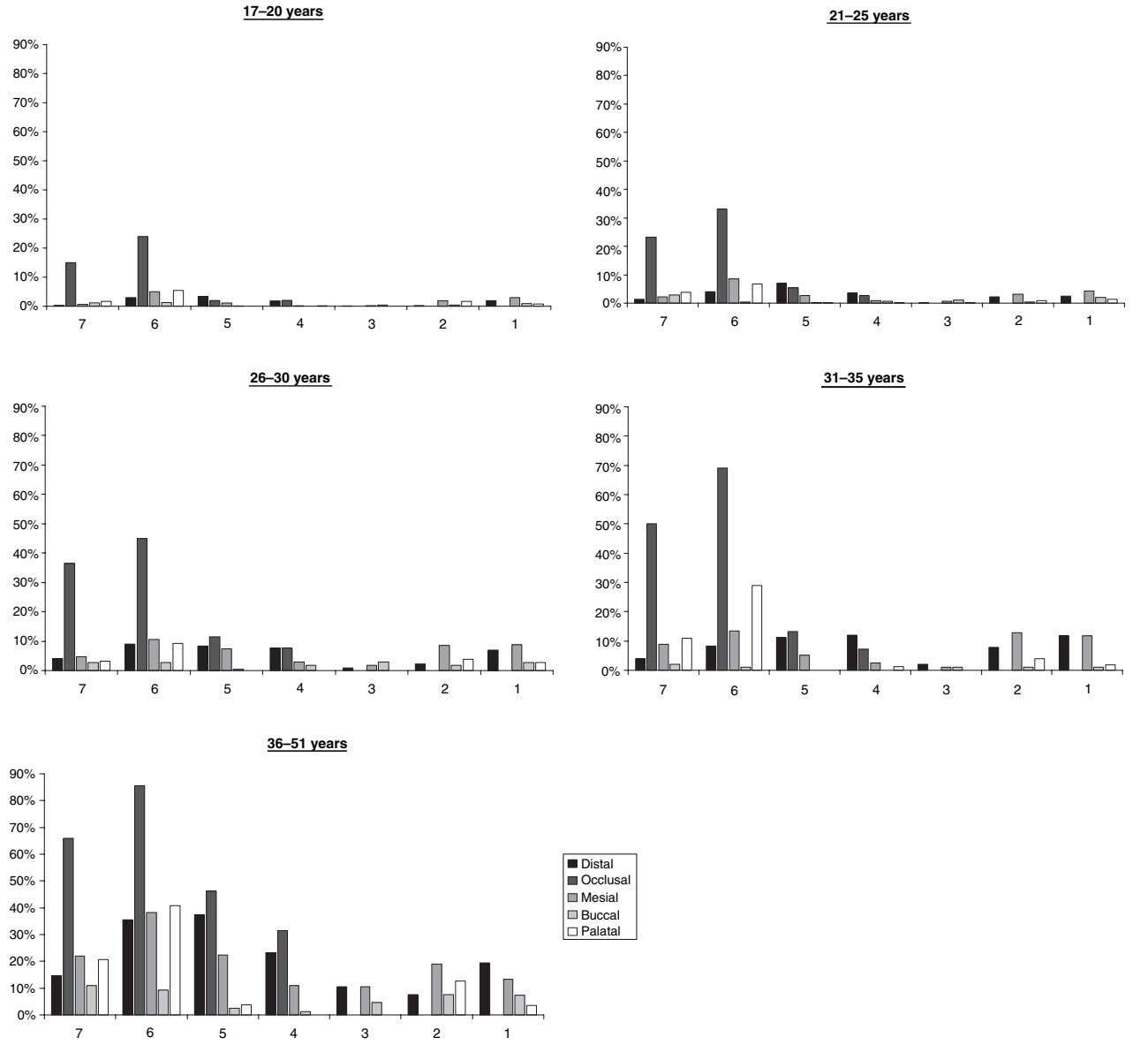

Fig. 1. Caries prevalence (DF) in upper tooth surfaces by age group.

