

Exposure to airborne methacrylates and natural rubber latex allergens in dental clinics

Maj-Len Henriks-Eckerman,^a Kristiina Alanko,^b Riitta Jolanki,^b Heidi Kerosuo^c and Lasse Kanerva^b

^aTurku Regional Institute of Occupational Health, Turku, Finland. E-mail: maj-len.henriks-eckerman@occuphealth.fi

^bFinnish Institute of Occupational Health, Helsinki, Finland

^cFaculty of Dentistry, Kuwait University, Kuwait

Received 12th February 2001, Accepted 4th April 2001
First published as an Advance Article on the web 26th April 2001

The exposure of dental personnel to airborne methacrylates and natural rubber latex (NRL) allergens was studied during placing of composite resin restorations in six dental clinics in Finland. Both area and personal sampling were performed, and special attention was paid to measurement of short-term emissions from the patient's mouth. Methacrylates were collected onto thermal desorption tubes filled with Tenax TA and NRL allergens onto membrane filters. The methacrylate samples were thermally desorbed and analysed by gas chromatography with mass selective detection. The NRL allergen concentrations were determined by the allergen-specific IgE-ELISA-inhibition method. The median concentration of 2-hydroxyethylmethacrylate (2-HEMA) was 0.004 mg m⁻³ close to the dental nurse's work-desk and 0.003 mg m⁻³ in the breathing zone of the nurse with a maximum concentration of 0.033 mg m⁻³. Above the patient's mouth the concentration of 2-HEMA was about 0.01 mg m⁻³ during both working stages, *i.e.*, during application of adhesive and composite resins and during finishing and polishing of the fillings. Maximum concentrations of 3–5 times higher than median concentrations were also measured. Triethyleneglycol dimethacrylate was released into the air mainly during the removal of old composite resin restorations (0.05 mg m⁻³) and only to a minor extent during finishing and polishing procedures. The median concentration of the NRL allergen was 0.12 au m⁻³ (au = arbitrary unit) with a maximum concentration of 1.1 au m⁻³. The results show that, except for short-term emissions from the patient's mouth, the exposure of dental personnel to methacrylates and NRL allergens is very low. Measures to reduce exposure are discussed, as the airborne concentrations of methacrylates should be kept as low as possible in order to reduce the risk of hypersensitivity.

Introduction

Acrylates are reactive compounds polymerized by heat, light or catalysts. The main acrylic compounds in current use are acrylates, methacrylates and cyanoacrylates. Methacrylic compounds, like methyl methacrylate (MMA), are widely used in floorings, bone cements and in restorative dentistry. In Finland there are about 7600 dental nurses/hygienists and about 4800 dentists working in dental clinics.

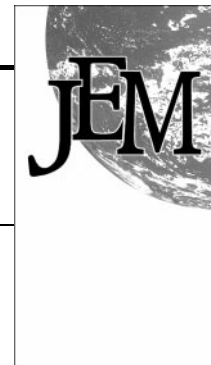
In Finland, similar to other Nordic countries, composite resin restorations (CRRs) have largely replaced amalgam fillings as the treatment of choice for caries during the past 10 years.¹ The CRR materials consist of a resin matrix and filling particles. The resin consists of methacrylic prepolymers, mainly 2,2-bis(4-(2-hydroxy-3-methacryloxypropoxy)phenyl)propane (bis-GMA) and uretanedimethacrylate (UDMA). When bonding CRR to tooth enamel the adhesive resin (without filling particles) must have a low viscosity to enable the flow of material into the tiny irregularities of the etched enamel surface. This effect has been achieved by adding low molecular dimethacrylates, such as triethyleneglycol dimethacrylate (TEGDMA), to the compound. This also enhances the crosslinking of the resins. However, to enable the dentin bonding, the material must be hydrophilic, as dentin tubules lead to the vital pulp and cannot, unlike enamel, be dried without damaging the pulp. As the hydrophobic acrylate groups cannot penetrate into the wet structure, semivolatile 2-hydroxyethylmethacrylate (2-HEMA) or other short chain

oligomers are usually added to the adhesive resins. The hydroxy groups in these molecules render the material hydrophilic. Both bonding materials and composite resins are mostly cured with light, and this technique has largely replaced the former chemical curing for polymerization of the raw materials. Apart from CCRs, methacrylate resins are also used in other fields of clinical dentistry, *e.g.*, in bonding of fixed partial dentures and orthodontic appliances.

