BRIEF COMMUNICATIONS

Occupational Exposure to Acidic Chemicals and Occupational Dental Erosion

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Abstract

Objective: *This study investigated the association between occupational acidic chemicals (ACs) exposure and occupational dental erosion.* ***Methods:*** *A cross-sectional study was conducted in which three dentists surveyed 951 subjects from 42 factories using five types of ACs below Korean Threshold Limit Values (K-TLVs). Subjects agreed to participate by a written consent; 519 were acid exposed workers and 431 were non-exposed. The modified ten Bruggen Cate's criteria was used to classify erosion. Length and type of exposure to ACs were assessed using questionnaires. Logistic regression analysis including interaction terms was applied.* ***Results:*** *ACs exposure was associated with erosion severity. Multiple exposures to ACs were found to be strongly associated with severe erosion. Interaction between wearing masks and AC exposure was significant.* ***Conclusions:*** *This study showed a clear association between AC exposure below K-TLVs and erosion. Hence, the authors propose to lower K-TLVs of five types of ACs.*

Key Words: Acidic chemicals; TLV; dental erosion; epidemiology; occupation

Introduction

Dental erosion, defined as the loss of tooth surface by acids without bacterial involvement (1), has been a focus of research, clinical practice and prevention. Although this tooth surface condition is not life threatening, it is socially problematic (2).

Occupational dental erosion is caused by exposure to various types of acidic contaminants in the workplace such as chemicals, petrochemicals, metals and semiconductors (1-4). Age, wearing masks and life style influence dental erosion (5,6). Severe dental erosion involving dentin among workers exposed to five types of acidic chemicals (ACs) such as sulfuric acid, hydrochloric acid, nitric acid, fluoric acid and chloride gas has been an occupational disease in Korea since 1994 (2). The prevalence of occupational dental erosion was 8% in 1993 (2) and 11.3% in 2003 (6) among the workers exposed to acids below Korean Threshold Limit Values-Time Weighted Amount (K-TLVs).

The purpose of this study was to evaluate the association and impact of exposure to ACs and occupational dental erosion.

Methods

Subjects. A cross-sectional study for active dental erosion by ACs exposure was designed. The sample size needed at 0.05 for the two-sided alpha error and 0.20 for the beta error was approximately 430 per group, considering the difference in proportions of erosion (5% vs 11.4%) from previous findings (7).

Subjects were recruited from 42 factories selected through a three-stage stratified cluster sampling from 2,246 factories using five types of ACs. The first sampling unit was the type of industry; next, the number of full-time employees in the factory; and finally, the region.

Before joining this study, subjects agreed to participate by providing written consent. A total of 951 subjects (519 acid-exposed workers and 431 non-exposed workers) joined this study. The exposed and unexposed workers were selected from the same factories. There were 862 (90.6 %) males and 89 (9.4%) females, and their ages ranged from 18 to 65 years with a mean age of 36.1 (SD=8.9) years for all subjects. Length of employment ranged from 0 to 35 years with a mean employment duration of 8.6(SD=6.5) years for all subjects.

Data collection. Three dentists were trained for standardized examinations and the recording of clinical findings. The calibration training procedure consisted of three steps; dictation, slide calibration, and field calibration.

The clinical dental examination was executed from April 2003 to March 2004. Dentists examined the presence of teeth and dental erosion on facial, occlusal and lingual teeth surfaces. The modified ten Bruggen Cate's criteria (5) was used for dental erosion diagnosis on each tooth surface: G0= normal; G1=enamel surface erosion (etched surface); G2=enamel erosion (enamel loss not involving dentine); G3=dentine erosion (dentinal cupping not showing secondary dentine); G4=secondary dentine erosion (showing secondary dentine); G5 pulp erosion (showing pulp cham-

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Table 1
Socio-demo-occupational characteristic of subjects according to the history of exposure to acids and length of exposure