with 15.0–24.6% of these surfaces affected by caries. Figures 1 and 2 show caries experience (DF) for individual tooth surfaces by age for upper and lower teeth. Across all age groups, the first molar showed the highest prevalence of caries experience, with the lower first molar showing greater caries experience in subjects aged 17–30 years, and the upper first molar showing greater caries experience in the older subjects. The mesial surfaces of upper first molars were more susceptible than the distal surfaces, although this trend was reversed in lower first molars. First molars had more than twice the approximal caries experience of second molars, except in the upper arch for subjects aged 31–35 years. Caries experience in premolars was low, although distal and occlusal surfaces were more than twice as susceptible as mesial surfaces. Apart from upper second premolars, the occlusal surfaces on all molars and premolars were more susceptible to dental caries than either the mesial or distal surfaces.

The buccal surfaces of lower first molars were the most susceptible of all buccal surfaces, whereas the palatal surfaces of the upper first molars were the most susceptible of all palatal surfaces. Other than these two sites, caries experience was relatively low on buccal and lingual surfaces, although no distinction was made between buccal and palatal pits and smooth surfaces. Therefore, it is possible that most of the caries experience associated with these surfaces on molars is actually pit and fissure caries rather than smooth surface caries.

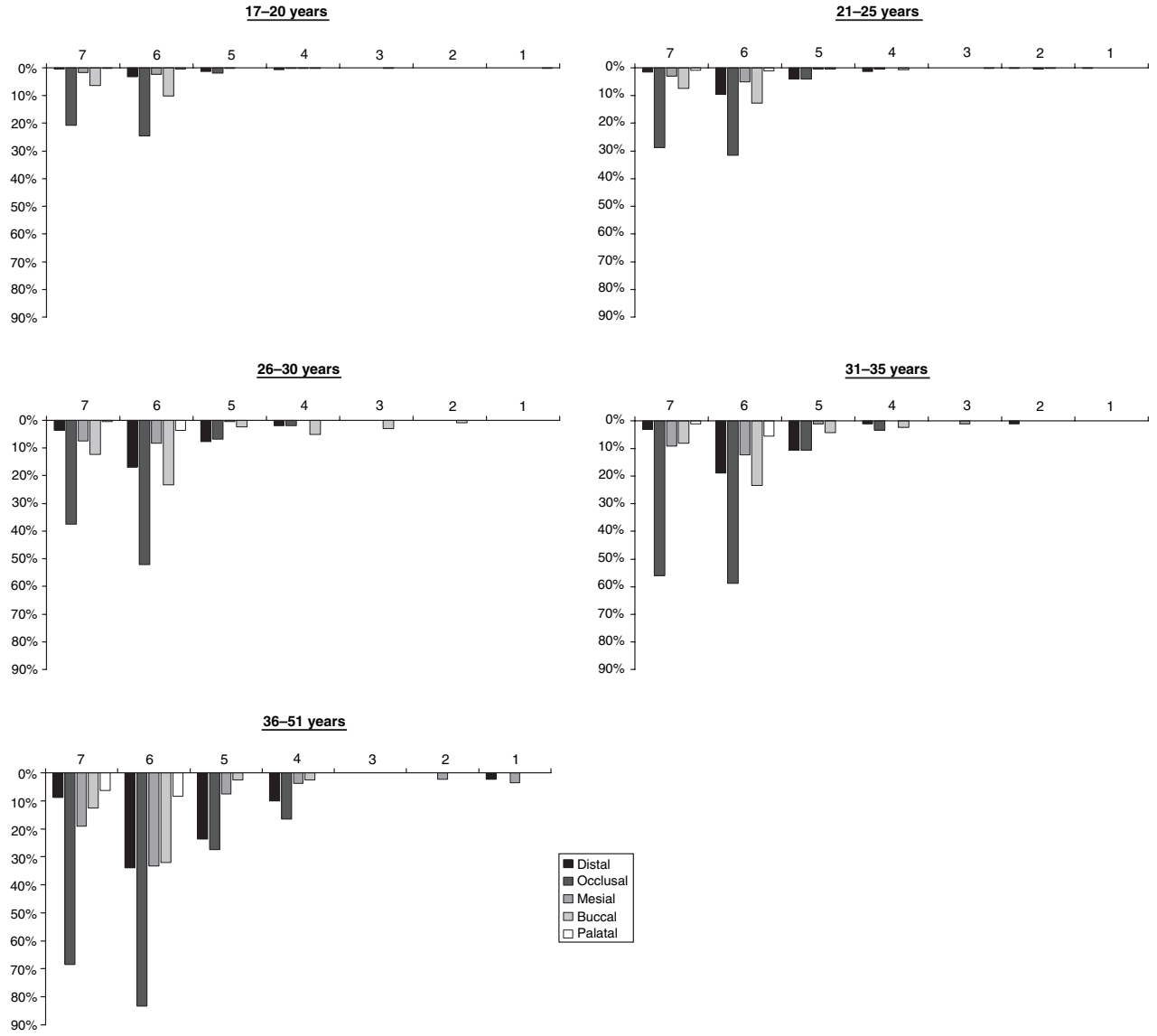

Fig. 2. Caries prevalence (DF) in lower tooth surfaces by age group.

Caries experience was low in canines and lower incisors across all age groups, with the exception of the upper canine in the oldest age group, with nearly 11% of mesial and distal surfaces affected by caries. The mesial surfaces of upper lateral incisors showed greater susceptibility than distal surfaces, whereas mesial and distal surfaces of upper central incisors had a similar level of caries experience to that of mesial surfaces of upper lateral incisors.

