

Original article

Respiratory effects of exposure to methacrylates among dental assistants

Background: Case reports of occupational asthma in dental personnel have been published, but there is little data on the risk of respiratory disorders related to occupational exposure to methacrylates in dental assistants. The objective of this study was to investigate the relation of exposure to methacrylates to occurrence of respiratory symptoms and diseases among dental assistants.

Methods: A cross-sectional study of female dental assistants from the membership register of the Finnish Association of Dental Hygienists and Assistants was conducted in the Helsinki metropolitan area. A CATI was carried out to collect information on health and exposures. A total of 799 dental assistants participated (response rate 87%).

Results: Daily use of methacrylates was related to a significantly increased risk of adult-onset asthma (adjusted OR 2.65, 95% CI 1.14–7.24), nasal symptoms (1.37, 1.02–1.84), and work-related cough or phlegm (1.69, 1.08–2.71). Nasal symptoms showed a dose–response relation with increasing years of exposure to methacrylates, and those with > 10 years of exposure had also increased risk of hoarseness, dyspnoea, and wheezing with dyspnoea. Dental assistants with a history of atopic diseases were particularly susceptible to exposure to methacrylates, the adjusted OR for adult asthma being in this group 4.18 (95% CI 1.02–28.55) and for nasal symptoms 2.11 (1.08–4.19).

Conclusions: This study provides new evidence that the risk of adult-onset asthma, nasal symptoms and other respiratory symptoms increase significantly with daily use of methacrylates in dental assistants' work. The results suggest that exposure to methacrylates poses an important occupational hazard for dental assistants.

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Key words: asthma; atopy; chronic bronchitis; dental methacrylates; respiratory symptoms.

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Accepted for publication 1 March 2007

Plastic dental filling materials became common in the early 1980s, and after that, composites, glass ionomers, resin ionomers and compomers have largely replaced traditional filling materials, i.e. amalgam, in Finland. As a consequence of this, dental personnel are exposed to (meth)acrylates, for example from acrylic resin-based composites and bonding agents (1, 2). Dental assistants' exposure to airborne methacrylates takes place mainly when dosage and mixing of the material is carried out and during the placement and removal of restorations (3–5). Methacrylates are also used in bonding of porcelain veneers, crowns and bridges, as well as in cementing orthodontic applications. Dental assistants can be exposed in their work to many different (meth)acrylates, including 2-hydroxyethyl methacrylate (2-HEMA), triethyleneglycol dimethacrylate (TEGDMA), ethyleneglycol dimethacrylate (EGDMA), urethane dimethacrylate (UEDMA), and 2,2-bis-[4-(2-hydroxy-3-methacryloxypropoxy) phenyl]-propane (bis-GMA) (3, 5). The most important airborne exposures are 2-HEMA and TEGDMA (3).

In a cross-sectional study from France, dental technicians had increased prevalence of respiratory symptoms (6). However, that study did not investigate the specific causes for this excess of symptoms. In a recent Finnish case-control study of new adult-onset asthma, the risk of asthma was increased among dental workers when compared with administrative personnel and professionals (7). Some case reports/series of occupational asthma and rhinitis related to exposure to methacrylates have been published (8, 9), but in the literature search we were not able to identify any previous study that had assessed the risk of respiratory symptoms or diseases in relation to methacrylate exposure among dental assistants.

We conducted a cross-sectional study of registered dental assistants in the Helsinki metropolitan area, Finland, to investigate the relation of occupational exposure to methacrylates to occurrence of respiratory symptoms and diseases. We also addressed the question whether atopy modifies the relation between methacrylate exposure and asthma.

Methods

Study design and population

In a cross-sectional study we invited all female dental assistants registered in 1998 in the membership register of the Finnish Association of Dental Hygienists and Assistants ($n = 923$) in the Helsinki metropolitan area to participate in a computer-assisted telephone interview (CATI) on health, exposures at work, and some life style factors. Computer-assisted telephone interview is an interactive computer system that aids interviewers to enter the answers into the database immediately. The program controls the interview logic, branching to or skipping questions as needed according to answers, and validates the logic of the data as it is entered. A total of 799 dental assistants participated in the interview (response rate 87%).

