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Periodontal health and oral mucosal lesions as related to occupational exposure to acid mists

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Abstract – *Objectives:* The association between exposure to acid mists and periodontal changes and oral mucosal lesions was measured using data from an Oral Health Promotion Program in a large metal plant. The role of sociodemographic factors, lifestyle, and oral health behavior in relation to these outcomes was also examined. *Methods:* This is a cross-sectional study of 665 active male workers who volunteered to participate in the oral health program. A job exposure matrix was constructed with industrial hygienist scores and job titles to estimate years of exposure to acid mists. Oral health outcomes were identified during standardized dental examinations. Unconditional logistic regression models were utilized in the analysis. *Results:* Duration of exposure to acid mists exposure was positively associated with oral mucosal lesions among workers without lip sealing. Only age, low salaries and oral hygiene-related variables were associated with periodontal changes, and estimates varied according to lip sealing. *Conclusions:* Results suggest that long-term occupational exposure to acid mists is associated with oral mucosal lesions, and that absence of lip sealing may increase the intensity of exposure.

Key words: acid mists; oral mucosal lesions; periodontal changes

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The etiology of oral cavity diseases involves an array of environmental, genetic, immunologic, and sociobehavioral factors including education, oral hygiene habits, and dental care access.

The location and multiple functions of the mouth make it particularly vulnerable to external aggressions. Occupational or environmental exposures to acid mists affect a large number of workers worldwide (1). They can cause dental erosion (2–4) and oral cavity neoplasm (1). These are already well-documented causal associations (1). They may also irritate soft tissues resulting in other oral health-related effects, such as periodontal changes or oral mucosal lesions. It is plausible that a long-term presence of acid mist in the workers' breathing area have an irritant effect on periodontal and soft tissues (5). This chronic irritative process can increase the susceptibility to infections and the long-term contact with acid may promote salivary changes that favour the occurrence or progression of periodontal diseases (6). In addition, organic and inorganic acids are known to cause protein coagulation and consequently oral lesions (7). Only a small number of studies have focused on these outcomes (8), and fewer have controlled for potential confounding factors (5). In these studies, acid mist exposure was reported as a risk factor for gingival bleeding (5, 8, 9) deep periodontal pockets (≥4 mm) (5, 8), red lesions, and ulcerative lesions of the oral mucosa (10).

In this study, the effect of acid mist exposure on oral health outcomes was investigated. Social, demographic, lifestyle, and oral health-related behaviors were simultaneously examined in

relation to these outcomes. Oral health outcomes included periodontal changes, non-specific oral mucosal lesions, and red lesions.

Methods

A cross-sectional study was carried out with active workers who volunteered to participate in the first phase of an oral health promotion program implemented in a large metallurgical plant in Brazil, where inorganic acids – particularly sulfuric acid – are heavily used. Eligible workers were identified using an employee log as of December 1999. A free dental examination, treatment for simple oral diseases, fluoride therapy, oral health education, and other preventive-related measures were provided in a dental facility located in the plant. Edentulous subjects were excluded from this study.

Data were recorded during dental examinations conducted by two dentists who were trained to perform standardized procedures and record clinical findings. Periodontal changes were measured using criteria defined by the Community Periodontal Index of Treatment Needs (CPITN) (11), as follows: presence of gingival bleeding, dental calculus, and moderate (4–5 mm) or deep (≥6 mm) periodontal pockets identified by probing a previously defined tooth in each mouth sextant. Presence of each of these symptoms was coded 1, and absence was coded 0. A periodontal changes score was calculated by summing these codes and analyzed as a dichotomous variable: high (3 and 4) and low score (0 to 2). Nonspecific oral mucosal lesions (NOSML) were defined in accordance to their clinical appearance during the oral examination as at least one red, ulcerative, white, vesiculo-bullous, nodulated, pigmentated, or other lesion. Presence of NSOML was coded as 1, absence was coded as 0. Presence of at least one red oral mucosal lesion was also considered separately. Following the dental examination, a trained dental student interviewed each worker about social, demographic, occupational, and health-related factors using a structured questionnaire. Interviewers were blind to patients' dental health status; dentists were blind to patients' exposure status.

The exposure to acid mists was assessed using a job exposure matrix with job titles or location on one axis, and chemical hazards associated with the job on the other axis. Industrial hygienists for the industry determined whether exposure was likely to each source of acid mist. Exposure to acid mists came from sulfuric acid (H_2SO_4), hydrochloric acid (HCl), electrolytic solution of H_2SO_4, and 'acid water' that expressed diluted H_2SO_4. Years of work in a job with likely exposure to acid mists were summed across each workers' occupational history, to obtain a cumulative measure of exposure to any acid mist. Workers were characterized as never exposed, exposed ≤6, and ≥6 years.

