# Pneumoconiosis and Exposures of Dental Laboratory Technicians

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**Abstract:** One hundred and seventy-eight dental laboratory technicians and 69 non-exposed controls participated in an epidemiological respiratory study. Eight technicians who had a mean of 28 years' grinding nonprecious metal alloys were diagnosed as having a simple pneumoconiosis by chest radiograph. Mean values for per cent predicted FVC and $FEV_1$ were reduced among male nonsmoker technicians compared to male nonsmoker controls; after controlling for age, there was also a reduction in spirometry with increasing work-years. An industrial hygiene survey was conducted in 13 laboratories randomly selected from 42 laboratories stratified by size and type of operation in the Salt Lake City, Utah metropolitan area. Personal exposures to beryllium and cobalt exceeded the Threshold Limit Values (TLVs) in one laboratory. Occupational exposures in dental laboratories need to be controlled to prevent beryllium-related lung disorders as well as simple pneumoconiosis. (*Am J Public Health* 1984; 74:1252–1257.)

## *Introduction*

Dental laboratory technicians work with a variety of potentially toxic substances, including nonprecious metal alloys used in the manufacture of crowns, bridges, and dentures, silica used as an abrasive in cabinet-style sandblasters and as a constituent of porcelain, and methyl methacrylate used in preparing dentures. Nonprecious metal alloys used in dental laboratories may contain chromium, cobalt, molybdenum, beryllium, nickel, and small amounts of gallium, ruthenium, or aluminum. Per cent composition varies depending on the specific use. For example, nonprecious alloys used for crowns and bridges typically contain 67–98 per cent nickel and 12–15 per cent chromium, while nonprecious alloys for partial dentures typically do not contain nickel and have 40–61 per cent chromium plus 32–40 per cent cobalt. Nonprecious alloys typically contain 0.5–2 per cent beryllium, which is added to improve hardness, strength, fatigue and corrosion resistance, and elasticity. Over the past several years, nonprecious metal alloys have experienced a rapid increase in use due to the higher cost of gold and silver. The National Association of Dental Laboratories estimates that there are 44,000 dental laboratory technicians in the United States; in addition, there are many non-technicians and trainees working in dental laboratories.

In 1981, Kronenberger, *et al*, reported a clinical study of dental laboratory technicians from Germany.[1] They mailed questionnaires to 250 dental laboratory technicians and 70 volunteered for their study. Half complained of respiratory symptoms; pneumoconiosis was noted on 27 chest radiographs. Twenty-one had a fiberoptic bronchoscopy and interstitial fibrosis was noted on 12 biopsies; the lesions were topographically located near dust deposits.[2] X-ray microanalysis identified aluminum and silicon related to grinding and polishing materials and chromium, cobalt, nickel, and titanium related to the metal alloys.[2]

In February 1982, a 38-year-old male dental laboratory technician presented to a Salt Lake City community hospital complaining of a dry cough and two months' progressive dyspnea. His chest radiograph revealed a diffuse reticulonodular infiltrate, and pulmonary function testing showed a restrictive pattern with a reduced diffusing capacity. An open-lung biopsy revealed a generalized mononuclear cell infiltrate but no granulomas. Cultures for aerobic, anaerobic, fungal, and mycobacterial organisms were negative, as were acute and convalescent viral titers; cold agglutinins were negative, and a serum angiotension-1-converting enzyme test was normal. He had been grinding beryllium-containing metal alloys four to six hours a week for three months with only a nuisance dust respirator (surgical mask) for protection and virtually no local ventilation on his grinder. A diagnosis of chemical pneumonitis consistent with acute berylliosis was made, and he was treated with corticosteroids. Subsequently, two additional dental laboratory technicians with beryllium exposure and interstitial lung disease (one with granulomas) were brought to our attention.

Following the index case, we performed an epidemiological study and an industrial hygiene study to assess the respiratory health and exposures of dental laboratory technicians in Utah.