The study was approved by the ethical committee of Finnish Institute of Occupational Health (FIOH). The study subjects' informed consent was requested before the interview.

Questionnaire

A trained and experienced interviewer conducted the interview. The quality control system established by the CATI unit of FIOH was applied. The structured questionnaire included questions on current and past respiratory and skin symptoms and diseases, modified from a previous study on hairdressers (10). The questionnaire also inquired about atopic diseases, smoking habits, occupational history, use of (meth)acrylates in different dental work tasks, use and type of protective gloves, and exposure to some other chemicals.

Outcome assessment

The outcomes of interest were prolonged or repeated occurrence of respiratory symptoms during the past year at times other than in connection with a cold, and occurrence of asthma and chronic bronchitis. Respiratory symptoms included nasal symptoms, hoarseness, cough or phlegm production, dyspnoea, and wheezing in connection with dyspnoea. It was also asked, whether these symptoms occurred mainly at work (no/yes).

Asthma was defined based on affirmative answers to questions: 'Have you ever had asthma?' and 'Was it diagnosed by a physician?' The participant was also asked, whether she had asthma in the past 12 months. The age of onset of asthma symptoms was inquired and adult-onset asthma was defined as doctor-diagnosed asthma that had started at the age of ≥ 18 years. Chronic bronchitis was defined as cough and phlegm production for ≥ 3 months in a year for ≥ 2 years and no asthma.

Exposure assessment

The exposure of interest was occupational exposure to methacrylates, which was measured as daily performance of work tasks that involved exposure to methacrylates during the past 3 months (contrasted to no use or less than daily use of methacrylates). These tasks included assisting in making dental fillings and sealings, cementing of orthodontal brackets, cementing of veneers, crowns and bridges, and repairing dentures. The duration of daily (meth)acrylate exposure was divided into four categories: (i) no exposure (the reference category); (ii) up to 5 years; (iii) > 5 –10 years; and (iv) > 10 years.

Potential confounders and modifiers

Multivariate analyses adjusted for potential confounders. Age was grouped into: (i) ≤ 34 years; (ii) 35–44 years; and (iii) ≥ 45 years. Smoking habits were categorized into: (i) current smoker (currently smoked at least one cigarette/cigar/pipe each day); (ii) ex-smoker (had smoked daily for > 1 year, but had given up smoking at least 1 month before this study); and (iii) never smoker (had never smoked daily). Atopy was defined as atopic dermatitis or rhinitis in childhood or adolescence (when studying nasal symptoms as the outcome, rhinitis was not included in the definition). Atopy was also addressed as potential modifier of the observed relations in separate analyses. Exposure to natural rubber latex (NRL) gloves was categorized into three groups based on reported professional use of NRL: (i) current users; (ii) ex-users; and (iii) those who had never used NRL gloves.

Data analysis

Odds ratio (OR) was used as the measure of effect and was estimated along with 95% confidence interval (95% CI) in multivariate logistic regression analysis. First, we compared dental assistants with daily exposure to (meth)acrylates in the past 3 months to the unexposed subjects. Then, we studied the effect of the duration of daily methacrylate exposure in comparison to no such exposure/less than daily use of methacrylates. Models were adjusted for age, smoking, atopic diseases, and use of NRL gloves. Finally, we studied the role of atopy as a potential modifier of the relations between exposure to methacrylates and respiratory conditions by stratifying by atopic status. All the statistical analyses were performed using the SAS statistical program package, version 8.2 (11).

Results

Characteristics and symptoms of the study population

The median age of this population of dental assistants was 36 years (range 21–63). About one-third of the dental assistants had had atopic disease in childhood and/or adolescence (30%). A total of 16% were current smokers, and of those smoking, 56% smoked < 10 cigarettes per day. Twenty-six percent were ex-smokers and 58% never smokers. Dental assistants in our study belonged to three educational backgrounds: dental nurses ($n = 602$), dental hygienists ($n = 149$), and specialized dental nurses ($n = 46$). Two persons had another type of education that could not be categorized in any of these groups. Dental nurse's main task is to assist a dentist in various dental procedures. Dental hygienists and specialized dental nurses are allowed to do limited dental procedures independently, such as scaling and root planing, fluoride treatment, and sealing of fissures. Among the participants working currently in dental practices, 66% ($n = 516$) assisted a dentist in dental procedures, 10% ($n = 72$) worked independently, and 24% ($n = 185$) did both type of tasks.

