

Exposure to Methyl Methacrylate and Its Subjective Symptoms Among Dental Technicians, Tehran, Iran

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Exposure to methyl methacrylate (MMA), total dust and health symptoms were investigated in 20 dental laboratories located in Tehran, Iran. Time-weighted average (TWA) of MMA and peak concentrations were determined, using XAD-2 tubes followed by GC-ID analysis. Total dusts were evaluated gravimetrically. Health symptoms were asked using a questionnaire. TWA for technicians with direct and indirect exposure to MMA were 327.28 ± 79.42 and 282.9 ± 41.84 mg/m³, respectively. Peak concentration of MMA for those technicians were 337.0 ± 36.81 and 328.88 ± 45.40 mg/m³, respectively.

There were no significant differences between TWA of MMA and peak concentration in different weekly workdays; however, within-day variations were observed ($P < .05$).

TWA of MMA and peak concentration correlation with the laboratory volume were 0.61–0.65. Dust exposure of technicians was 2.35 ± 2.70 mg/m³. Cough and skin dryness were the common health symptoms. Smoking and asbestos exposure history were factors influencing cough prevalence ($p < .05$).

It is concluded that the current Short-Term Exposure Limit (STEL) is not low enough to protect technicians against the adverse effects caused by MMA.

methyl methacrylate (MMA) dental technicians dental laboratories health symptoms
time-weighted average (TWA) concentration peak concentration

1. INTRODUCTION

Acrylic plastics can be used for a wide variety of applications in dental laboratories. Their major uses are in the fabrication of complete or partial denture bases to support artificial teeth. Acrylic plastics are supplied in a variety of forms, such as powder-liquid, gels, and sheets, in which the powder-liquid system of methyl methacrylate (MMA) is the most common form used in acrylic dental laboratories. The liquid component of MMA is principally the monomer of MMA, which is clear, colorless, and

flammable with a strong odor described as acrid or pungent [1]. MMA has been reported as a lung, skin, and eye irritant [1, 2], and causing mild axonal degeneration of digital nerves when it is handled with bare hands before polymerization [3]. Systemic effects, including damage to the central nervous system and liver have been reported in animal studies after chronic oral exposure to high concentrations of the MMA monomer. Exposure to this compound has been reported as a risk factor of occupational asthma. Some cases of occupational asthma have been reported due to exposure to dental materials,

The authors acknowledge and thank Iranian Dental Technicians Association management, especially Mrs. Fariba Khayatti and Mr. Hossain Chaghari, for their sincere co-operation.

The authors are also grateful to Dr. M.B. Rokni for revising the present manuscript.

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especially MMA, among dental technicians [1, 4, 5]. When polymerized MMA is polished and finished with abrasive tools, dust is generated, causing dental technicians' exposure. Exposure to dust has been recognized to be responsible for dental technicians' pneumoconiosis [6].

The objectives of this study were to evaluate dental technicians' exposure to MMA and to assess their health with a focus on respiratory and dermal symptoms.

2. MATERIALS AND METHODS

Although there are many laboratories which make fixed and removable dentures in Tehran, capital of Iran, their real number is unknown, because some of them have not been registered by the Iranian Dental Technicians Association (IDTA).

Twenty Teheran laboratories, registered members of IDTA, involved in fabricating removable acrylic dentures, both complete and partial, were studied. First, in co-operation with IDTA, the processes and operations of fabricating acrylic prostheses were observed. Then, the area and volume of the laboratories and also the demographic data of the technicians were asked and recorded in a pre-prepared form.

The present study was conducted in the following stages.

2.1. Evaluation of Technicians' Exposure to MMA

All technicians with direct or indirect exposure to MMA were evaluated based on their personal breathing zone concentrations of MMA. A 3-day-a-week investigation was conducted in each laboratory (Saturday, Monday, and Wednesday). Air samples were collected using XAD-2 adsorbent tubes, 226-30, SKC Co. (UK) connected to calibrated personal sampler micro pumps; model 222-3 SKC Co.

