Effects of Occupational Environmental Controls on the Level of Co, Ni and Cr among Dental Technicians

Ninuk Hariyani, Titiek Berniyanti, and Dini Setyowati

***Abstract*—Dental laboratory technicians may be exposed to metal alloys that are used in the production of crowns, bridges and removable partial dentures. The aim of this study was to assess whether dental technicians are occupationally exposed to Cobalt, Nickel and Chromium by analyzing the concentration of Cobalt, Nickel and Chromium in the blood level and to investigate the effects of occupational environmental controls associated with dental prostheses production in dental laboratories in East Java Indonesia. Result found shows that the concentration of Cobalt, Nickel and Chromium in the blood level of dental technicians are higher than the certified reference material level recommended. The concentration of Cobalt, Nickel and Chromium in the dental technicians' blood level are 27 μg/L, 37 μg/L and 117 μg/L respectively. Although 50% of dental laboratories surveyed had ventilator and air dust respirator, almost all of the technicians did not do personal occupational environmental controls correctly.**

***Index Terms*—Cobalt, Chromium, exposure, Nickel, protection control.**

I. Introduction

Base metal alloys have been frequently used in dentistry for various dental appliances to replace the use of noble metals that are costly [1]. In prosthetic dentistry, alloys based on Cobalt, Nickel and Chromium are extensively used in a variety of applications, such as removable partial dentures, porcelain-fused-to metal restorations, resin bonded bridges, cast removable partial denture framework, an upper palatal section of a full denture, crown, and surgical implants [1]-[4]. Those base metals are selected because they pose acceptable biocompatibility, high strength, adequate tarnish and corrosion resistance [1], [3], [4].

Despite high value of the use of Cobalt, Nickel and Chromium base metal alloys in prosthetic dentistry, the exposure to those alloys during the process of making dental prosthesis in dental laboratory may have various adverse health impacts. Many experimental and epidemiological studies have proven potential health hazards of Cobalt, Nickel and Chromium exposures [5], [6]. The exposure to Cobalt, Nickel and Chromium may occur for short period of time or prolonged exposure by inhalation, ingestion, or skin contact, both in low concentration and in moderately high concentration [7], [8]. There is a range of signs and symptoms as a result of Cobalt, Nickel and Chromium exposure. The signs or symptoms may represent acute or chronic disease states, such as nausea, vomiting, abdominal discomfort, diarrhea, visual disturbance, headache, giddiness, chest pain, breathing problems and cough [7], [8]. A variety of pathological effects due to human exposure to Cobalt, Nickel and Chromium-polluted environment has been also well documented, such as contact dermatitis [8], pneumoconiosis [9], [10], postural tremor and parkinson's disease [11]. Cobalt, Nickel and Chromium are also possibly carcinogenic to humans [5], such as lung cancer [10], [12], [13], nasal sinus cancer and cancer of the respiratory tract [12].

Dental laboratory technicians are at risk of experiencing adverse health effects due to the exposure of Cobalt, Nickel and Chromium while constructing dental prostheses. Cobalt, Nickel and Chromium base metal alloys may affect the health of dental laboratory technician. Melting and grinding of Cobalt, Nickel and Chromium base metal alloys may pose a great risk to the health of dental laboratory technician [7]. An epidemiological and clinical study on dental technicians producing protheses using Cobalt, Nickel and Chromium alloys in a state school for dental technicians in Rome founds that there was a high prevalence of extrapyramidal signs and symptoms among dental technicians which possibly caused by metal exposure during laboratory work. Some of them were diagnosed as having Parkinson disease and postural tremor [11]. The exposure to Cobalt, Nickel and Chromium has been also attributed to elevated levels of those metals in blood and urin [8], [14]-[16].