Occurrence of respiratory symptoms in total population and by (meth)acrylate exposure is presented in Table 1. Nasal symptoms were most frequently reported symptoms (57%, work-related nasal symptoms 35%).

Table 1. Respiratory symptoms and diseases among dental assistants, total and by exposure to methacrylates

	Total	Methacrylates*	
	<i>n</i> = 799	No (<i>n</i> = 287)	Yes (<i>n</i> = 512)
	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)
<i>Symptoms</i>			
Nasal symptoms	453 (56.7)	149 (51.9)	304 (59.4)
Work related	268 (35.0)	89 (31.9)	179 (36.8)
Hoarseness	210 (26.3)	67 (23.4)	143 (28.0)
Work related	116 (15.1)	38 (13.6)	78 (15.9)
Cough and/or phlegm	202 (25.3)	65 (22.8)	137 (26.8)
Work related	116 (15.1)	29 (10.5)	87 (17.5)
Dyspnoea	142 (17.8)	50 (17.4)	92 (18.0)
Work related	72 (9.1)	26 (9.1)	46 (9.0)
Wheezing with dyspnoea	37 (4.7)	11 (3.9)	26 (5.1)
Work related	37 (4.7)	11 (3.9)	26 (5.1)
<i>Diseases</i>			
Doctor-diagnosed asthma in the last year	36 (4.5)	7 (2.4)	29 (5.7)
Adult-onset doctor-diagnosed asthma	35 (4.4)	7 (2.5)	28 (5.5)
Chronic bronchitis	86 (10.8)	28 (9.8)	58 (11.3)

*Daily exposure to methacrylates in the past 3 months

About one-fourth had cough or phlegm and hoarseness (work-related symptoms 15%). The prevalence of doctor-diagnosed asthma present in the past year was 5%. The occurrence of adult-onset asthma (doctor-diagnosed asthma reported to have started at or after the age of 18 years) was 4%.

Effects of exposure to methacrylates on respiratory symptoms

Table 2 shows adjusted ORs of respiratory symptoms in relation to exposure to methacrylates. Table 3 presents the same for respiratory symptoms reported to occur mainly at work. The risk of nasal symptoms (adjusted OR 1.37, 95% CI 1.02–1.84) and work-related cough or phlegm (1.69, 1.08–2.71) were significantly increased in relation to daily use of methacrylates. Increasing years of occupational exposure to methacrylates were related to a dose-dependent increase in the risk of nasal symptoms and hoarseness (both general and work-related symptoms). In the group with the longest occupational methacrylate exposure (> 10 years), the ORs of dyspnoea and wheezing with dyspnoea were also increased, although these did not reach statistical significance

Table 2. Adjusted odds ratio (OR) of respiratory symptoms in relation to exposure to methacrylates

Exposure	Nasal symptoms		Hoarseness		Cough or phlegm		Dyspnoea		Wheezing with dyspnoea	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Methacrylates*										
No (reference)	1.00		1.00		1.00		1.00		1.00	
Yes	1.37	1.02–1.84	1.22	0.87–1.72	1.20	0.85–1.70	0.99	0.67–1.47	1.34	0.66–2.90
Methacrylates† (years)										
No (reference)	1.00		1.00		1.00		1.00		1.00	
0–5	1.75	1.06–2.89	1.17	0.63–2.21	1.09	0.59–2.02	1.39	0.69–2.86	1.73	0.47–7.41
>5–10	1.82	1.15–2.90	1.43	0.82–2.53	1.17	0.68–2.02	0.92	0.47–1.82	1.34	0.38–5.36
>10	2.22	1.43–3.46	1.86	1.13–3.16	1.12	0.69–1.85	1.59	0.90–2.92	1.76	0.61–6.47

*Adjusted for age, atopy, smoking, and use of NRL gloves. Daily methacrylate exposure during the past 3 months.

†Adjusted for age, atopy, smoking, and use of NRL gloves. Daily methacrylate exposure.