Allergic contact dermatitis (ACD) is one of the well known adverse health effects of methacrylates, but they may also cause respiratory symptoms including asthma.^{2–6} In the nineties, 18 cases of occupational asthma and 6 cases of rhinitis among dental personnel caused by methacrylates were diagnosed in Finland.⁷ However, the air concentrations at which asthma respiratory hypersensitivity developed, were not known, so there was a need to get information about the concentrations of airborne composite resin methacrylates in dental clinics.

Protective gloves made from natural rubber latex (NRL) are common sources of contact allergy. NRL itself causes contact urticaria and rubber chemicals allergic contact dermatitis.^{8,9} Airborne glove powder has also been shown to cause occupational asthma in hospital nurses and dental personnel.^{7,9,10} Recently, a few reports of airborne concentrations of NRL allergens in hospitals have been published.^{11,12} However, to our knowledge no data about the exposure of dental personnel to airborne NRL allergens have been published.

The aim of the present study was to get information about the concentrations of airborne methacrylates and NRL



allergens at different working sites in dental clinics during various dental procedures in which methacrylates are used, although mainly during CRR placement and removal. The target group was dental nurses, *i.e.*, dental assistants and dental hygienists. We especially studied short-term exposure to airborne methacrylates by measuring emissions from the patient's mouth during the different CRR procedures. All these exposure data can be used to evaluate the risk for airborne contact urticaria, asthma and other respiratory diseases. Our data also support preventive measures to reduce the exposure.

Materials and methods

Six dental clinics, three private and three public, were chosen for the investigation of air allergens. The clinics varied in size, having 1–7 reception rooms. Mechanical ventilation was in use in four of the clinics during the measurement. In two of the clinics the ventilation was natural. They were all situated in Helsinki and surroundings. In all the selected clinics, placement of CRRs was among the most commonly practiced dental procedures. The personnel used the same bonding systems and restorative materials during the exposure measurements that they normally used. In five of the clinics, the personnel used mainly NRL gloves, in one clinic only vinyl gloves were used. Gloves were changed between every patient. The measurements were performed between September 1998 and March 1999.

Workplace air sampling

In the clinics airborne methacrylates were measured in the breathing zone of the dental nurses and at or above the nurse's work-desk within a distance of 0.5 m from the working point. One area sampling of ambient workplace air per clinic was performed in four of the clinics. The sampling point was a few metres from the treatment chair. In personal sampling and in the area sampling at the nurse's work-desk the collection time was equal to that of the treatment of one patient, usually 15–30 min. The workplace area sampling lasted 2–3 h. Short-term exposure during each stage of the CRR procedure was determined by keeping the collection device 20–30 cm above the patient's mouth during sampling. In this way, the emission of air allergens was measured separately during the following three work phases: (1) application of bonding materials and composite resins, (2) finishing and polishing of the CRR and (3) removal of old CRRs by drilling. The short-term emissions were the mean concentrations of 1–3 combined measurements in order to get detectable amounts for the analysis. Airborne methacrylates were collected onto thermal desorption tubes containing 150 mg of Tenax TA.¹³ The sampling rates were 100–300 ml min⁻¹ with the higher sampling rate for short-term emission samples above the patient's mouth.

NRL allergens were collected at a distance of about 50 cm above the package of gloves from where the personnel took their protective gloves, with a reciprotor pump (6–16 l min⁻¹) onto AAWPO37 (Millipore) membrane filters. The sampling time was about 5 h.

Analysis of methacrylates

The methacrylate samples were thermally desorbed with Chrompack PTI (Middelburg, the Netherlands) for 10 min at 270 °C. The sample was trapped at –100 °C and released from the trap by rapidly heating the trap to 220 °C during 3 min. The trap consisted of a 32 cm long column with 0.53 mm id and a 5 µm film thickness of CP-sil 5CB (Chrompack). Separation took place on a Varian 3400 gas chromatograph (Walnut Creek, USA) with an HP-5 column (30 m, 0.25 mm id, 0.25 µm film thickness of 95% dimethylpolysiloxane, 5% diphenylpolysiloxane; Hewlett-Packard, Waldbronn, Germany). The initial

oven temperature was held at 40 °C for 2 min and increased at 10 °C min⁻¹ to 255 °C, where it was held for 6 min. The methacrylates were detected by a mass selective detector (Finnegan ITS40, San Jose, CA, USA) at 200 °C. Quantification was done with external standards of 2-HEMA (Aldrich, purity 97%, Sheboygan, USA), TEGDMA (Fluka, purity 90–95%, Buchs, Switzerland), isobutylmethacrylate (i-BMA, purity 98%, Polyscience corp., USA) and MMA (Riedel-de Haën, 99% purity, Seelze, Germany) using the abundance of the fragment ions *m/z* 69, 87 and 113.