Table 1 shows the results of bivariate and multivariable Poisson regression models for caries experience (DMFS) using age, gender, level of education, socioeconomic status and lifetime exposure to fluoridated drinking water as explanatory variables. Subjects with a lifetime exposure to fluoridated drinking water reported 26% less caries experience compared with those with no exposure to fluoridated drinking water after adjusting for the effects of age, gender, socioeconomic status and education. Water fluoridation had a greater impact on approximal caries experience, with lifetime exposure resulting in a 38% reduction in approximal caries experience (Table 2), and less of an impact on occlusal caries, with a 26% reduction (Table 3) after adjusting for confounding. The impact on smooth surface appeared to be equivocal, with a 51–99% lifetime exposure to fluoridated drinking water resulting in a 25% reduction in smooth surface caries experience, but lifetime exposure not conveying a statistically significant reduction in smooth surface caries experience after adjusting for confounding (Table 4). Socioeconomic status did not generally appear to have a significant effect on overall caries experience when adjusting

Table 1. Poisson regression models for caries experience (DMFS)

			Unadjusted model		Adjusted model	
	n	DMFS	IRR	*P*-value	IRR	*P*-value
Age (years)						
17–20	525	3.21	1		1	
21–25	238	5.12	1.60	<0.001	1.72	<0.001
26–30	116	9.61	3.00	<0.001	2.72	<0.001
31–35	51	13.04	4.07	<0.001	4.57	<0.001
36–51	43	24.35	7.60	<0.001	6.77	<0.001
Gender						
Male	852	5.96	1		1	
Female	121	5.38	0.90	0.014	1.01	0.852
Education						
Up to Year 11	269	7.77	1		1	
Year 12	504	4.36	0.56	<0.001	0.75	<0.001
TAFE/Diploma	126	7.13	0.92	0.033	0.70	<0.001
Tertiary	74	7.32	0.94	0.221	0.77	<0.001
Socioeconomic status						
SES 1	380	4.72	1		1	
SES 2	304	6.44	1.36	<0.001	1.10	0.018
SES 3	124	5.32	1.13	0.009	1.07	0.190
SES 4	97	6.74	1.43	<0.001	1.07	0.194
Lifetime water fluoride exposure						
0%	162	6.25	1		1	
1–50%	144	7.44	1.20	<0.001	0.91	0.057
51–99%	154	6.12	0.98	0.659	0.68	<0.001
100%	345	4.12	0.66	<0.001	0.74	<0.001

IRR, incidence rate ratios.
Adjusted model: goodness-of-fit $\chi^2 = 4633.91$; $P > \chi^2 < 0.001$; pseudo-$R^2 = 0.2164$.