From the standpoint of dental laboratory technician safety and health hazard, it is highly important to adopt occupational health and safety standard procedures. The detrimental effects of the exposure to Cobalt, Nickel and Chromium base metal alloys during the process of constructing dental prostheses has been attributed to improper protection and inadequate working condition in dental laboratories [17]. Dental laboratory technician should escape inhalation of dust derived from Cobalt, Nickel and Chromium base metal alloys. Concern with the dust generated from grinding procedures of Cobalt, Nickel and Chromium base metal alloys, dental technicians should wear personal protective equipment, including working uniform, protective masks, protective gloves and protective glasses, and grinding those base metal alloys in well-ventilated working areas or using general exhaust ventilation (GEV) systems, and local exhaust ventilation (LEV) systems [1]. When ventilation, exhaust and filtration facilities are good and adequate, Cobalt, Nickel and Chromium levels in the air can be reduced to the levels considered safe [7]. Dental laboratory technicians should also regularly undergo blood examination to measure the level of Cobalt, Nickel and

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Chromium, so this will acquaint them with potential risks of their work and early symptoms of occupational diseases [17]. However, although adverse health effects of Cobalt, Nickel and Chromium exposures are widely known and documented, the level of Cobalt, Nickel and Chromium in blood among dental laboratory technicians in Indonesia has not been documented yet and, in this regard, little is known about the use of personal protective equipment and the availability of standardized and optimal working condition in dental laboratories in Indonesia.

II. Materials and Methods

A. Subjects

A cross sectional study was taken as it collected data from all participants at the same time. The study protocol was approved by the Ethics Committee of Faculty of Dentistry Airlangga University. Written informed consent was obtained from all participants. A convenient sampling was adopted for selecting of all participants. The investigated group consisted of 30 dental laboratory workers involved in the production of metal prostheses in dental laboratories in East Java province Indonesia. The laboratories located in the capital city of East Java Province. In the present study, not all dental laboratories had simple ventilation systems consisted of a fan and a window. A questionnaire on individual data, employment history, work place condition, tobacco consumption and use of personal protection during work was completed by each worker. 30 volunteer controls were selected from clerical workers at the Faculty of Dentistry, Airlangga University. The control group had not been exposed to metallic alloys or other chemicals during their work or leisure time. A questionnaire consisting of individual data and tobacco consumption was taken from the controls.

B. Determination of Cobalt, Nickel and Chromium in Blood

Blood samples were collected from all participants. The blood samples were taken by a professional nurse and were collected in "trace metal free" evacuated tubes. EDTA was added in the blood sample to prevent the coagulation. Blood was sent to laboratory to test the Cobalt, Nickel and Chromium dose. The concentration of cobalt, nickel and chromium were analyzed by Atomic Absorption Spectrophotometer (AAS) Zeenit 700, which allow for the measurement of a wide range of concentrations of metals in biological samples.

C. Statistical Analysis

The mean and standard deviation were calculated for each level of Cobalt, Nickel and Chromium. The significance relation of the means and each characteristic of occupational environmental controls was calculated using Student's *t*- and ANOVA test. All tests were performed using SPSS 16. Significance levels of 5% or less were referred to as significant. All *P*-values were two-tailed.

III. Results

Subjects were healthy and not taking medication on the day of blood samples collection. General characteristics of the study group and controls are presented in Table I.

TABLE I: Characteristics of Subjects

	Dental technicians (*n*=30)	Control (*n*=30)
Age (years) (mean ± S.D.)	34 ± 8.75	38 ± 9.32
Weight	59.47 ± 10.59	60.50 ± 10.16
Gender : Male (%)	93.3	73.3
Female (%)	6.7	26.7
Smoking habit - yes (%)	53.3	46.7
Work period (years) (mean ± S.D.)	9 ± 6.96	-a
Protheses made per days (mean ± S.D.)	10 ± 6.35	-
Condition of working room		
Have Ventilator And Air Dust Respirator (%)	53.3	-
Without Ventilator and Air Dust Respirator or Have One of Them (%)	46.7	-

a: We did not evaluate work years in control (clerical workers)
*: $P<0.05$

The mean age of the study group is 34 ± 8.75 years (varied from 18-47), while controls' is 38 ± 9.32 (varied from 20-61). The mean age of the exposed group was not significantly different from that of the controls ($P>0.05$). The average weight of exposed group and control was 60 and 61 respectively. In this study, there is a slight difference in term of gender and smoking habit among dental technicians and controls.

Almost all of the dental technicians in this study were mainly involved in casting and finishing operations (polishing, cleaning and buffing alloys) during the production of dental prostheses. Controls as clerical workers in Faculty of Dentistry Airlangga University have never been exposed to metallic alloys during their works or hobbies. As can be seen, on average, dental technicians in this study have worked for nine years and during their work length, they usually make ten metal protheses per days. In the study group, 53.3% of dental technicians working in a room completed with both ventilator and air dust respirator, while the rest of them work in a room completed with ventilator or air dust respirator only or even without both of them.