## *Methods*

### Study Subjects

Dental laboratories and technicians were identified through a regional trade newsletter, a professional listing of certified dental technicians, and the yellow pages of area telephone books. We were able to identify 142 dental laboratories and 319 dental laboratory technicians in Utah and the adjoining Intermountain Area through these sources. All dental laboratories and dental laboratory technicians were sent a letter inviting them to participate in a study of their respiratory health, which would include a questionnaire, chest radiography, and pulmonary function test. Two medical surveys were conducted in April 1982 and 1983, concurrent with the dental laboratory technicians' state convention. Notices were placed in the trade newsletter announcing each survey, and participation was encouraged at each state convention by the president of the National Association of Dental Laboratories (NADL). Before the second survey, the remaining dental laboratory technicians were contacted by telephone, encouraging them to participate in the survey.

A non-exposed comparison group studied with the same

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tests included employees of a local ice cream manufacturer and the personnel of the Salt Lake City-County Division of Health. They were recruited with a letter inviting them to participate in a respiratory health survey. All of the ice cream factory employees participated, as did the majority of the Division of Health employees. The non-exposed comparison group was frequency-matched with the exposed for age and sex.

Those defined as ex-smokers had not smoked for at least one year; nonsmokers had smoked less than one cigarette per day for one year or had never smoked.

**Medical and Laboratory Tests**

Trained interviewers took a chronological occupational history, emphasizing the task and exposures involved in performing dental laboratory work, and administered the American Thoracic Society (ATS) respiratory symptoms questionnaire.[3] Urine beryllium levels were performed on 177 urine samples from dental laboratory technicians according to Hurlbut's method (Flameless Atomic Absorption Spectroscopy).[4]

Spirometry was performed according to ATS criteria using an Ohio-Med 822 (Pine Brook, New Jersey) dry rolling seal spirometer and a Spirotech 300 microprocessor (Spirotech, Inc., Atlanta, Georgia).[5] The forced expiratory maneuvers were repeated until at least two were within 5 per cent of each other and within 5 per cent of the best test (of at least three acceptable tests). The best forced vital capacity (FVC) and forced expiratory volume in the first second ($FEV_1$) were used, and the mid-expiratory flow rate ($FEB_{25-75}$) from the best curve (largest sum of FVC and $FEV_1$) was used for interpretation. Predicted values were obtained from Crapo, *et al,* who, using similar techniques, studied 251 nonsmoking, healthy men and women during 1979–80 from the Salt Lake City area.[6] The chest radiographs were classified in random order according to the 1980 International Classification of the Radiographs of the Pneumoconioses by two NIOSH*-certified B readers.[7]

Peripheral blood lymphocyte transformation to $BeSO_4$ was performed on 42 dental laboratory technicians in 1982.[8] The technicians were selected on the basis that they had ground nonprecious metals containing beryllium. A positive lymphocyte transformation was defined as a twofold or greater increase in $^3$H-thymidine uptake to $BeSO_4$ compared to control values.

Statistical methods included the two-tailed t-test, Fischer exact test, multiple regression, and the chi-square test to compare pulmonary function values and respiratory symptoms between dental laboratory technicians and the non-exposed group. The 95 per cent confidence intervals of the differences in the means of the per cent predicted pulmonary function values between the technicians and controls were calculated to assess differences between the two groups.

**Dental Laboratories**

The process flow of work in a dental technician's laboratory includes three principal activities: production of crowns and bridges with precious or nonprecious metals, production of partial acrylic dentures with nonprecious metals, and production of full acrylic dentures. An impression of the patient's teeth and mouth tissues is received from the dentist. A positive reproduction out of plaster is made and attached to an articulator to orient the upper and lower casts. An anatomical wax or plastic pattern is prepared and attached to a sprue-former, which holds the mold for the molten metal. The sprue-former and wax pattern are placed in a small casting ring, which is filled with a refractory investment material that surrounds the pattern and produces a mold. The casting ring is placed in a 1650° oven for two hours. All of the wax or plastic is eliminated, leaving an empty mold chamber. The restoration is cast as molten metal and forced into the mold chamber. Each casting is complete in two or three minutes. After the cast is cooled, the mold is broken, and residual investment material is removed with an abrasive sandblaster or a hand-finishing tool. The metal crown or bridge then undergoes additional finishing work with hand grinding and polishing. A tooth-color porcelain veneer may be applied to improve the aesthetics of the restoration.