Table 2. Poisson regression models for caries experience in approximal surfaces

			Unadjusted model		Adjusted model	
	n	DMFS(P)	IRR	*P*-value	IRR	*P*-value
Age (years)						
17–20	525	0.71	1		1	
21–25	238	1.48	2.10	<0.001	2.28	<0.001
26–30	116	3.17	4.49	<0.001	3.71	<0.001
31–35	51	4.39	6.22	<0.001	7.07	<0.001
36–51	43	10.19	14.41	<0.001	10.94	<0.001
Gender						
Male	852	1.84	1		1	
Female	121	1.52	0.83	0.014	0.96	0.619
Education						
Up to Year 11	269	2.72	1		1	
Year 12	504	1.08	0.40	<0.001	0.59	<0.001
TAFE/Diploma	126	2.37	0.87	0.046	0.66	<0.001
Tertiary	74	2.45	0.90	0.199	0.75	0.006
Socioeconomic status						
SES 1	380	1.21	1		1	
SES 2	304	2.14	1.76	<0.001	1.33	<0.001
SES 3	124	1.35	1.11	0.247	1.07	0.537
SES 4	97	2.24	1.84	<0.001	1.25	0.026
Lifetime water fluoride exposure						
0%	162	2.04	1		1	
1–50%	144	2.68	1.32	<0.001	0.96	0.623
51–99%	154	1.73	0.85	0.050	0.50	<0.001
100%	345	0.99	0.49	<0.001	0.62	<0.001

IRR, incidence rate ratios.
Adjusted model: goodness-of-fit $\chi^2 = 2487.80$; $P > \chi^2 < 0.001$; pseudo-$R^2 = 0.2476$.

Table 3. Poisson regression models for caries experience in occlusal surfaces

			Unadjusted model		Adjusted model	
	n	DMFS(O)	IRR	*P*-value	IRR	*P*-value
Age (years)						
17–20	525	1.82	1		1	
21–25	238	2.62	1.44	<0.001	1.54	<0.001
26–30	116	4.14	2.27	<0.001	2.15	<0.001
31–35	51	5.63	3.09	<0.001	3.37	<0.001
36–51	43	8.51	4.68	<0.001	4.52	<0.001
Gender						
Male	852	2.79	1			
Female	121	2.75	0.99	0.804		
Education						
Up to Year 11	269	3.24	1		1	
Year 12	504	2.33	0.72	<0.001	0.87	0.011
TAFE/Diploma	126	3.18	0.98	0.760	0.79	0.001
Tertiary	74	3.58	1.10	0.156	0.89	0.199
Socioeconomic status						
SES 1	380	2.47	1		1	
SES 2	304	2.98	1.21	<0.001	1.01	0.808
SES 3	124	2.65	1.07	0.274	1.01	0.881
SES 4	97	2.91	1.18	0.017	0.94	0.437
Lifetime water fluoride exposure						
0%	162	2.94	1		1	
1–50%	144	3.19	1.09	0.201	0.88	0.066
51–99%	154	2.97	1.01	0.853	0.78	<0.001
100%	345	2.11	0.72	<0.001	0.74	<0.001

IRR, incidence rate ratios.
Adjusted model: goodness-of-fit $\chi^2 = 2117.91$; $P > \chi^2 < 0.001$; pseudo-$R^2 = 0.1160$.