	Exposure to acids (N=951)			Length of exposure (N=519)			
Characteristic	Never (N=432) n(%)	Exposed N=519) n(%)	p-value*	1-5 years (N=206) n(%)	6-10 years N=148) n(%)	>11 years N=165) n(%)	p-value*
Age			.09				<.001†
18-29	121(28.0)	125(24.1)		105(51.0)	19(12.8)	1(0.6)	
30-39	160(37.0	230(44.3)		67(32.5)	100(67.6)	63(38.2)	
40-49	117(27.1)	118(22.7)		25(12.1)	20(13.5)	73(44.2)	
≥ 50	34(7.9)	46(8.9))		9(4.4)	9(6.1)	28(17.0)	
Gender			.03				<.001‡
Female	50(11.6)	39(7.5)		33(16.0)	4(2.7)	2(1.2)	
Male	382(88.4)	480(92.5)		173(84.0)	144(97.3)	163(98.8)	
Income($/year)			.08				<.001†
<15,000	73(16.9)	60(11.6)		46(22.3)	10(6.8)	4(2.4)	
15,000-30,000	225(52.1)	298(57.4)		132(64.1)	90(60.8)	76(46.1)	
30,000-50,000	118(27.3)	136(26.2)		23(11.2)	45(30.4)	68(41.2)	
≥50,000	16(3.7)	25(4.8)		5(2.4)	3(2.0)	17(10.3)	
Work Type			<.001				.003
White color	190(44.0)	31(6.0)		15(7.3)	7(4.7)	9(5.5)	
Blue color	226(52.3)	430(82.9)		155(75.2)	133(89.9)	142(86.1)	
Researcher	16(3.7)	58(11.2)		36(17.5)	8(5.4)	14(8.5)	
Factory Size			<.001				.5†
Small	98(22.7)	124(23.9)		56(27.2)	36(24.3)	32(19.4)	
Medium	125(28.9)	85(16.4)		30(14.6)	24(16.2)	31(18.8)	
Large	209(48.4)	310(59.7)		120(58.3)	88(5.4)	102(61.8)	
Position			<.001				<.001
Staff	342(79.2)	456(87.9)		192(93.2)	133(89.9)	131(79.4)	
Manager	90(20.8)	63(12.1)		14(6.8)	15(10.1)	34(20.6)	
Wear Mask			<.001				.5
Non Wearer	333(77.1)	293(56.5)		121(58.7)	78(52.7)	94(57.0)	
Wearer	99(22.9)	226(43.5)		85(41.3)	70(47.3)	71(43.0)	

*P-value determined from the Pearson chi-square
† P-value determined from the linear by linear chi-square
‡P-value determined from the Fisher's exact chi-square

ber). When a tooth surface exhibited more than one type of condition, the highest level of each condition was recorded.

The test-retest reliability of the examination, with half-hour to one-hour intervals, was assessed among 795 teeth from 30 workers prior to the main survey: Kappa index using the prevalence of dental erosion ranged from .89 to .93 for intra-examiner comparison and from .78 to .86 for inter-examiner comparison.

Self-registered questionnaires, tested in a preliminary survey, included questions regarding exposure to acids during service including length of exposure and type of acids, and other information about socio-demo-behavioral and occupational factors (Table 1), lifestyle factors (brushing frequency, smoking status, alcohol consumption, acidic food preference not including dietary sources of acids) and systemic factors (vomiting frequency and history of gastritis).

To validate the information received about acid exposure, we traced the personnel record in the factory from the day of data collection. Length of exposure was estimated as the sum of the number of years employed in jobs exposed to acids during the whole life. Length of exposure was categorized into three ordinal scales (Table 1). The type of ACs that subjects were exposed to was classified into 9 categories (Table 2).

Statistical analysis. Dental erosion, the outcome variable, was classified into three different patterns by the severity of dental erosion (normal G0, light erosion G1-2, severe erosion G3-5), because numbers of cases of grade 1, grades 4 and grade 5 were so small.

The main explanatory variables were occupational exposure to acids (Table 2). Based on previous reports, candidates for potential confounders and/or effect modifier were occupational factors, socio-demo-behavioral factors, lifestyle factors, and systemic factors (6).

