Level of Silica in the Respirable Dust Inhaled by Dental Technicians with Demonstration of Respirable Symptoms

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Abstract: Dental technicians are exposed to various dusts in working laboratories. This study was conducted to measure level of silica in the respirable dust generated from dental fixed prosthodontics manufacturing processes using Fourier Transform Infrared Spectroscopy (FTIR), and to compare their occurrence of respiratory symptoms with that of non-dental hospital workers (control group). Respirable dusts were personally sampled from dental technicians working at dental laboratories in Seoul Korea according to NIOSH Method 0600. Fifty personal samples were obtained during porcelain or polishing process and weighed by a gravimetric method. Concentration of respirable dust was 651 ± 548 µg/m³ (Mean ± SD) with highest concentration of 2874 µg/m³ during the porcelain process and 725 ± 414 µg/m³ with highest concentration of 1764 µg/m³ during the polishing process. Concentration of silica was 6.51 ± 6.07 µg/m³ with 18.85 µg/m³ highest and 14.88 ± 11.21 µg/m³ with 50.98 µg/m³ highest for the porcelain and polishing process, respectively. Level of silica contents in the dust was 0.81% and 1.66% for the porcelain and polishing process, respectively. The level of silica contents and silica concentration were significantly different between the two processes. Comparing prevalence of respiratory symptoms between non-smoking seventeen dental technicians and thirty-five control workers, wheezing and rhinorrhea were significantly more manifested in the dental technicians than the controls. Total frequency of respiratory symptoms was also significantly higher in the dental technicians than the controls.

Key words: Dental technician, Silica, Respirable dust, FTIR, Respiratory symptoms

Introduction

Dental laboratory technicians are exposed to various chemical hazards at workplace such as denture base materials, metallic or acrylic resins, and additives containing methyl methacrylate monomer (MMA), hydroquinone, MMA polymer, colorants, or often benzoyl peroxide (a catalyst)\(^1\). When working with these materials, liquid and powder are usually mixed in a bowl, either with an instrument or with the hands, then moulded and formed. Dust generated through
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grinding and polishing procedures, to which pathogenic microbes are sometimes found, is specifically concerned for dental technicians' health.

Some risk factors are synergistic, such as chemical aerosols, poor ventilation, poorly adapted equipment and stresses. Workload stress combined with prolonged muscular work under unnatural working posture have led to musculoskeletal disorders and even impaired eyesight.

Health problems attributed to activities in the dental laboratory are connected to all the above mechanisms. Case reports indicated that dust generated through grinding metallic dental materials containing chromium, cobalt, molybdenum, beryllium or tungsten have caused pneumoconiosis together with dusts of silica, alginate and plaster.

Even though etiological agents have been difficult to be identified because of dental dust's complicated characteristics, a new type of dust-induced fibrotic lung disease called dental technician's pneumoconiosis has been found among professionals involved in making of metal framed removable partial dentures, usually based on various cobalt-chromium-molybdenum alloys. Health effects associated with the prolonged overexposure to respirable free crystalline silica has been well established. But no dental pneumoconiosis has been reported in Korea.

Since dental laboratories are self-employed small businesses usually having less than five workers, it is not enforced to monitor the level of work hazards by the Korean Labor Act. Therein we conducted this study to measure level of respirable dust and silica content in the respirable dust generated from dental laboratory, and to compare occurrence of respiratory symptoms in dental workers with that of non-dental hospital workers, as the control.

Materials & Methods

Thirty porcelain workers and 30 polishing workers willingly participated in the study (dental technicians group) at the beginning of our study. But numbers (N) shown in the results are various depending on the information available from those workers. All of those are male and were working at the dental laboratories employing more than five workers. Personal air sampling was performed according to NIOSH Method 0600 to measure the concentration of respirable dust. PVC membrane filter (37 mm, 5 µm pore size, Coastar) with 10 mm Dorr-Oliver nylon cyclone at flow rate of 1.7 liter/min was used to determine respirable dust concentration for at least 6 hours. Dust concentration was assessed by gravimetric method. To determine level of silica in the respirable dust, the treated filters were scanned using FTIR (Bio-Rad) at the wavenumber of 799, 779 and 695 cm⁻¹, and the weight in micrograms of silica in respirable dust was determined by referring to a standard curve.

Fig. 1 shows a brief process making crown and porcelain. Porcelain is used extensively in restorative dentistry, such as for denture teeth, metallic bridges and inlays. Materials found in the porcelain include various amounts of kaolin, silica, feldspar (K₂O·Al₂O₃·6SiO₂), and alumina (Al₂O₃). Various processes including devesting, sand blasting, polishing, or porcelain build-up are expected to use the silica. Quartz is also used for sandpapers, abrasive paper disks, or in sandblasting procedures, particularly for Co-Cr-Mo alloys. The dust generated during these processes may be a source of exposure to silica dust.

Self-administered questionnaires with a Korean translated version of the British Medical Research Council (BMRC) Questionnaire were obtained from 49 dental laboratory technicians. As the control subjects, 88 clinical laboratory workers or administrative workers from a university hospital were participated in the study. They are not exposed to any known source of dust in their job. Each subject completed
a questionnaire on individual characteristics such as age, height, duration of employment, working hours a day, smoking habit, occupational history, and etc.

For statistical analysis, SAS Version 6.12 was used\textsuperscript{17}. Shapiro-Wilk test for normal distribution and Student’s t-test for comparing the concentration of respirable dust or silica were used. To compare the frequency of respiratory symptoms, Fisher’s exact test was used.