TABLE II: Mean (±SD) values of Cobalt, Nickel and Chromium on Blood among Dental Technicians and Controls

	Dental technicians (*n*=30)	Control (*n*=30)
Co (µg/L)		
- dose in blood (mean ± S.D.)*[a]	27.16 ± 20.32	0.41 ± 0.19
- Range	1.06 – 73.20	0.08 – 0.81
Ni (µg/L)		
- dose in blood (mean ± S.D.)*[b]	36.76 ± 39.64	3.19 ± 1.27
- Range	0.54 – 136.80	1.04 – 5.07
Cr (µg/L)		
- dose in blood (mean ± S.D.)*[b]	116.84 ± 150.37	0.06 ± 0.11
- Range	0.08 – 467.20	0.00 – 0.42

*: $P<0.05$
a: parametric test
b: non parametric test

In Table II, the average dose of Cobalt, Nickel and Chromium from blood are given both for dental technicians and controls. The mean concentration of Cobalt, Nickel and Chromium in blood samples of dental technicians were 27 µg/L, 37 µg/L and 117 µg/L respectively. The average doses

of Cobalt, Nickel and Chromium among technicians were about 66-, 11- and 1900- times higher than those of controls (Table II). These metals concentrations were statistically differ from those of controls. The mean of all metal levels (Cobalt, Nickel and Chromium) in study group (27 µg/L, 37 µg/L and 117 µg/L respectively) was higher than the certified reference material level recommended (0.04-0,64 µg/L, 0,09-4,18 µg/L and 0.1-0.2 µg/L respectively [18], [19], while that of control group was still in the normal level.

Special test performed to investigate whether the difference in the blood Cobalt, Nickel and Chromium levels was caused by occupational exposure or also influenced by smoking habits and age. The result was revealed in Table III. This Analysis of variance (Table III) indicated a significant effect of occupational exposure on blood levels of Cobalt, Nickel and Chromium in dental technicians. No effect of age and smoking was observed.

In order to analyze the effects of occupational environmental controls associated with dental prostheses production in dental laboratories in East Java Indonesia, we investigate personal protection applied by dental technicians during working hour using a self-questionnaire. Results showed in Table IV indicated that dental technicians used 3 standard protection (gloves, protection clothing and mask) during working hour showed lower metal level compared to dental technicians who used only one or two kinds of protection (13 compared to 28, 33 compared to 37, 51 compared to 119 for Cobalt, Nickel and Chromium levels respectively). Dental technicians applying self-protection such as gloves, protection clothing and mask separately, tend to have lower blood metal levels (Cobalt, Nickel and Chromium levels, except the use of protective clothing and mask on Cobalt level). Even though this results were not statistically significant, dental technicians using gloves, protective clothing and mask showed a lower Nickel and Chromium level compared to those who do not.

TABLE III: ANALYSIS OF VARIANCE FOR BLOOD LEVEL OF COBALT, NICKEL AND CHROMIUM BY TAKING INTO ACCOUNT AGE, EXPOSSURE (BEING DENTAL TECHNICIANS OR NOT) AND SMOKING

	Mean square	F-ratio	P-value
Blood Co (µg/L)			
Covariate : age	2083.02	12.4	0.001
Factors :			
Exposure	12509.01	74.6	0.001
Smoking	87.99	0.5	0.472
Blood Ni (µg/L)			
Covariate : age	1.18	0.001	0.970
Factors :			
Exposure	15855.23	19.2	0.001
Smoking	114.08	0.14	0.711
Blood Cr (µg/L)			
Covariate : age	34682.24	3.31	0.074
Factors :			
Exposure	153983.73	14.72	0.001
Smoking	12686.67	1.21	0.276