Nonoccupational variables were also considered in this analysis. Sociodemographic variables were age (years), education (0 = college/technician/high school, 1 = less than high school), and monthly wage in US$ (0 = over $579, 1 = $579 or less). Lifestyle variables were alcohol consumption (0 = nondrinker or occasional drinker, 1 = drinks 2 to 7 days/week), and smoking (0 = never/ex-smoker, 1 = current smoker). Oral health-related variables were presence of oral prosthesis (0 = no, 1 = yes), frequency of dental visits, measured by number of months after the last dentist visit (0 = up to 6 months, 1 = >6 months), oral hygiene, measured as frequency of daily toothbrushing (0 = <3, 1 = ≥3), dental flossing (0 = daily, 1 = never/occasional). Lip sealing was defined as an individual's ability to keep his lips sealed during occlusive resting, and it was treated as a potential modifier of the effect of acid mists on oral health. Absence of lip sealing may be a morphological trait, i.e. upper lip shortening. It may also be a result of acquired occlusive dysfunction, or oral breathing (12).

Statistical analysis

Odds ratios (OR) and 90% confidence intervals were estimated using Mantel–Haenszel methods in stratified analyses, and Wald methods in multiple variable logistic regression(13). An alpha of 0.10 was utilized because of the small sample size upon stratifying variables by lip sealing. Unconditional logistic regression with backward selection was used. Statistical criterion for variable retention was a *P*-value of 0.10. Age was retained in all models for adjustment (14, 15). Based on evidences that lip sealing absence may increase the intensity of inhalable exposures (14, 16), data were analyzed separately according to lip sealing. Statistical analysis was performed with SAS 8.1 (17).

This study was approved by the Internal Review Board of the Federal University of Bahia, Hospital Professor Edgard Santos. Results have been presented to industry workers and administrative staff.

Results

Of 870 workers who enrolled in the oral health promotion program, 731 (84%) voluntarily participated in first phase. Women were excluded because there were few ($n = 65$; 8.9%), and they tended to be in administrative jobs with little to no exposure. One male worker with incomplete data was also excluded, leaving 665 male workers in the study population. Among those exposed to acid mists, 19.6% (130) had ≤6 years and 18.2% (121), >6 years of exposure (Table 1). Workers tended to be >34 years of age (66.2%). The majority had less than high school education (85%), and monthly wage below US$579 (67.8%). The majority described themselves as nondrinkers or occasional drinkers of alcoholic beverages (69.8%), and nonsmokers (88.3%). Most workers reported a dental visit within at least 6 months prior to interview (59.1%), tooth-brushing three or more times daily (70.4%), and no or occasionally dental flossing (63%) (Table 1).

Table 1. Sociodemographic, life style, health behavior and occupational characteristics of the study population ($n = 665$)

Variables	*n*	%
Exposure time to acid mists		
Never exposed	414	62.3
Six or less years	130	19.6
Over 6 years	121	18.2
Sociodemographic		
Age in years		
18–34	225	33.8
35–44	257	38.7
45–65	183	27.5
Education		
High (College/Technician/High school)	103	15.5
Low (Less than High school)	562	84.5
Monthly wage		
High (over US$579.00)	214	32.2
Low (US$105.00–579.00)	451	67.8
Life style		
Alcohol consumption		
Nondrinker/drinks occasionally	464	69.8
Drinks 2 to 7 days a week	201	30.2
Smoking		
Never/former	587	88.3
Current	78	11.7
Oral health-related factors		
Lips sealing		
Present	548	82.4
Absent	117	17.6
Oral prosthesis		
No	195	29.3
Yes	470	70.7
Time since last dental visit (months)[a]		
0–6	389	59.0
Over 6 months	270	41.0
Frequency of daily teeth-brushing		
Three or more times	468	70.4
Less than three times	197	29.6
Dental flossing		
Daily	247	37.2
No/occasionally	418	62.8

[a]Data from four subjects were missing.

Crude prevalence of oral health outcomes was not significantly associated with categories of duration of acid mists exposure (Table 2), except for the strong association found between having ≤6 years of exposure and vesiculo-bullous oral mucosal lesions (OR 6.54; 90% CI 1.56–27.44).

Table 3 shows that no significant positive association between acid mist exposure and high periodontal change was found after controlling for covariates and stratifying by lip sealing. Among workers without lip sealing, a high periodontal score was more common among workers with low salaries (OR 2.58; 90% CI 1.08–6.15), and less frequent among those who had a dental visit in the last 6 months (OR 0.38; 90% CI 0.16–0.87), or among those who flossed daily (OR 0.31; 90% CI 0.11–0.90). In the group of workers with lip sealing, however, age was the most important factor associated with a high periodontal change score in the group of 35–44 years of age (OR 3.23; 90% CI 2.00–5.24), and for subjects >44 years of age (OR 2.89; 90% CI 1.76–5.10) compared with workers 18–34 years of age. Smoking was unexpectedly associated with a low periodontal change score (OR 0.54; 90% CI 0.30–0.96).