Analysis of NRL allergens in dust powder

The air concentration of NRL allergens in the collected dust samples was determined by the allergen-specific IgE-ELISA-inhibition method.¹⁴

Results

Methacrylates that could be identified in the air samples were MMA, 2-HEMA, i-BMA and TEGDMA (Fig. 1), of which MMA and i-BMA were not detected in all clinics. When MMA was detected, it was in all measurement sites of the clinic in air concentrations of 0.01 mg m⁻³ or below. A concentration of 0.12 mg m⁻³ of i-BMA was found in the air above the patient's mouth during bonding of an orthodontic fixed appliance. Adhesive bonding of a fixed partial denture on a patient resulted in a concentration of 0.014 mg m⁻³ of 2-HEMA and 0.007 mg m⁻³ of TEGDMA above the patient's mouth.

The results of the air sampling for 2-HEMA and TEGDMA during the CRR procedure are summarized in Table 1. In the ambient workplace air the 2-HEMA concentrations were close to the detection limit of the method (0.0005 mg m⁻³). The median concentration of 2-HEMA was 0.004 mg m⁻³ close to the work-desk of the dental nurse and 0.003 mg m⁻³ in the breathing zone of the nurse, with a maximum concentration of 0.033 mg m⁻³. This air concentration was measured during the filling of three cavities for the same patient during 30 min. Above the patient's mouth the median concentration of 2-HEMA was about 0.01 mg m⁻³ in both working stages, during application of adhesive and composite resins and during finishing and polishing of the fillings. The maximum concentrations were 3–5 times higher than the median concentrations. TEGDMA was released into the air mainly during the removal of old CRRs (0.05 mg m⁻³) and to a minor extent during finishing and polishing procedures.

In the clinics, where NRL gloves were used, the median concentration of the allergen in the collected airborne dust was 0.12 au m⁻³ (au = arbitrary unit, *n* = 11). The maximum concentration was 1.1 au m⁻³. In the clinic, where vinyl

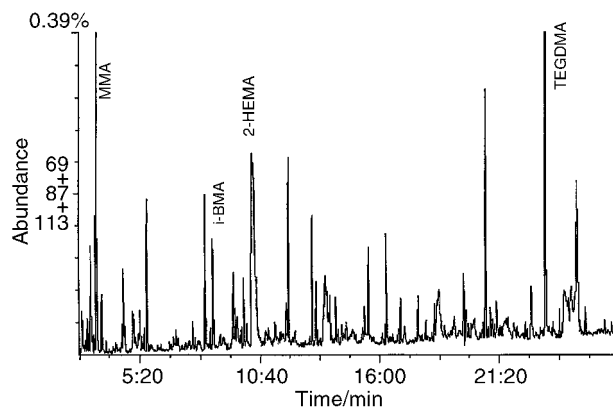


Fig. 1 Extracted chromatogram of an air sample collected above the patient's mouth during application of resin material. MMA = methylmethacrylate, i-BMA = isobutylmethacrylate, 2-HEMA = 2-hydroxyethylmethacrylate, TEGDMA = triethyleneglycol dimethacrylate.

Table 1 Median concentrations of 2-HEMA and TEGDMA in workplace air during procedures related to placing and removing of CRRs in six dental clinics^a

			Air concentration/mg m ⁻³	
Measurement site	Methacrylate detected	<i>n</i>	Median	Max
<i>Area sampling—</i>				
Ambient work place air	2-HEMA	4	< 0.0005	0.002
	TEGDMA		n.d.	
Around the work-desk of the nurse	2-HEMA	10	0.004	0.011
	TEGDMA		< 0.001	0.002
<i>Personal sampling—</i>				
In the breathing zone of the nurse	2-HEMA	12	0.003	0.033
	TEGDMA		< 0.001	0.015
<i>Emission measurements above the patient's mouth—</i>				
Application of resin material	2-HEMA	9	0.013	0.068
	TEGDMA		0.001	0.016
Finishing and polishing	2-HEMA	10	0.012	0.036
	TEGDMA		0.008	0.019
Removing of old CRRs	2-HEMA	3	0.004	0.005
	TEGDMA		0.054	0.081

^aMax = the highest measured concentration, *n* = the number of measurements, n.d. = not detected.

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gloves were used, the allergen concentration was close to the detection limit 0.02 au m⁻³.