Table 4. Poisson regression models for caries experience in smooth surfaces

			Unadjusted model		Adjusted model	
	n	DMFS(S)	IRR	*P*-value	IRR	*P*-value
Age (years)						
17–20	525	0.68	1		1	
21–25	238	1.01	1.49	<0.001	1.61	<0.001
26–30	116	2.30	3.38	<0.001	3.19	<0.001
31–35	51	3.02	4.44	<0.001	5.18	<0.001
36–51	43	5.65	8.31	<0.001	7.83	<0.001
Gender						
Male	852	1.32	1			
Female	121	1.11	0.84	0.051		
Education						
Up to Year 11	269	1.81	1		1	
Year 12	504	0.95	0.53	<0.001	0.72	<0.001
TAFE/Diploma	126	1.58	0.87	0.110	0.59	<0.001
Tertiary	74	1.30	0.72	0.003	0.60	<0.001
Socioeconomic status						
SES 1	380	1.04	1		1	
SES 2	304	1.32	1.27	<0.001	1.00	0.983
SES 3	124	1.32	1.28	0.009	1.20	0.072
SES 4	97	1.60	1.54	<0.001	1.17	0.149
Lifetime water fluoride exposure						
0%	162	1.27	1		1	
1–50%	144	1.56	1.23	0.033	0.90	0.322
51–99%	154	1.42	1.11	0.270	0.75	0.007
100%	345	1.03	0.81	0.014	0.91	0.322

IRR, incidence rate ratios.
Adjusted model: goodness-of-fit $\chi^2 = 1884.58$; $P > \chi^2 < 0.001$; pseudo-$R^2 = 0.1423$.

for confounding, although subjects from SES 2 and SES 4 had significantly higher caries experience on proximal surfaces than those from SES 1.

Figures 3 and 4 show the distribution of DF surfaces across individual tooth surfaces by exposure to water fluoridation in upper and lower teeth.