Flow rate was maintained at 50 ml/min. Then, the tubes were recapped after sampling and kept at 4 °C until they were shipped to the laboratory for analysis.

In this study, the National Institute for Occupational Safety and Health (NIOSH) method

No. 2537 was used. For the analysis of the samples and assessment of the exposure level, a standard solution of MMA 99% from Merck (Germany), GC grade Art, No. 800590 was prepared in carbon disulphide from Merck (Germany) >99.5% purity, GC grade Art, No. 102211.

The analyte was extracted by carbon disulphide. Then, the extracts were analyzed, using a gas chromatograph (GC), model 910.310, from Buck Scientific, Inc. (USA) equipped with a flame ionization detector (FID) and a MXT-1 column (15 m, 0.53 mm I.D., 1 µm film thickness). Chromatographic conditions were as follows: injection port 240 °C, detector oven 300 °C, column oven temperature 100 °C, nitrogen carrier gas inlet pressure 8 psi, which was 24 ml/min gas flow and split injection of 4 µl.

The column that was selected after pre-testing was different from that in the NIOSH method No. 2537. The analysis of MMA was carried out within 2 days.

2.2. Determination of Peak Concentration of MMA

Because generation of peak MMA vapor concentration happens in the process of mixing monomers and polymers of MMA, for evaluation of the maximum technicians' exposure to MMA, short-term (5–15 min) samples were collected during this process. The sampling media, method, and analysis were the same as the evaluation of time weighted average (TWA), except for sampling duration.

Short-term sampling was simultaneously performed for both technicians with and without direct exposure (as environmental samples) to MMA.

2.3. Evaluation of Dust Exposure

In dental laboratories, during various operations, especially finishing and polishing polymerized MMA processes, dust is generated. It is predicted that most generated dust contains acrylic dust. In this study, total dust samples were collected, using a 25-mm diameter fiber glass filter attached to a 25-mm closed-face filter cassette at flow rate of 2 l/min (SKC, Co., UK, model 224-PCXR3).

The mass of dust in all samples was weighed to 0.0001 gram on a calibrated Sartorius (Germany) balance (0.0001) before and after sampling. To determine TWA, sampling was done twice a day ($2 \times 4 = 8$ hrs for a full shift).

Dust monitoring was simultaneously performed in two situations: (a) in the area of the technicians who worked with grinding machines, thus directly exposed; (b) in the area of the technicians who were indirectly exposed to dust.

2.4. Investigation of Respiratory and Dermal Symptoms

All subjects were interviewed, using a validated questionnaire. To obtain information on health, it was focused on respiratory and dermal symptoms, as well as individual habits, including cigarette smoking and the subjects' history of exposure to asbestos. None of the technicians were seen to use protective devices during the study. The collected data were analyzed, using R statistical software [7].

3. RESULTS

This research was carried out in 20 dental laboratories, located in Tehran, Iran, on 51 subjects: 6 (11.76%) female and 45 (88.24%) male. Their average age was 38.83 ± 4.1 and 37.58 ± 9.8 years

respectively. For work history, these figures were 12.25 ± 8.8 and 15.58 ± 10.9 years, respectively. Twenty-three technicians (45.1%) had academic education, while 54.9% (28 individuals) had on-the-job training.

To determine MMA concentration, a standard curve was generated by plotting peak area against sample concentrations for solutions of different standard sample concentrations of 96.21, 163.76, 384.84, 818.81, 3848.42 mg/m^3 for MMA. A correlation coefficient of .999 was obtained and the limit of detection was 10 $\mu\text{g/ml}$ (S/N 3:1) for the compound of interest.

Table 1 shows MMA monitoring results in the technicians' breathing zone. The MMA concentrations (TWA and peak concentrations) have been expressed as arithmetic and geometric values. As shown in Figures 1 and 2, the MMA concentrations were independent on workdays and the concentrations were the same in different days. This was also true for maximum concentrations.

The technicians' exposure to dust in finishing and polishing processes is shown in Table 2.