Air sampling was limited to the Salt Lake City area, which had 42 laboratories. The laboratories were stratified according to four types and sizes and a minimum 20 per cent random sample drawn from each. This scheme selected six small crown and bridge operations, three large crown and bridge laboratories, two small denture and partial laboratories, and two large denture and partial operations, for a total of 13 operations.

Personal air sampling was performed for nickel, chromium, cobalt, beryllium, total free silica, and methyl methacrylate, utilizing portable battery-operated sampling pumps attached to the worker's belt and connected to collection media located in the worker's breathing zone by tygon tubing. The metals in the personal air samples were collected on a mixed cellulose ester 0.8 μm filter and analyzed by atomic absorption spectroscopy. Full-shift (i.e., greater than seven hours) sampling was conducted, and eight-hour, time-weighted-average exposures were calculated assuming no exposure during any unsampled period. Total free silica was similarly collected to determine if airborne free silica was present in porcelain grinding dust or from the bench-top sandblasters. Total free silica particles were collected on a desiccated and tared polyvinyl chloride 5.0 μm filter and analyzed by x-ray diffraction. Methyl methacrylate vapors were collected on a sorbent tube containing XAD-2 resin and analyzed by gas chromatography.

## *Results*

Approximately 66 per cent (94 of 142) of the laboratories participated, and 178 dental laboratory technicians (146 males and 32 females) out of the 319 contacted (55.8 per cent) agreed to participate in the respiratory study. Our non-exposed group included 69 participants (52 males and 17 females) who were not exposed to respiratory toxicants. The technicians had a mean age of 35.9 years and a mean of 12.8 years employment. The smoking habits of both groups were similar.**

**Medical Findings**

Compared to this comparison group, the male nonsmoking dental laboratory technicians had reduced mean values for per cent predicted FVC and for per cent predicted $FEV_1$ (Table 1). After adjusting for age, there was a significant ($p = 0.02$) association between exposure-years and reduced FVC and $FEV_1$ for the nonsmoking male technicians. The female

*National Institute for Occupational Safety and Health.

**Technicians—63 per cent nonsmokers, 21 per cent ex-smokers, 16 per cent smokers; non-exposed—71 per cent nonsmokers, 19 per cent ex-smokers, 10 per cent smokers.

TABLE 1—Mean and 95% Confidence Intervals of the Differences of the Per Cent Predicted Pulmonary Function Values for Male Dental Laboratory Technicians Compared to Male Controls by Smoking Habit

| | N | FVC | $FEV_1$ | $FEV_1$/FVC | $FEF_{25-75}$ |
|---|---|---|---|---|---|
| Smokers | | | | | |
| Technicians | 21 | 95.2 | 89.6 | 94.4 | 81.3 |
| Non-exposed | 5 | 99.6 | 93.9 | 94.7 | 82.3 |
| Difference | — | −4.4 (−17.3, 8.5)* | −4.3 (−18.9, 10.3) | −0.3 (−10.4, 9.8) | −1.0 (−33.3, 31.3) |
| Ex-smokers | | | | | |
| Technicians | 32 | 99.0 | 96.1 | 97.5 | 96.0 |
| Non-exposed | 12 | 95.8 | 90.6 | 94.7 | 80.1 |
| Difference | — | 3.2 (−4.7, 11.1) | 5.5 (−2.7, 13.7) | 2.8 (−3.1, 8.7) | 15.9 (−2.9, 34.7) |
| Nonsmokers | | | | | |
| Technicians | 93 | 95.3 | 93.8 | 97.5 | 94.2 |
| Non-exposed | 35 | 103.0 | 98.6 | 95.9 | 89.5 |
| Difference | — | −7.7 (−12.2, −3.2) | −4.8 (−9.9, 0.3) | 1.6 (−2.8, 6.0) | 4.7 (−8.5, 17.9) |

*95% Confidence limit.

nonsmoker and ex-smoker dental laboratory technicians had similar reductions in FVC and $FEV_1$, but the number of participants was too small for statistical analyses. Male ex-smoker dental laboratory technicians, however, had greater mean values for per cent predicted compared to the non-exposed.