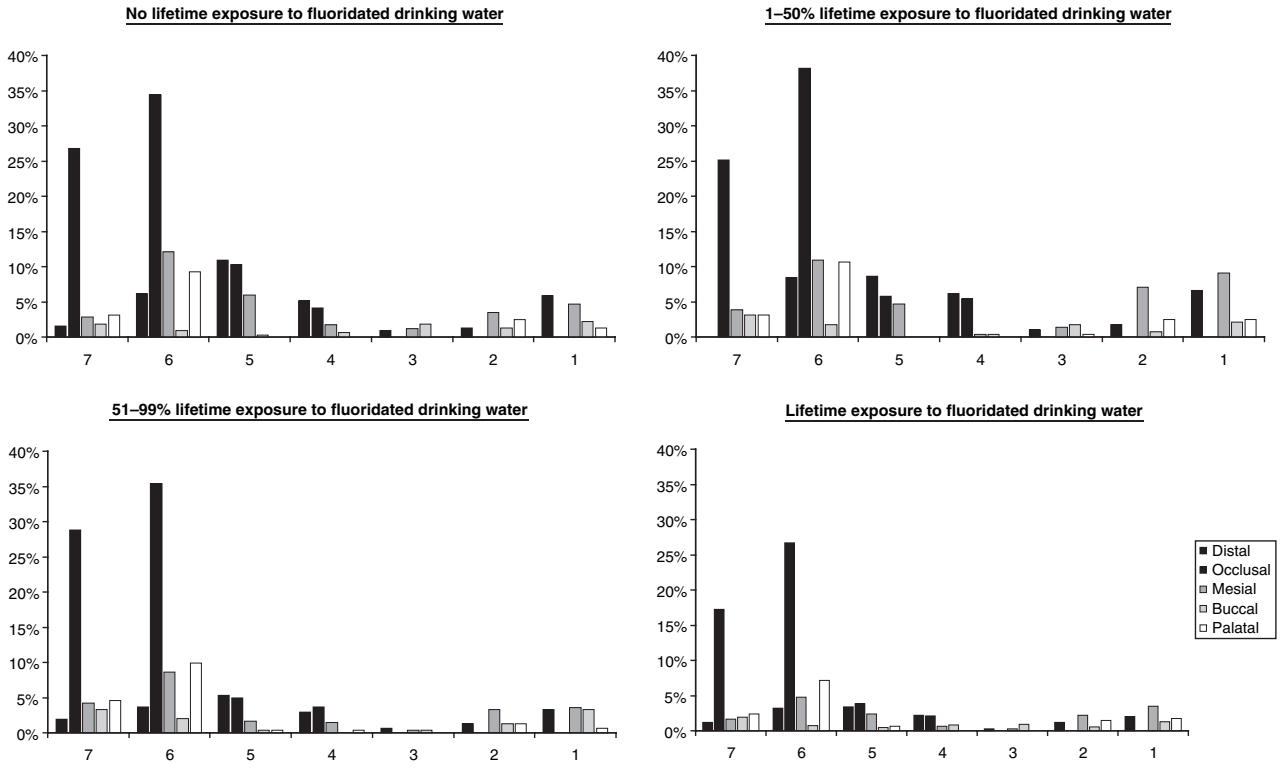

Fig. 3. Caries prevalence (DF) in upper tooth surfaces by exposure to fluoridated water.

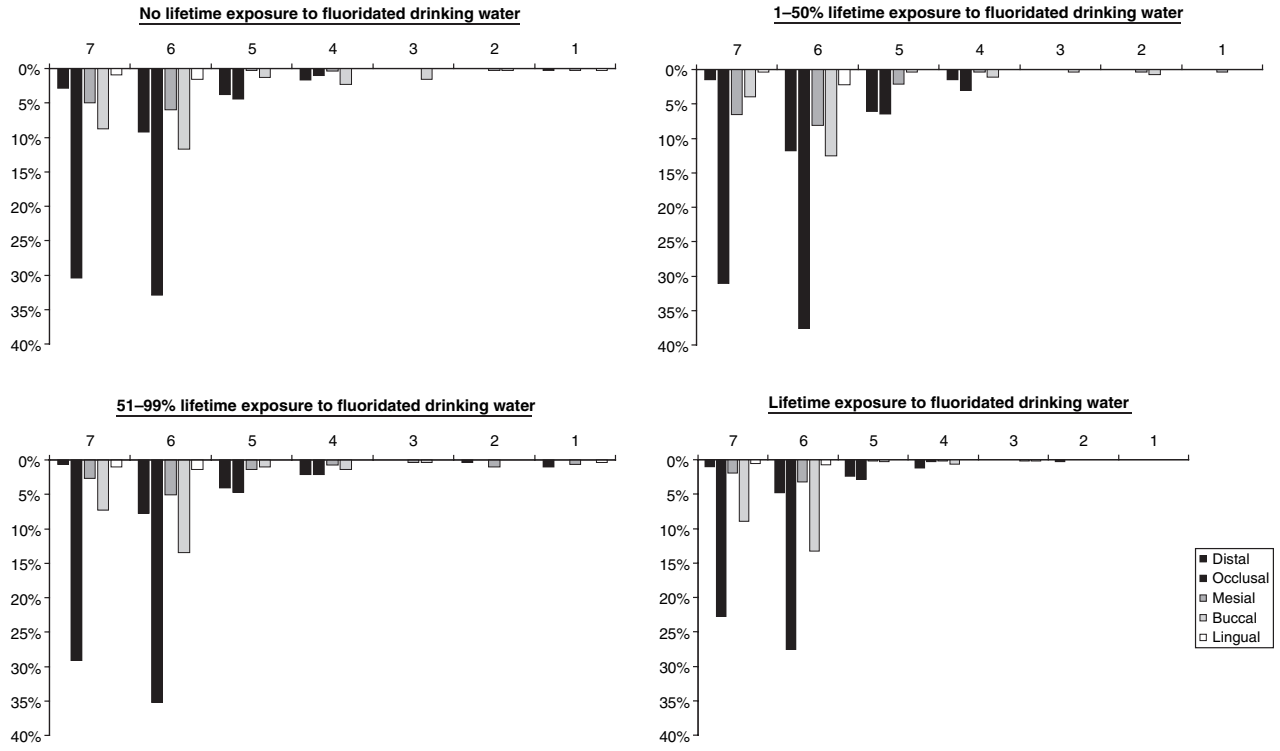

Fig. 4. Caries prevalence (DF) in lower tooth surfaces by exposure to fluoridated water.

Occlusal surfaces of first and second molars were more susceptible to dental caries in subjects with no lifetime exposure to fluoridated drinking water. The mesial and distal surfaces of the maxillary first molar had more than twice the caries experience in subjects with no exposure to fluoridated drinking water compared with subjects with a lifetime exposure to fluoridated drinking water, and there was a similar pattern in premolars.