To calculate the adjusted odds ratio (AOR), a multivariate logistic regression analysis including various potential confounders was performed. Interaction terms of wearing masks with acids exposure were also tested.

Table 2
Adjusted association between acid exposure, length of exposure, type of acids exposed and dental erosion by severity of dental erosion (Multi-variate analysis)

Explanatory Variable	Odds Ratio (95% Confidence Interval)* G0 vs. G1-5#	G0 vs. G3-5#	G0 vs. G1-2 vs. G3-5¶
Acid Exposure History†			
Never exposed	reference	reference	reference
Exposed	1.81 (1.32, 2.49)	6.42(3.03, 13.59)	2.05(1.52, 5.78)
Length of Exposure‡			
Never exposed	reference	reference	reference
0-5 years	1.50(1.01, 2.25)	5.76(2.15, 15.44)	1.76(1.19, 2.60)
6-10 years	1.74(1.12, 2.70)	5.15(2.00, 13.22)	1.91(1.26, 2.88)
≥11 years	2.43(1.53, 3.86)	7.81 (3.30 18.51)	2.63(1.75, 3.95)
P-value			<.001**
Type of Acid Exposed§			
Never exposed	reference	reference	reference
Sulfuric A.(S)	1.94(1.27, 2.97)	4.00(1.58, 10.13)	2.02(1.37, 2.99)
Hydrochloric A.(H)	1.16(.62, 2.20)	8.13(2.42, 27.30)	1.63(.38, 2.97)
S+H	1.47(.80, 2.71)	7.51(2.12, 26.53)	1.69(.94, 3.01)
Nitric A.(N)	1.37(.61, 3.09)	10.06(2.21, 45.73)	1.81(.85, 3.87)
S+H+N	3.27(1.50, 7.13)	16.85 (4.02, 70.65)	3.49(1.78, 6.85)
S+H+N+Fluoric A.(F)	2.10(.81, 5.45)	5.70(.94, 34.76)	2.58(1.06, 6.28)
S+H+N+Chloric A.(C)	2.99(1.06, 8.47)	14.05(2.13, 92.60)	2.94(1.15, 7.53)
S+H+N+F+C	3.40(1.44, 8.03)	10.65(1.98, 57.20)	3.39(1.62, 7.07)
Others(F,C,H+C, etc)	1.22(.68, 2.18)	4.64(1.26, 17.14)	1.40(.80, 2.46)

*Adjusted for age, gender, income, work type, factory size, position, wearing masks, brushing frequency, smoking status, alcohol consumption, acidic food preference, vomiting frequency and gastritis history

†N=951, Cox and Snell R-square=.156 for G0 vs. G1-5; N=536, Cox and Snell R-square=.233 for G0 vs. G3-5; N=951, Cox and Snell R-square=.183 for G0 vs. G1-2 vs. G3-5

‡N=951, Cox and Snell R-square=.159 for G0 vs. G1-5; N=536, Cox and Snell R-square=.234 for G0 vs. G3-5;
N=951, Cox and Snell R-square=.186 for G0 vs. G1-2 vs. G3-5

§N=951, Cox and Snell R-square=.166 for G0 vs. G1-5; N=536, Cox and Snell R-square=.241 for G0 vs. G3-5; N=951, Cox and Snell R-square=.191 for G0 vs. G1-2 vs. G3-5

#Odds Ratio(95% CI) from Logistic regression model

¶Odds Ratio(95% CI) from Ordinal logistic regression model

***P*-value from the trend analysis

Results

Workers with dental erosion compared to the controls showed no difference in smoking and drinking habits, tooth brushing, acidic diet preference and history of vomiting and gastritis (data not shown in tables).