The results obtained for frequency of respiratory and dermal symptoms have been shown in Tables 3 and 4. Based on those findings, the most common dermal symptom among technicians was skin dryness. Cough was the most common respiratory dysfunction especially in smokers and technicians with asbestos exposure background.

TABLE 1. TWA and Peak Concentration of MMA Vapor in Directly and Indirectly Exposed Dental Technicians in Terms of mg/m^3 (ppm)

| Exposure Concentration | N | Arithmetic | | | | Geometric | | | | |
|------------------------|------|------------|-------------------|------------------|---------------------------------|-----------------|-----------------|-----------------|----------------|----------------------------|
| | | M | SD | Range | M* | Median* | GM | GSD | Range | |
| Direct | TWA | 60 | 290.14 (70.94) | 81.55 (19.94) | 237.26–339.55 (58.01–83.02) | 17.38 (4.25) | 17.34 (4.24) | 17.42 (4.26) | 4.21 (1.03) | 16.60–18.08 (4.06–4.42) |
| | Peak | 60 | 329.98 (80.68) | 40.04 (9.79) | 271.37–386.096 (66.35–94.40) | 17.91 (4.38) | 17.91 (4.38) | 17.06 (4.39) | 4.21 (1.03) | 17.13–18.61 (4.19–4.55) |
| Indirect | TWA | 20 | 282.70 (69.12) | 41.80 (10.22) | 235.30–338.45 (57.53–82.73) | 17.30 (4.23) | 17.22 (4.21) | 17.26 (4.22) | 4.21 (1.03) | 16.56–18.08 (4.05–4.42) |
| | Peak | 20 | 328.55 (80.33) | 45.36 (11.09) | 240.25–378.82 (58.74–92.62) | 17.91 (4.38) | 18.16 (4.44) | 17.96 (4.39) | 4.21 (1.03) | 16.65–18.53 (4.07–4.53) |

Notes. MMA—methyl methacrylate, *—logarithm base e, GM—geometric mean, GSD—geometric standard deviation, TWA—time-weighted average.

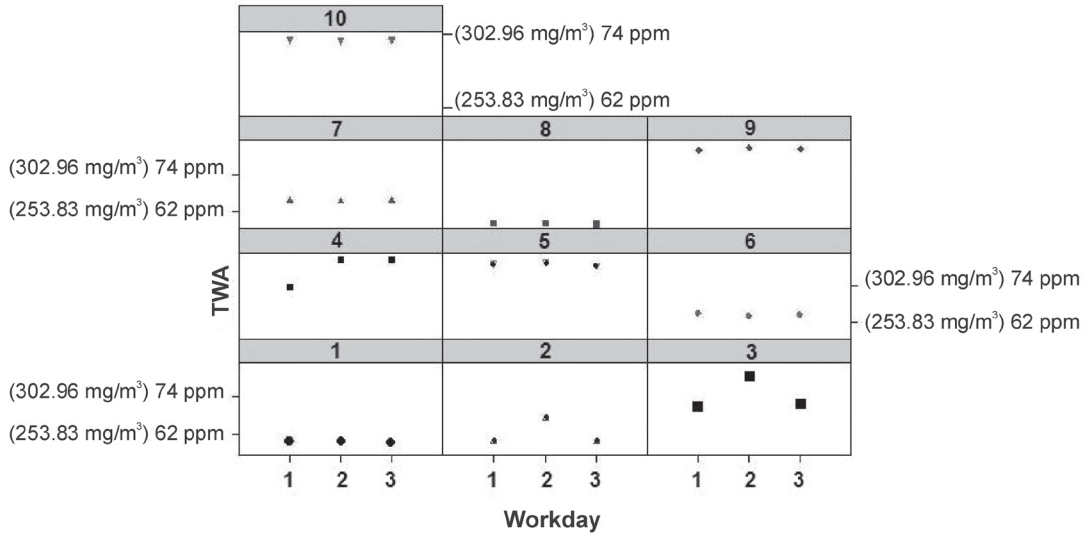


Figure 1. The trend of TWA of MMA concentrations during workdays. Notes. TWA—time-weighted average, MMA—methyl methacrylate.