Discussion

The present study showed that molar teeth were more susceptible to caries than either canines or incisors in all age cohorts. These results are comparable with those obtained by other authors (3, 4, 8). The first molar tooth was the most susceptible to dental caries in the present study, accounting for more than 40% of the total DFS in the upper arch and more than 50% of the total DFS in the lower arch for all subjects. Similar results were found in a study of young Swedish adults, with the first molar accounting for 60% of all restored surfaces at the age of 21 years (10). Macek et al. (4) found that the mandibular second molar was the tooth most susceptible to dental caries in a group aged 4–20 years, in a method that took into consideration the posteruptive tooth age. However, in the present study, the mandibular first molar had consistently more caries experience than the mandibular second molar at every age group, confirming the findings of others (8).

Water fluoridation has been reported to be more effective in reducing dental caries in approximal surfaces rather than occlusal surfaces, and the results from this study support this. Subjects with a lifetime exposure to fluoridated drinking water were found to have 38% less caries experience in approximal surfaces than subjects with no exposure to fluoridated drinking water, when taking into account the effects of age, gender, education and socioeconomic status, compared with a 26% reduction in caries experience in occlusal caries experience. This study showed a greater reduction in caries experience in approximal and occlusal surfaces in subjects with a lifetime exposure to fluoridated drinking water than those with no exposure from a similar study on Australian Army recruits in 1996 (18). Another confounding factor is that many approximal caries lesions are restored to include the occlusal surface, so that in fluoridated areas less approximal carious lesions and consequently a reduction in occlusal restorations would be observed in the DMFS score.

It is difficult to assess, from this cross-sectional study, whether caries is being prevented or merely delayed until later in life, particularly given the selective nature of the sample population. However, what this study shows is that caries experience is relatively low in the younger cohorts, especially compared with a similar sample of recruits examined in 1996 (18). For example, the 21–25-year cohort in the present study had a mean DMFS score of 5.12, compared with the 17–20-year cohort from 1996 with a mean DMFS score of 6.4. The higher caries experience in the older age groups would indicate that perhaps caries experience is being delayed until later in life, with a threefold increase in mean DMFS from 17–20 years to 26–30 years. A longitudinal study design would be required to provide a more accurate assessment.

There are several limitations to the present study. One of the shortcomings is the small number of subjects in the older age cohorts, and the large age range in the oldest age group. This is primarily because subjects of this age are uncommon as Army recruits. Nonetheless, it was decided to include these subjects in the study to determine the pattern of caries in this age group, although it is difficult to determine if this data is representative of that particular age group. Another potential problem is recall bias associated with the questionnaire information regarding lifetime exposure to fluoridated drinking water, and the fact that no attempt was made to quantify exposure to fluoride supplements and fluoride dentifrices. Classification of socioeconomic status was also a limitation in the present study. Socioeconomic status was measured using self-reported parental occupation. Parental occupation can change over the course of 20 years, making it difficult to adequately classify subjects. Furthermore, it is difficult to determine the relative impact of socioeconomic changes on the risk of developing dental caries over a period of ≥20 years. However, other measures such as parental income and education would also be unsuitable for the same reasons. Socioeconomic status of the subject themselves, measured by occupation or income, would still have the same problem of ignoring the socioeconomic environment of childhood and adolescence during which a substantial proportion of caries experience may have occurred. Finally, the study population was predominantly male, well educated and from a relatively high socioeconomic background, so caution must be exercised in

extrapolating the results from this study to the broader Australian population.

In summary, this study showed that caries prevalence, although relatively low in the study population, was found predominantly in occlusal surfaces, with an increasing prevalence in approximal surfaces of posterior teeth in older subjects. Caries prevalence was low in canines and incisors. Subjects with a lifetime exposure to fluoridated drinking water had a lower level of caries experience than subjects with no exposure to fluoridated drinking water, and this was more noticeable in approximal surfaces than occlusal surfaces.

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