Discussion

Methacrylates and NRL are the most common causes of occupational respiratory diseases in dental personnel.⁷ Respiratory hypersensitivity from NRL results from an IgE-mediated immediate allergy,¹⁴ whereas the mechanism of respiratory hypersensitivity from methacrylates is not known.^{3,6} In dental clinics, handling of composite materials, resulting in airborne methacrylates, happens mainly in two sites. Either at the nurse's desk where the dosage and mixing of the material is done, or in the patient's mouth during the application procedure and the drilling of the composite material. The sampling strategy was chosen according to this assumption. Table 1 shows that the main source of airborne methacrylates was the patient's mouth. The measurement results also revealed that short-term but relatively high-level air concentrations are missed, if airborne impurities are determined only by personal or long-term area sampling.

The Finnish occupational exposure limit for MMA has recently been set to 42 mg m⁻³ for 8 h. There is also a WHO guideline of 200 µg m⁻³. All measured MMA concentrations were well below these limit values. No exposure limit value has been established for i-BMA.

In the European Union, only Holland has an occupational exposure limit for 2-HEMA, which is set to 0.05 ppm (0.27 mg m⁻³) for 8 h. All the measured 2-HEMA concentrations, including those above the patient's mouth, were below this limit value. The highest air concentrations of 2-HEMA were measured during filling of three cavities in the same patient during 30 min in a mechanically ventilated clinic. Usually one CRR per patient was done. This means that the amounts of primer and adhesive used per time unit, both containing 2-HEMA, were higher than usual, resulting in a higher evaporation rate. Another factor that may influence the air concentration, is that the low volatility of 2-HEMA makes it difficult to remove vapours from the workplace air quickly. Anyhow, no systematic difference in methacrylate concentrations was noticed between mechanically or naturally ventilated clinics. Therefore, one way of reducing the exposure to airborne 2-HEMA would be to make only one CRR per patient at each visit. Another way to reduce exposure would be to use products that contain no 2-HEMA or other volatile methacrylates. Use of the recently launched one-step bonding systems, which do not require mixing, are also likely to reduce the evaporation

rate. In any case to reduce the risk of hypersensitivity, the airborne concentrations of methacrylates should be kept as low as possible.

No exposure limit has been established for TEGDMA, which was detected in every sample from the air above the patient's mouth during finishing and polishing. TEGDMA is hardly volatile, and therefore it is likely to be present in the air as mist or dust. A sampling rate of 300 ml min⁻¹ was explicitly used in order to decrease the quantitation limit of the method. As a result it was evident that not only vapours were collected. The air concentrations measured during finishing are probably exceeded during very short periods, as the finishing work is discontinuous with breaks for adjustment of the restoration. The highest air concentrations of TEGDMA were measured during removal of old fillings. Along with the rapid increase in CRRs the removal of old fillings will become more and more common in the future, especially as the life span of newer restorations seems to be shorter than with amalgam restorations. This may result in increased exposure to airborne TEGDMA. It may be difficult to reduce the exposure to TEGDMA, as it is released into the air by a high speed drill. It has earlier been demonstrated that the normal high-volume evacuation system is not very efficient in removing composite dust.¹⁵

As the target of this study were the dental nurses, no personal sampling was performed in the breathing zone of the dentists. However, the air concentrations measured above the patient's mouth can also be used to evaluate the exposure of dentists to airborne methacrylates. The dentists are closer to the patient's mouth than the dental nurses and usually working at a distance similar to where the sampling tubes were placed in this study. Thus, the same results may apply to dentists as well.

NRL allergens can be released from surgical protective gloves into the air in hospitals.^{11,12} In health care workers in a hospital in UK the geometrical mean concentration of NRL allergen was 0.46 µg m⁻³ as determined by personal sampling.¹¹ This was much lower than in glove manufacturing factories (up to 17.8 µg m⁻³) or rubber plantation workers (2.4 µg m⁻³).¹² Our area measurement results also showed that small amounts of NRL allergens were released into the air in dental clinics, during removal of gloves from package boxes and applying them to the hands. However, our results are not directly comparable with results from the two other studies, as they used different methods. Our results show that a low exposure to airborne NRL allergens is possible in dental clinics. This exposure should be reduced by using protective gloves with a low content of NRL allergens or by using gloves made from other materials.

Acknowledgements

We thank Kaija Lappalainen and Sari Wahlström for their skilful technical assistance. We also gratefully acknowledge Eero Kerosuo for his expertise in restorative dentistry and his help in the preparation of the manuscript.

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