Respiratory symptoms were not more common among the technicians than among the controls. Chronic cough and phlegm were similar (12.9 per cent of the technicians versus 10.1 per cent of the controls), as was shortness of breath when hurrying up a slight hill (21.3 per cent of the technicians versus 18.8 per cent of the controls). However, one or more instances of irritation*** considered to be work-related were more common among the technicians.

Lymphocyte transformation to $BeSO_4$ performed on blood from 42 technicians yielded six borderline positive tests (twofold increase in $^3$H-thymidine uptake by peripheral blood lymphocytes when exposed to $BeSO_4$ in vitro); three of these were negative (less than twofold increase) upon retesting, and three were not retested. Only one of the 178 technicians had a urine beryllium slightly above 2 μg/l.

Table 2 lists the characteristics of the eight (seven male, one female) dental laboratory technicians among the 178 (4.5 per cent) who had a simple pneumoconiosis. All had a profusion of small rounded or irregular opacities (profusion 1/0 or 1/1), predominantly in the upper zones. They had worked a mean of 28 years as dental laboratory technicians, and all had spent considerable time grinding and polishing precious and nonprecious metals. Seven had worked extensively with nonprecious metal alloys, and one had worked with precious metals only. The prevalence of pneumoconiosis in technicians with 20 or more years' exposure (16.7 per cent) was significantly higher than those with less than 20 years' exposure (1.4 per cent, $p < 0.001$). There was a significant trend in prevalence of pneumoconiosis with age ($p < 0.01$). Their pulmonary function was generally within the normal range; two with a history of cigarette smoking had symptoms of chronic cough and phlegm.

***Eyes (27 versus 5), nose (26 versus 0), throat (9 versus 0), or skin (17 versus 1).

TABLE 2—Characteristics of Dental Laboratory Technicians with Simple Pneumoconiosis

| | | | | | Pulmonary Function Values (Percent Predicted) | | | |
|---|---|---|---|---|---|---|---|---|
| No. | Age | Years Employment | Approximate Hours Grinding/ Day | Smoking History * | FVC | $FEV_1$ | $FEV_1$/ FVC | $FEF_{25-75}$ |
| 1 | 47 | 32 | 3 | NS | 5.07 (99) | 4.01 (102) | 0.79 (104) | 3.87 (90) |
| 2 | 61 | 35 | 2 | S | 4.29 (88) | 3.29 (85) | 0.77 (96) | 2.65 (73) |
| 3 | 48 | 5 | >4 | NS | 3.63 (86) | 2.60 (90) | 0.72 (104) | 1.82 (62) |
| 4 | 48 | 32 | 0.5 | S | 3.34 (68) | 2.96 (75) | 0.89 (110) | 4.34 (111) |
| 5 | 38 | 13 | 1 | NS | 4.89 (95) | 3.92 (95) | 0.80 (100) | 3.67 (87) |
| 6 | 69 | 46 | 3 | NS | 3.66 (97) | 2.32 (95) | 0.63 (98) | 1.20 (86) |
| 7 | 45 | 22 | 1.5 | XS | 4.59 (83) | 3.95 (95) | 0.86 (114) | 5.47 (133) |
| 8 | 66 | 39 | 2 | NS | 4.57 (82) | 3.79 (82) | 0.83 (100) | 3.98 (119) |