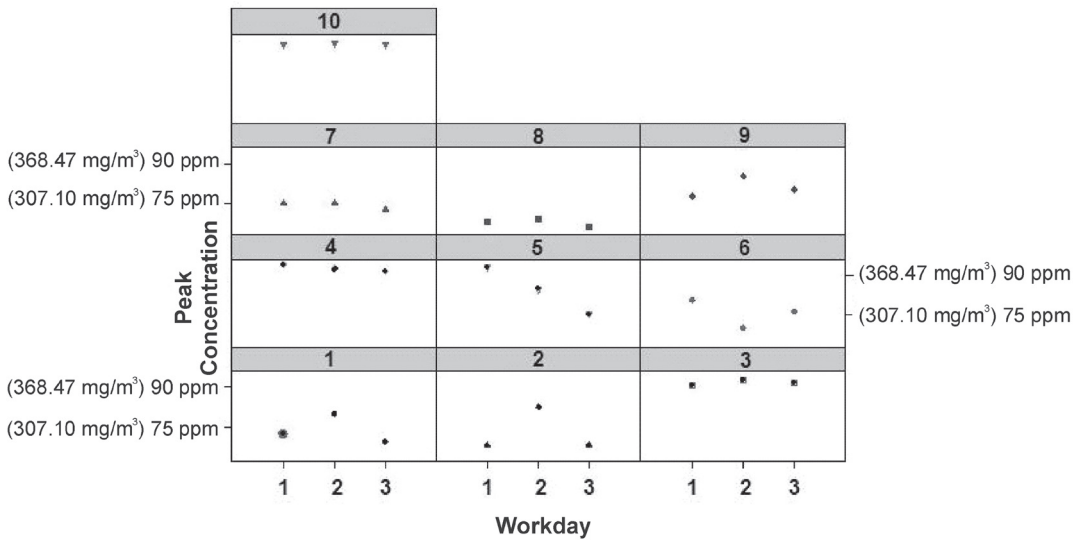


Figure 2. The trend of MMA peak concentrations in workdays. Notes. MMA—methyl methacrylate.

TABLE 2. Personal and Environmental Dust Concentration in Dental Laboratories in Terms of mg/m³.

| Sampling | Arithmetic | | | Geometric | | |
|---------------|------------|-------|-------------|-----------|------|-----------|
| | M | SD | Range | M | SD | Range |
| Personal | 2.35 | 2.7 | 0.126–9.601 | 7.09 | 1.21 | 4.84–9.12 |
| Environmental | 0.431 | 0.549 | 0.031–2.236 | 5.31 | 1.25 | 3.44–7.71 |

TABLE 3. Prevalence of Dermal Symptoms Among Dental Technicians

| Exposure | Eczema | | Crack | | Lesions | | Itching | | Vesicule | | Fingertips | | Skin Dryness | |
|----------|--------|-------|-------|-------|---------|-------|---------|-------|----------|-------|------------|-------|--------------|-------|
| | N | % | N | % | N | % | N | % | N | % | N | % | N | % |
| Direct | 4 | 10.53 | 8 | 21.05 | 10 | 26.32 | 5 | 13.16 | 10 | 26.32 | 3 | 7.89 | 18 | 43.37 |
| Indirect | — | — | 1 | 7.69 | 1 | 7.69 | 2 | 15.38 | 3 | 23.10 | 2 | 15.38 | 2 | 15.38 |

TABLE 4. Prevalence of Respiratory Symptoms Among Dental Technicians

| Exposure | Cough | | Phlegm | | Asthma | |
|----------|-------|-------|--------|-------|--------|-------|
| | N | % | N | % | N | % |
| Direct | 7 | 18.42 | 9 | 23.68 | 16 | 42.11 |
| Indirect | 2 | 15.38 | 4 | 30.77 | 5 | 38.46 |

4. DISCUSSION

Investigation of technicians' exposure to MMA was done for 3 days a week, when mixing and packing operations were being accomplished.