The adjusted odds ratio (AOR) for overall erosion and acid exposure was 1.81 (95% confidence interval (CI)=1.32,2.49), 6.42 (95% CI=3.03, 13.59) for severe erosion and 2.05 (95% CI=1.52, 5.78) for erosion severity (Table 2). Length of exposure showed a stronger association with severe dental erosion than with overall dental erosion, and showed a dose-relationship with dental erosion severity (*P*<.001). AOR for overall dental erosion was 1.94 (95% CI=1.27, 2.97) for sulfuric acid, 3.27 (95% CI=1.50, 7.13) for multiple exposure to sulfuric acid, hydrochloric acid and nitric acid, and 3.40 (95% CI=1.44, 8.03) for multiple exposure to sulfuric acid, hydrochloric acid, nitric acid, fluoric acid and chlorine gas. The etiologic fraction of multiple exposures to sulfuric acid, hydrochloric acid and nitric acid was the highest in any type of ACs exposure: .71 for dental erosion severity and .94 for severe erosion. Exposure to fluoric acid decreased the strength of association with any type of dental erosion.

The interaction term between acid exposure (yes vs. no) and wearing masks for severe dental erosion reached statistical significance (*P*=.038) (data not shown in tables). The association between acid exposure and severe erosion was significantly different between mask wearers (AOR=4.15, 95% CI=.88, 19.50) and non-mask wearers (AOR=10.86, 95% CI=3.96, 29.75), whereas the AOR of severe erosion was 6.4 in the acid exposed workers.

Discussion

Since dental erosion is multi-factorial (6), the study's data were adjusted for various covariates such as systemic, dietary, gastric and behavioral lifestyle factors. The data showed that the history of ACs exposure was strongly associated with all three outcomes of dental erosion. The association of length of exposure with overall erosion was strong, supporting previous findings (2,3,5). Wearing masks decreased the association of acid exposure or length of exposure with severe dental erosion.

Exposure to any type of ACs, with the exception of fluoric acid, was associated with dental erosion. These data support the previous finding that exposure to fluoric acid could reduce the occurrence of dental erosion (8). Since fluoride exposure provided protection from tooth wear (9), the protective association of exposure to fluoric acid with dental erosion should be clarified by a more systematic longitudinal study including the information of fluoride exposure.

In the data of this study, single exposure to sulfuric acid was strongly associated with all three outcomes of dental erosion. The case of exposure to multiple acids such as sulfuric acid, hydrochloric acid and nitric acid showed the strongest association with dental erosion. To the knowledge of the authors, these are the first data that showed the relationship between type of ACs exposure and occupational dental erosion.

TLV has been used as a guideline to keep a safe working environment in many countries including Korea and the US. K-TLVs are 1.0 mg/m^3 for sulfuric acid, Ceiling 7 mg/m^3 for hydrochloric acid, 5 mg/m^3 for nitric acid, Ceiling 2.6 mg/m^3 for fluoric acid and 3mg/m^3 for chlorine gas. Although the 42 factories investigated had kept the K-TLV guidelines, prevalence of occupational dental erosion below the K-TLV was not low (7) and a 4- month acid exposure to 0.23 mg/m^3 of sulfuric acid caused dental erosion (10). Therefore, the current TLV of five types of ACs in Korea and other countries should be lowered to a level that is safe for human organs including teeth. National Institute of Occupational Safety and Health in America (NIOSH) lowered TLV of sulfuric acid from 1.0 mg/m^3 to 0.2 mg/m^3 in 2004.

Limitations. First, this is a cross-sectional study not intended to demonstrate causation. Second, the potential for misclassification bias of exposure cannot be ruled out. Third, more information on the ambient ACs values should have been obtained. Fourth, the individual differences in buffering capacity, salivary flow rate, pH of resting saliva and mouth breathing habits were not considered. Although the cost of collecting this information would have been prohibitive, there is a need for a well-controlled longitudinal study to confirm these findings.

Summary

The present study showed a clear association between occupational exposure to five types of ACs below the current K-TLVs and occupational dental erosion. Hence, for ameliorating occupational hazards such as occupational dental erosion, the authors propose lowering the relatively high K-TLVs of five types of ACs in the workplace.

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