*NS = Nonsmoker
X = Smoker
XS = Ex-smoker

**TABLE 3—Comparison of Measured Air Concentrations and Standards for Eight-Hour Time-Weighted-Average Exposure**

| | Breathing Zone, 8-hour TWA* Air Concentration (μg/m³) | | | | |
|---|---|---|---|---|---|
| Laboratory | Nickel | Chromium (metal) | Cobalt | Beryllium | Methyl Methacrylate |
| 1 | 30 | 5.8 | — | — | — |
| 1 | 19.6 | 4.1 | — | — | — |
| 2 | 6.6 | <2.2 | — | — | — |
| 3 | — | <2.0 | <2.0 | — | — |
| 4 | 4.1 | <1.8 | — | <0.29 | — |
| 5 | — | <2.5 | <2.5 | — | 2200 |
| 6 | <2.0 | <2.0 | — | <0.34 | — |
| 7 | <1.8 | <1.8 | — | — | 3300 |
| 7 | — | 2.2 | <2.3 | — | — |
| 8*** | — | — | — | — | 4070 |
| 9 | <4.3 | <4.3 | — | <0.72 | — |
| 10*** | — | — | — | — | — |
| 11 | 60 | 9.0 | — | 1.5 | — |
| 12 | 1.4 | <1.4 | — | <0.23 | — |
| 13 | 100 | 20 | — | 2.7 | 5600 |
| 13 | 160 | 20 | — | 4.4 | — |
| 13 | — | 68 | 160 | — | — |
| OSHA PEL (μg/m³) | 1000 | 1000 | 100 | 2 | 410,000 |
| ACGIH TLV (μg/m³) | 1000 | 500 | 50* | 2 | 410,000 |

*Eight-hour TWA based on the assumption that exposure metal was zero during any unsampled period.
**Proposed TLV for cobalt metal.
—Metal sampling not done (not present in alloy).
***Laboratories 8 and 10 used only precious metals.

**Air Sampling**

The results of the air sampling compared with Threshold Limit Values (TLVs), which are standards recommended by the American Conference of Governmental Industrial Hygienists (ACGIH), and required Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) are presented in Table 3. Six of the 13 laboratories were using nonprecious metal alloys containing beryllium and were sampled for beryllium. Two full-shift personal air samples taken on two technicians from one of the six laboratories (No. 13) exceeded the 2.0 μg/m³ eight-hour time-weighted-average TLV (2.7 μg/m³ and 4.4 μg/m³ for beryllium). Four laboratories used a nonprecious metal alloy containing cobalt and, in one of them, full-shift personal air samples exceeded the 50 μg/m³ eight-hour time-weighted-average TLV (160 μg/m³) for cobalt. Air samples taken for nickel and chromium metal were all below recommended TLVs. The overexposures to beryllium and cobalt occurred primarily during grinding processes with inadequate local ventilation; some dental laboratory technicians spent four to six hours daily performing this task. Poor work practices, specifically improper use of available local ventilation, may have contributed to high exposures. Area samples taken during the brief casting procedure detected very small amounts of beryllium or none at all. NIOSH-approved respirators were not being worn by any of the technicians. Re-creating the grinding exposure in the dental laboratory of our index case of chemical pneumonitis consistent with acute berylliosis, we measured 2.6 μg/m³ of beryllium during a 30-minute grinding period. Of nine air samples taken for total free silica in the 13 study laboratories, only two had detectable quantities that were less than one-fifth the TLV; only two of nine porcelain samples had detectable quartz ranging from 2.4–5.6 per cent. Methyl methacrylate vapors were very low (see Table 3). Air velocity measurements during grinding measurements were quite low (40–215 feet per minute, with 2,000 feet per minute recommended).

*Discussion*

Dental laboratory technicians are at risk for beryllium-related lung disorders, and for simple pneumoconiosis from grinding nonprecious metal alloys. Our index case of chemical pneumonitis consistent with acute berylliosis had spent several hours per week in an inadequately ventilated area grinding dental crowns and bridges containing a nonprecious metal alloy with 1.8 per cent beryllium. His exposure history, clinical symptoms and signs, roentgenographic features, and lung biopsy findings were similar to those described by Van Ordstrand and Denardi in 315 cases of acute beryllium poisoning (including 43 cases of acute chemical pneumonitis) observed from 1940 to 1947.[9,10] The diagnosis of acute berylliosis is made based on a convincing beryllium exposure history and/or evidence of beryllium in tissue or urine and documented lower respiratory tract disease. Recreating the grinding exposure in the index case (i.e., 2.6 μg/m³) resulted in levels of beryllium which, if continued for a full eight hours, would exceed recommended standards (i.e., 2.0 μg/m³). However, the measured levels were below the 5.0 μg/m³ level required by OSHA standard for 30-minute periods. Chronic beryllium disease has been previously reported in a beryllium worker with only four months' exposure to a 1.8 per cent beryllium-copper alloy.[11]

The eight technicians with a simple pneumoconiosis had spent many years grinding nonprecious metals but were generally symptom-free and without respiratory impairment. As a group, the male technicians had reduced pulmonary function compared to a nonexposed group, and more skin and upper airway irritation symptoms. After controlling for age, the reduction in FVC and $FEV_1$ for nonsmoking male technicians was related to duration of employment. However, the values, when reported as per cent predicted, were within the normal range. As previously discussed, in our air sampling survey of 13 laboratories, we identified time-weighted-average personal exposures to beryllium and cobalt in excess of recommended standards.