Table 3. Adjusted odds ratio (OR) of work-related respiratory symptoms in relation to exposure to methacrylates

Exposure	Work-related nasal symptoms		Work-related hoarseness		Work-related cough or phlegm		Work-related dyspnoea		Work-related wheezing with dyspnoea	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Methacrylates*										
No (reference)	1.00		1.00		1.00		1.00		1.00	
Yes	1.22	0.89–1.68	1.20	0.79–1.86	1.69	1.08–2.71	0.98	0.59–1.64	1.34	0.66–2.90
Methacrylates (years) †										
No (reference)	1.00		1.00		1.00		1.00		1.00	
0–5	1.41	0.79–2.54	0.89	0.39–2.06	1.24	0.56–2.79	1.72	0.69–4.56	1.73	0.47–7.41
>5–10	1.90	1.13–3.25	1.24	0.61–2.61	0.96	0.47–1.98	1.00	0.40–2.56	1.34	0.38–5.36
>10	2.70	1.66–4.48	2.11	1.13–4.18	1.34	0.74–2.49	1.56	0.73–3.64	1.76	0.61–6.47

*Adjusted for age, atopy, smoking, and use of natural rubber latex (NRL) gloves. Daily methacrylate exposure during the past 3 months.

†Adjusted for age, atopy, smoking, and use of NRL gloves. Daily methacrylate exposure.

Table 4. Adjusted odds ratio (OR) of asthma and chronic bronchitis in relation to exposure to methacrylates

Exposure	Doctor-diagnosed asthma in the last year		Adult-onset doctor-diagnosed asthma		Chronic bronchitis	
	OR	95% CI	OR	95% CI	OR	95% CI
Methacrylates*						
No (reference)	1.00		1.00		1.00	
Yes	2.76	1.19–7.54	2.65	1.14–7.24	1.14	0.71–1.87
Methacrylates (years)†						
No (reference)	1.00		1.00		1.00	
0–5	7.61	1.66–55.36	5.25	1.08–38.70	0.63	0.26–1.54
>5–10	4.20	0.98–29.21	3.46	0.79–24.04	1.10	0.53–2.36
>10	3.02	0.80–19.75	3.24	0.88–20.95	1.29	0.67–2.61

*Adjusted for age, atopy, smoking, and use of natural rubber latex (NRL) gloves. Daily methacrylate exposure during the past 3 months.

†Adjusted for age, atopy, smoking, and use of NRL gloves. Daily methacrylate exposure.

because of smaller occurrence of these symptoms in the population.

Effects of exposure to methacrylates on respiratory diseases

Table 4 shows the adjusted ORs of respiratory diseases in relation to exposure to methacrylates. The risk of doctor-diagnosed asthma in the last 12 months (adjusted OR 2.76, 95% CI 1.19–7.54) and adult-onset asthma (2.65, 1.14–7.24) were significantly increased in relation to methacrylate exposure compared with dental assistants who did not use (meth)acrylates or used them less than daily. When studying the risk in relation to increasing duration of methacrylate exposure, significantly increased risk of asthma was observed, but there did not seem to be any obvious dose–response relation. Chronic bronchitis did not show any obvious relation with exposure to methacrylates.

Modification by atopy

Those dental assistants who had previous atopic diseases were found to be particularly sensitive to exposure to methacrylates, their OR for asthma in the past year being 3.24 (0.98–14.85) and for adult-onset asthma 4.18 (1.02–28.55) (Table 5). The risk of nasal symptoms was also clearly increased among atopic dental assistants (2.11, 1.08–4.19). Among nonatopics the ORs were smaller and did not reach statistical significance.