TABLE IV: BLOOD METAL LEVEL (COBALT, NICKEL AND CHROMIUM) AND PERSONAL OCCUPATIONAL CONTROLS IN THE EXPOSURE GROUPS

	(%)	Co Mean ±SD	Ni Mean ±SD	Cr Mean ±SD
Personal occupational controls				
Gloves				
Yes (*n*=2)	6,7	10,49±3,62	17,10±23,42	62,30±15,80
No (*n*=28)	93,3	28,35±20,52	38,17±40,45	120,74±155,05
Protective clothing				
Yes (*n*=17)	56,7	35,48±19,84	34,89±37,20	70,11±120,92
No (*n*=13)	43,3	16,27±15,68	39,21±44,05	177,96±167,35
Mask				
Yes (*n*=29)	96,7	27,61±20,52	35,30±39,50	108,15±145,16
No (*n*=1)	3,3	13,99	79,29	368,80
Combination of protection				
3 Standard protection (*n*=1)	3,3	13.05	33.66	51.13
1-2 Standard protection (*n*=29)	96,7	27.64±20.50	36.87±40.33	119.11±152.51

IV. DISCUSSION

We revealed, for the first time, that dental technicians in this study have a significant higher blood metal level compared to controls'. The average doses of Cobalt, Nickel and Chromium among technicians were about 66-, 11- and 1900- times higher than those of controls. This phenomenon showed that a dental technician is one of occupations that is risky for metal hazard such as Cobalt, Nickel and Chromium exposure. This result supports the finding of other research such as research in the Northern Jordan [14], Ankara [15] and Japan [16] showing the occupational health hazard of being dental technicians. We know that, metal interfere with many cellular reactions. The carcinogenic potential of Nickel, Chromium and cobalt compound is well established for Humans and experimental animals. The exposure to genotoxic metals could enhance the endogenous amount of reactive oxygen species. Oxidative DNA Damage is mediated by reactive oxygen species and is supposed to play an important role in various diseases including cancer [20].

Nevertheless, sample of dental technicians in this study was gained through a convenient sampling as there is no complete data of the total number of Indonesian dental technicians in Surabaya. This sampling method could lead to a study bias and prevent generalization from the study. However, the result of this study could give an overview of blood metal level related to occupational risk as dental technicians in Indonesia.

In relation to occupational environmental control studied in this research, majority of dental technicians only used gloves and mask during working hour. However, they only use surgical mask, which is not recommended for the purpose of providing a physical barrier for protection from the dust of Cobalt, Nickel and Chromium. Surgical mask is designed to prevent inhalation or contamination of large droplets or splashes of blood. It cannot protect from inhalation of small particles or droplets and body fluids. The evidence from human and experimental studies indicated that exposure via respiratory route to soluble compound of nickel result in respiratory cancer. Nickel has been shown to inhibit DNA oxidative lesions. A reduce repair of capacity DNA damage might enhanced the level of the studied lesions in vivo and hence might increase the risk of developing cancer. As the repair of oxidative DNA damage is essential for the prevention of cancers, the inhibition may account for the carcinogenic action of nickel. In this case, the use of respirator is recommended [21]. Respirator can reduce exposure of small particles, including dust from Cobalt, Nickel and Chromium, to the respiratory system. It can fully cover mouth and nose, fit and seal tightly and properly against face. It can also restrain small particles from passing through gaps between the face and the respirator [21]. Therefore, wearing respirator can prevent damage of respiratory organs and nervous system. Furthermore, the majority of dental laboratory technician in this study did not wear protective gloves. For some dental laboratory technicians, wearing protective gloves can hamper their works and can reduce precision and efficacy in work [17]. Dental laboratory technicians who wear gloves commonly use latex or vinyl gloves, which are not recommended to provide adequate protection from penetrating small particles. For protecting small particles or dust generated from grinding process, high-quality, well-fitting and comfortable cotton, nitrile or rubber gloves are advised [17].

In addition, in order to prevent high concentration value of Cobalt, Nickel and Chromium in the air and preserve health of dental laboratory technicians, dental laboratories should have adequate ventilation system [17]. Ventilation and dust respirator system are important to prevent the exposure of dust containing metal particles. However, almost 50% of dental laboratories in this study did not have adequate ventilation and dust respirator system which was partly caused by the shortage of money.

The fact that almost all dental technicians did not use three standard protections as personal occupational controls and that they used the wrong kind of protection control equipment alerts us that dental technicians probably were not well informed about the standard for personal occupational environmental control and the possible harmful effect if the personal protection are not undertaken.

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