Participation by dental laboratories was relatively good (94 of 142, 66 per cent), but only 55.8 per cent of identified dental laboratory technicians participated. When we contacted the directors of 36 of 48 nonparticipating laboratories, we obtained the following reasons why technicians did not participate: five stated that they did not work with metals, seven had not known about the survey, one refused, and 23 were not interested.

Not all of the dental laboratory technicians working in participating laboratories were studied. Many of these were employees in dental laboratories where we contacted only the owner-director. Reasons for their nonparticipation could include lack of encouragement by the laboratory owner-director, heavy work schedules, non-use of metal alloys, or fear of identifying a health problem which might have jeopardized their jobs.

Both German[1,2] and French[12–15] scientists have noted pneumoconiosis among dental laboratory technicians. Hugonnaud and Lob studied 25 technicians with a mean age of 38 years.[13] There was one technician who had an abnormal chest radiograph with reticulonodular opacities and five with suspicious films. A lung biopsy of the technician with pneumoconiosis showed many birefringent crystals corresponding to small crystals of silica. Cobalt, chromium, aluminum, iron, and molybdenum were identified on elemental analysis of histological lung sections.[12] Carlos *et al,* reported a case who had decreased pulmonary function and a bilateral micro-nodular apical infiltrate.[14] On biopsy, birefringent particles were found, and elemental analysis of lung tissue found chromium and cobalt that were the same as in the dental alloy, and silica and aluminum. They listed five additional cases with a reticulonodular infiltrate who had worked as technicians from 8 to 22 years. Peltier, *et al,* reported that increased respirable dust was found in dental laboratories and mentioned that seven cases of pulmonary fibrosis had occurred in the same workshop.[15]

Cobalt has been implicated in causing the progressive, diffuse, interstitial pulmonary fibrosis seen in tungsten carbide workers, although tungsten has been found in lung tissue and bronchoalveolar lavage cells.[16,17] Cobalt is used as a binder in tungsten carbide manufacture, where levels above the TLV have been detected.[18] Inhalation of finely powdered cobalt in animal studies has produced pulmonary edema and obliterative bronchitis.[16] The tungsten carbide workers complained of dyspnea, dry cough, or asthmatic bronchitis.

The simple pneumoconiosis that we found in eight dental laboratory technicians may be related to past silica exposure or exposure to nonprecious metal alloy dust generated during the grinding process over many years. Silica has been detected in lung biopsy specimens by others,[2,15] but we did not detect any silica exposure hazard during our industrial hygiene survey. Although the simple pneumoconiosis may not decrease pulmonary function, male dental laboratory technicians as a group had decreased pulmonary function compared to a nonexposed group, suggesting that physiologic changes may occur prior to or without radiographic changes.

Acute and possibly chronic beryllium disease may occur in dental laboratory technicians exposed to nonprecious metal alloys while grinding. Proper ventilation and good work practices can substantially reduce this risk. Hinmann, *et al,* have documented short-term exposure levels to beryllium of 22 $\mu g/m^3$ for 10 minutes at the breathing zone of grinders when exhaust ventilation was turned off.[19] Their sampling techniques did not allow estimations of eight-hour time-weighted-average (TWA) exposure. As an eight-hour TWA, Moffa, *et al,*[20] reported area concentrations of 3.2 and 5.6 $\mu g/m^3$ of beryllium in a dental laboratory having no ventilation.

Informing the dental laboratory technician about the potential hazards of exposure to dust and fumes of beryllium and other nonprecious metal alloys, along with proper work practices and industrial hygiene, is essential. The dental alloy suppliers and primary beryllium and cobalt manufacturers have responsible roles in labeling and alerting this working population to potential occupational hazards.

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