Discussion

In this relatively large study of 799 registered dental assistants from the Helsinki metropolitan area, Finland, daily exposure to methacrylates was related to significantly increased risk of nasal symptoms and work-related

Table 5. Adjusted odds ratios (OR) of respiratory symptoms and asthma in relation to daily exposure to methacrylates stratified by atopy. OR for the nonexposed is 1.00 (reference categories, not shown in the table)

	Atopy			
	Yes (n = 240)		No (n = 548)	
	OR*	95% CI	OR*	95% CI
<i>Symptoms</i>				
Nasal symptoms	2.11	1.08–4.19	1.24	0.89–1.73
Cough and/or phlegm	0.96	0.51–1.86	1.21	0.80–1.85
Dyspnoea	1.25	0.65–2.46	0.86	0.53–1.41
Wheezing with dyspnoea	2.26	0.61–11.12	1.04	0.44–2.64
<i>Disease</i>				
Doctor-diagnosed asthma in the last year	3.24	0.98–14.85	2.64†	0.84–11.67
Adult-onset doctor-diagnosed asthma	4.18	1.02–28.55	2.18	0.71–6.69

*Adjusted for age, smoking, and use of natural rubber latex (NRL).

†Adjusted for smoking and use of NRL only due to small numbers in some cells).

cough or phlegm production. Nasal symptoms and hoarseness (both general and work-related) showed a dose-dependent increase with increasing duration of occupational methacrylate exposure. Those with the longest methacrylate exposure had also increased risks of dyspnoea and wheezing in relation to dyspnoea.

Those with daily exposure to methacrylates had over twofold risk of asthma compared with no or less than daily use of methacrylates. This was seen for adult-onset asthma and for asthma in the past 12 months, the effect being somewhat larger on the latter. We excluded aggravation of childhood asthma as an explanation for our findings in the analyses that restricted asthma to disease that had started at or after the age of 18 years. Daily exposure to methacrylates was common in this study population (64%), so the observed high risk of asthma related to methacrylate exposure suggests that methacrylates pose an important occupational hazard for dental assistants. Those with atopic diseases seemed to be particularly susceptible to the harmful effects of methacrylates, as the risks of asthma and nasal symptoms were especially high among dental assistants with atopic disease in childhood and/or adolescence.

A previous study from Finland measured methacrylate concentrations in dental practices and identified the following methacrylates in air samples: methyl methacrylate (MMA), 2-HEMA, and TEGDMA (3). The median concentration of 2-HEMA was 0.004 mg/m³ close to the work-desk of a dental nurse and 0.003 mg/m³ in the breathing zone. The maximum concentrations were 3–5 times higher than the median concentrations. In a Swedish study quantifying exposure to methacrylates among dental personnel, the median 8-h time weighted average of 2-HEMA was 2.9 µg/m³ among dental nurses (1). The maximum short-term exposure level of 2-HEMA was 79 µg/m³. These studies demonstrate that there are

detectable air concentrations of methacrylates in dental practices, so sensitization through inhalation is a possible mechanism for our findings. (Meth)acrylates have been reported to be common causes of occupational skin diseases in dental personnel in previous studies (12–14) as well as in this study population (15) and dermal sensitization may play a role for respiratory diseases. Irritative inflammation is also a possible mechanism, so in the future, more research is needed on the mechanisms that underlie the adverse effects of exposure to methacrylates on respiratory health.

The risk of asthma did not show any obvious dose-dependence with duration of methacrylate exposure. This may be due to at least two possible explanations: (i) sensitization to methacrylates develops usually within 5 years from the beginning of exposure; or (ii) dental assistants who have developed asthma or whose asthma has become worse while working with methacrylates are advised to quit this exposure.

Those who were not exposed to methacrylates daily (36%) performed clearly less frequently work tasks with potential methacrylate exposure such as making dental fillings and sealings (76% did not perform these at all) compared with the exposed group (7% did not perform these tasks at all). Our unexposed group did more advising and educational work on dental health, plaque control, and oral hygiene than those with daily methacrylate exposure. Other tasks performed more commonly by the unexposed dental assistants include removing of deposits and stains from teeth by scaling and root planning, performing preventive dental procedures, such as fluoride treatment, and assisting in surgical procedures. The first two tasks are performed mainly by dental hygienists.

Validity issues

The response rate in our study was good (87%), so selection bias is an unlikely explanation for our results. This sample formed about 20% of all registered dental assistants in Finland. Because of the high unionization rate (over 90% of dental assistants are registered members) and rather uniform working methods in different parts of Finland, we consider this sample to represent well the situation in Finland in general.