This study demonstrated that technicians working in the fabrication of removable denture process were exposed to MMA, which had an influence on their respiratory systems and skin. The results revealed that the exposure levels of MMA were not the same for all technicians in the laboratory. The technicians involved in mixing and packing operations had the highest exposure: $327.28 \pm 81.64 \text{ mg/m}^3$ ($79.94 \pm 19.94 \text{ ppm}$), while the other technicians were exposed to $282.98 \pm 41.84 \text{ mg/m}^3$ ($69.12 \pm 10.22 \text{ ppm}$), which was much more than the concentrations reported by another study [3]. These differences may be due to the poor ventilation in the studied laboratories and hygienic behavior of technicians. The geometric standard deviation for TWA concentration of MMA was 0.57 mg/m^3 (0.14 ppm), indicating an unnoticeable variation between studied days. This finding may result from the fact that the type of work and materials used in dental laboratories were the same on different days. However, on other weekdays (not the studied days) MMA might have existed in the laboratory at a detectable level. According to another study [10], this can be attributed to the release of MMA from polymerized dentures or acrylic debris in the laboratory or leakage from the container. In contrast, the geometric deviation for MMA concentrations within a day was moderated, $S_g = 2.03$, indicating a considerable within-day variation. This may be due to noncontinuous work in dental laboratories in a day, so this can be the reason for having peak concentration equal to $337.26 \pm 36.81 \text{ mg/m}^3$ ($82.46 \pm 9.0 \text{ ppm}$), detected in the mixing operation. MMA concentration depends on different parameters, including laboratory capacity (small, medium or large), house-keeping,

a ventilation system or lack of it, and the number of bases and trays ordered for fabrication. The rate of requests for dentures depends on the time of the year; e.g., it increases with the approach of the new year and during annual holidays (mostly summer in Iran). Therefore regarding those effective parameters, TWA of MMA concentrations were between 238.60 and 339.90 mg/m^3 (58.28 and 83.02 ppm).

The results showed that in larger laboratories, the exposure level to MMA vapor was lower than in smaller laboratories. This finding was the same for TWA and peak concentrations (Figures 3 and 4). In other words, there is a relationship between the volume of the laboratory and MMA TWA concentration ($r = -.65$, $P < .05$). Such a relationship was found for the volume of the laboratory and peak concentration of MMA ($r = -.44$, $P < .05$). Thus, larger dental laboratories provided better control measures and safer work conditions than smaller ones.

Mass concentration of acrylic particles was generated by high-speed grinding machines, i.e., $0.126\text{--}9.601 \text{ mg/m}^3$ ($2.35 \pm 2.70 \text{ mg/m}^3$), Environmental dust concentration, i.e., $0.031\text{--}2.236 \text{ mg/m}^3$ ($0.431 \pm 0.550 \text{ mg/m}^3$), did not exceed the occupational exposure guidelines for "Particles not otherwise classified" either. However, the results were much higher than those of another study [8].

Respiratory symptoms, especially cough, were seen among dental technicians, which is inconsistent with another study [9]. It was found that there was a significant difference between prevalence of cough among smoker technicians (92.86% of individuals) and non-smoker technicians ($P < .05$). This difference was also found for technicians with an asbestos exposure background (41.86% of individuals) ($P < .05$). Like in another study [10], it is concluded that occupational exposure to MMA in dental technicians did not affect seriously the respiratory