**Results**

Table 1 shows general characteristics of the study subjects. Mean age of the dental technicians and control group was 32.8 ± 5.9 years and 36.2 ± 5.9 years, respectively. Duration of employment was similar between the two groups (9.8 ± 7.1 years for the dental technicians and 10.8 ± 6.2 years for the controls), but working hours a day was a little bit longer to the dental technicians than the controls (10.0 ± 1.5 hours and 8.4 ± 0.8 hours, respectively). Smoking rate of the study subjects was 65% for the dental technicians and 60% for the controls.

There is no statistically significant difference in respirable dust concentration between the porcelain (average: 651 ± 548, range: 115–2,874 µg/m\textsuperscript{3}) and polishing (average: 725 ± 414, range: 119–1,764 µg/m\textsuperscript{3}) part. Level of silica in the respirable dust was approximately two-fold higher in the polishing part with a statistical significance (P<0.01) than the porcelain part (average: 6.510 ± 6.072, range: 0.472–18.852 µg/m\textsuperscript{3} in the porcelain part and average: 14.883 ± 11.211, range: 2.843–50.981 µg/m\textsuperscript{3} in the polishing part). When comparing silica contents in the respirable dust between the two parts, similar aspect was obtained to the levels of silica (Table 2).

No significant relationship was found between the level of silica and frequency of respiratory symptoms reported by the dental technicians (data not shown). Furthermore, no difference in the frequency was observed between the porcelain and the polishing dental workers (data not shown). Regarding potential confounding effect of smoking on respiratory illness, we excluded smokers from the analysis\textsuperscript{3,18–24}. Non-smoker was defined as never-smoker or ex-smoker who had stopped smoking completely at least six months before this study. After excluding smokers, data for respiratory symptoms frequency could be obtained from only 17 dental workers and 35 non-dental hospital workers, henceforth further analyses were undergone after pooling the porcelain and polishing workers. General characteristics of the dental and control non-smoking workers were similar (Table 3).

Among respiratory symptoms, the occurrence of wheezing and rhinorrhea was significantly higher in the dental technician group than the control (P<0.05 and P<0.01, respectively). Total frequency of respiratory symptoms was
also significantly higher in the dental workers than the controls (P=0.001) (Table 4).

### Discussion

It has been well recognized that degree of dust deposition in the lung depends on aerodynamic diameter of the dust\(^{25}\) and respirable dust in the lung cause lung disease such as pneumoconiosis. Pneumoconiosis was often reported from dental laboratory technicians\(^{2,3,7}\), but not yet in Korea. Neither work environment monitoring nor health examination has not been systematically conducted in dental laboratories

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<th>Table 3. General characteristics of non-smoking study subjects</th>
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<td>Characteristics</td>
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<td>Age (years)</td>
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<td>Duration for the present job (years)</td>
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<th>Table 4. Frequency of respiratory symptoms in the non-smokers</th>
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<td>Phlegm</td>
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*P<0.05, **P<0.01, ***P=0.001.
in Korea because dental laboratories are usually self-employed small businesses employing less than five workers. This study is the first investigation in Korea for revealing relationship of occurrence of respiratory symptoms with levels of respirable dust and silica content in the dust generated from dental laboratories.

The respirable dust concentration demonstrated at this study is much lower than the concentration of coal mine’s respirable dust (average 4,900 µg/m³) but not lower than other industries including chemical or rubber industry, metal refinery, or lumber industry of Korea. Even though concentration of silica in the respirable dust was two-fold higher in the polishing part than the porcelain part, the level of silica at the polishing part is not exceeding the exposure criteria of quartz (100 µg/m³), cristobalite and tridymite (50 µg/m³). However, most of the dental technicians did not wear any protective equipment, e.g. respirator, therefore they could inhale relatively more dust. Furthermore, considering generation of a high proportion of respirable dust associated with cutting, grinding, or polishing operations and breathing close to workpiece, i.e. within 20 cm, their occupational risk to respiratory diseases should not be overlooked. Since the dental laboratories evaluated at our study were rather big businesses employing more than five workers and installing a local ventilation system, investigation on small dental laboratories with less than five workers and poor ventilation system, which is representative business type in Korea, could demonstrate higher respirable dust and silica level than our results. The investing materials, containing approximately 60 to 65% of quartz and cristobalite, could contribute to the two-fold higher silica level at the polishing part than the porcelain part.

Total frequency of respiratory symptoms was significantly higher in the dental technicians (76.5%) than the controls (28.6%) (Table 4). Among those respiratory symptoms, wheezing, rhinorrhea, and dyspnea are often resulted from allergic airway hyperreactivity, therefore the materials found in porcelain and polishing processes could be involved with incidence of allergic responses in the dental workers. A number of chemicals including aluminum, chromium, nickel, and methyl methacrylate, which are exposed to dental workers through inhalation, have been reported to cause occupational asthma. The present frequency of respiratory symptoms among the dental workers are relatively higher than other reports. In Norway, 54% of the dental laboratory technicians had experienced various job-related health problems, among which respiratory complaints were 16%. The prevalence of respiratory health problems among the Swedish dental technicians was 31%. We presently have no obvious explanation for the higher respiratory complaints in our study, but this observation could be explained by several means. Information on the symptoms may be biased, in that non-smoking dental workers might relate their respiratory symptoms with job, resulting in an overreported response. Furthermore, precise information could not be reflected into the self-administered questionnaire in the absence of validation by qualified medical personnel. Moreover, since health survey was carried out during winter season from November to March, cold weather could be a contributing factor for the increased respiratory symptoms.

On the basis of our data, it is further needed to conduct a more extensive study considering scale of dental laboratory, condition of ventilation system, reliable measurement tool for respiratory illness such as pulmonary function test or radiograph, and so on.

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