The cross-sectional design is a limitation of this study. If symptomatic dental assistants tend to avoid exposures, our study underestimates the true effects. However, while latex is a well-known cause of occupational diseases in health care personnel, the risks related to (meth)acrylate exposure for respiratory health have not been well understood. Based on our study, avoidance of methacrylates was not common among dental personnel, whereas only a minority used NRL gloves. Eighty-one percent of dental assistants reporting regular use of protective gloves used mainly plastic gloves (vinyl, PVC).

In this epidemiological study we were interested in relation of methacrylate exposure to respiratory symp-

toms and diseases in general and did not limit our outcomes to occupational diseases only. We studied also the more specific work-related symptoms as outcomes, but these analyses had less statistical power because of smaller numbers. We were not able to separate new (occupational) asthma from previous adult asthma aggravated by occupational exposures, but were able to exclude aggravation of childhood asthma in the analyses that used adult-onset asthma only as the outcome. However, we think that both new occupational asthma and asthma aggravated by occupational exposure to methacrylates are of importance for the preventive perspective.

The exposure assessment was based on self-report, but the findings from this study suggest that over-reporting of exposures was not a problem, as only small effects were detected in relation to the better-known occupational sensitizer NRL (data not shown). This finding is plausible, as NRL gloves have been recognized as an occupational hazard in health care, including dental personnel, for a long time, and information on preventive possibilities has been published (16–20). As a consequence of this, the use of NRL gloves has declined in Finland dramatically and the NRL concentrations of the gloves still used have diminished (21). In this study, we adjusted for use of NRL gloves along with other potential confounders, including age, smoking habits and atopic disorders in childhood or adolescence. We did not adjust for adulthood atopy, as it may be in the causal pathway.

Synthesis with previous knowledge

A recent population-based incident case-control study from Finland investigated the relation of different occupations, coded according to the ISCO-88, with new adult-onset asthma (7). The risk of asthma was clearly increased among dental workers (including dentists and dental assistants), although the CI was wide because of the small number of cases in this occupational category (OR 4.74, 95% CI 0.48–46.5). In a cross-sectional analysis of 14 151 adults from the French PAARC air pollution study, the risk of asthma was slightly increased (OR 1.45, 95% CI 0.57–3.66) among dentists (22). In this study, the risks of asthma, nasal symptoms and work-related cough or phlegm were significantly related to daily exposure to methacrylates and ORs of hoarseness, dyspnoea, and wheezing with dyspnoea were also increased. Some case reports/series of occupational asthma and rhinitis in relation to (meth)acrylates in dental work have been previously published (8, 9), but no earlier study had assessed the risk of respiratory conditions related to methacrylate exposure among dental workers according to a Medline database search.

Our findings suggest that dental assistants who have had atopic disorders in childhood and/or adolescence are more susceptible to the harmful effects of dental methacrylate exposure on respiratory health. This is an

original finding, as the potential modifying role of atopy has not been investigated previously in relation to (meth)acrylate exposure. A recent review of occupational asthma conducted by the British Occupational Health Research Foundation Working Group (23) concluded that there is evidence that atopy increases the risk of occupational asthma caused by exposure to many high molecular weight agents. The role of atopy for susceptibility to low molecular weight (LMW) agents is more controversial. Some studies have suggested that atopy increases susceptibility to some chemicals, such as isocyanates (24, 25) and reactive dyes (26), in relation to asthma, and to acid anhydrides (27) in relation to sensitization, while other studies have found no such modifying effect for LMW agents (23).

Conclusions

This study provides new evidence that the risk of asthma, nasal symptoms and cough or phlegm increase signifi-

cantly with daily use of methacrylates in dental assistants' work. Also hoarseness, dyspnoea, and wheezing with dyspnoea are more common among those with occupational exposure to methacrylates for more than 10 years. Those with previous atopic diseases seem to be particularly susceptible to the respiratory effects of methacrylates. Exposure to methacrylates is common among dental assistants and the results indicate that such exposure may pose an important occupational hazard for them. Consequently, measures to control this exposure might protect dental assistants' respiratory health. Such measures could include installation of local exhausts in dental practices, improvement of the working processes, and increasing use of personal protective equipment.

Acknowledgments

The authors thank the staff at the CATI unit of the FIOH. This study was supported by a grant from the Finnish Work and Environment Fund.

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