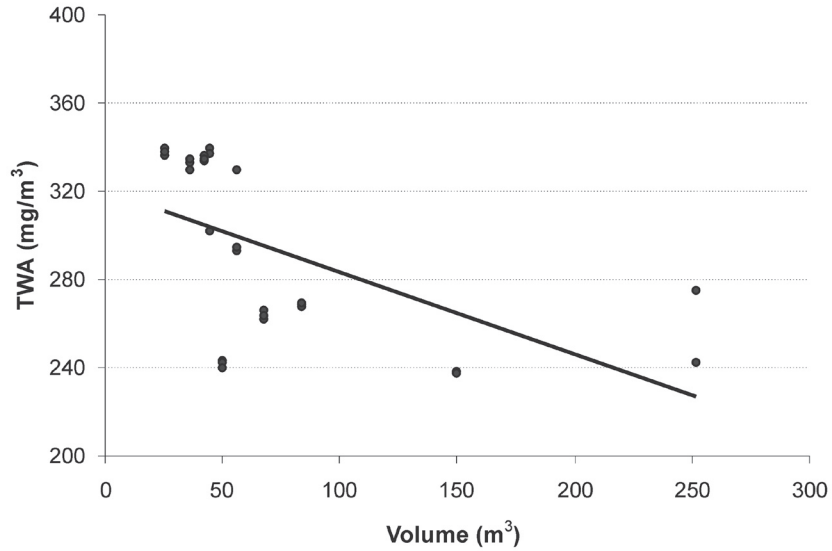


Figure 3. Correlation of TWA of MMA concentration and laboratories' volume. Notes. TWA—time weighted average, MMA—methyl methacrylate.

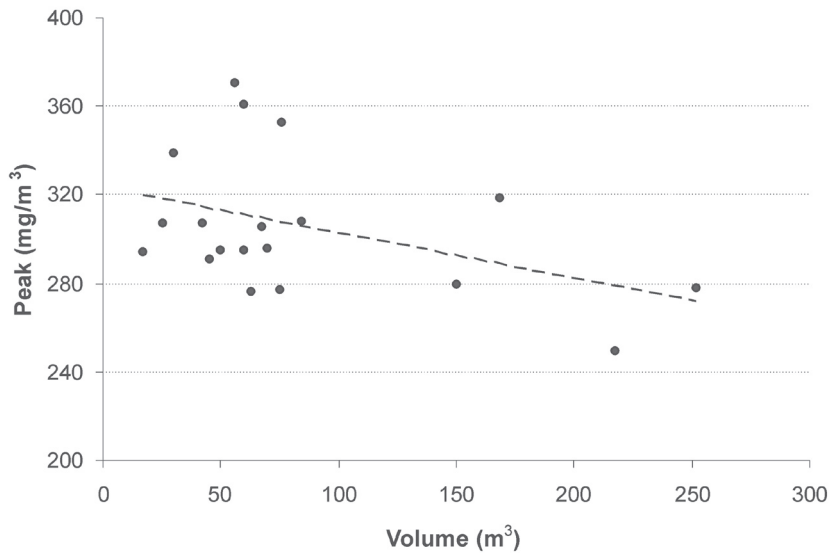


Figure 4. Correlation of peak concentration of MMA and laboratories' volume. Notes. MMA—methyl methacrylate.

system. Smoking and technicians' pre-exposure to asbestos seem to be responsible for respiratory symptoms, especially cough.

Occupational skin disease in dental technicians has also been steadily rising in recent years, causing considerable costs for medical care and rehabilitation. In this study, the obtained data indicated that skin dryness was the most common dermal symptom among dental technicians. Through this study, a relationship between dryness of skin (especially in hands) and MMA

concentration was also indicated ($P = .03$). Some similar data and results were reported by Bichman et al. confirming the consequences of this study [11].

Although MMA concentrations in short-term sampling were lower than STEL, 409.41mg/m³ (100 ppm), its TWA concentrations increased from TLV-TWA, 204.70 mg/m³ (50 ppm), causing the technicians to suffer from strong odor as well as respiratory and skin disorders. It is concluded that the current STEL is not low enough to protect

technicians against the adverse effects of MMA. According to the observations and obtained data, the trend of the work is the same in all dental laboratories. Hence, the obtained results could be considered for all dental laboratories. So, based on the results, a lower value of Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) is recommended, which would provide greater protection for the respiratory system and skin.

Although MMA is not thought to be carcinogenic to humans, techniques should be used to reduce dental technicians' exposure to MMA during denture fabrication. The integrity of latex gloves may be compromised during mixing and packing operations. Dental technicians should avoid direct contact with MMA, considering that room ventilation should be efficiently optimized.

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