Six or more years of exposure to acid mist was positively associated with oral mucosal lesions (OR 2.96; 90% CI 1.23–7.16) in workers without lip sealing (Table 4). Among workers with lip sealing, however, low education (OR 1.54; 90% CI 1.12–2.13) and oral prosthesis (OR 2.21; 90% CI 1.44–3.38) were positively associated with oral mucosal lesions; and as a potential protective factor, tooth-brushing three or more times daily (OR 0.70; 90% CI 0.50–0.98). In Table 5, it can be observed that in the group of workers without lip sealing, there is a borderline positive association between ≤6 years of acid mist exposure and red lesions (OR 2.99; 90% CI 0.98–9.14). Use of oral prostheses was positively associated with red mucosal lesions (OR 5.30; 90% CI 1.77–15.85) and, contrary to what was expected, low salaries were negatively associated with these lesions (OR = 0.36; 90% CI: 0.14 0.94). Workers without lip sealing, low education (OR 1.98; 90% CI 1.33–2.94) and oral prosthesis were positively associated (OR 5.51; 90% CI 2.85–10.67) with red

Table 2. Crude prevalence, odds ratio and their Mantel–Haenszel 90% confidence intervals for the association between exposure to acid mists and oral health ($n = 665$)

	Exposure to acid mists					
	Over 6 years ($n = 121$)		Less than 6 years ($n = 130$)		Unexposed ($n = 414$)	
Variables	*n* (%)	OR (90% CI)	*n* (%)	OR (90% CI)	*n* (%)	OR (90% CI)
High periodontal changes score[a, b]	29 (24.17)	1.17 (0.78–1.74)	30 (23.08)	1.10 (0.74–1.63)	88 (21.46)	1.00 (–)
All oral mucosal lesions[c]	41 (33.88)	1.29 (0.89–1.85)	41 (31.54)	1.16 (0.81–1.65)	118 (28.50)	1.00 (–)
Red	30 (24.79)	1.40 (0.93–2.09)	20 (15.38)	0.77 (0.49–1.21)	79 (19.08)	1.00 (–)
Ulcerative	14 (11.57)	1.56 (0.89–2.73)	15 (11.54)	1.56 (0.90–2.68)	32 (7.73)	1.00 (–)
Vesiculo-bullous	1 (0.83)	–	4 (3.08)	6.54 (1.56–27.44)	2 (0.48)	1.00 (–)
White	0	–	2 (1.54)	0.52 (0.15–1.86)	12 (2.90)	1.00 (–)
Nodulated	0	–	1 (0.77)	–	1 (0.77)	1.00 (–)
Pigmentated	0	–	0	–	0	1.00 (–)
Nodulated-ulcerative	0	–	0	–	0	1.00 (–)
Other	1 (0.83)	0.57 (0.10–3.38)	2 (1.54)	1.06 (0.27–4.11)	2 (1.54)	1.00 (–)

OR, odds ratio; 90% CI, 90% Mantel–Haenszel confidence interval.
[a]Periodontal changes score coded as: 0 = low (<3); 1 = high (≥3).
[b]Edentulous were excluded.
[c]At least one oral mucosal lesion.

Table 3. Odds ratios and 90% Wald test-based confidence intervals from logistic regression for periodontal scores, according to lips sealing

	Lips sealing	
Variables in the final model	Absent [OR (90% CI)]	Present [OR (90% CI)]
Referent	1.00	1.00
Exposure time to acid mists[a]		
Six or less years	1.55 (0.57–4.23)	1.47 (0.90–2.42)
Over 6 years	0.68 (0.22–2.14)	1.10 (0.70–1.71)
Sociodemographic		
Age in years[a]		
35–44	1.60 (0.61–4.25)	3.23 (2.00–5.24)
44–65	1.35 (0.41–4.44)	2.89 (1.70–4.90)
Low monthly wage (US$105.00–579.00)	2.58 (1.08–6.15)	–
Life style		
Current smoker	–	0.54 (0.30–0.96)
Oral health-related factors		
0–6 months from the last dental visit	0.38 (0.16–0.87)	–
Daily dental flossing	0.31 (0.11–0.90)	–

Periodontal score – 0 = low (<3) and 1 = high (≥3).
OR, odds ratio; CI, Wald confidence interval.
[a]To analyze exposure time to acid mists and age, dummy variables were created taking as referent category never exposed, and age of 18 to 34 years. Other variables were coded as: Skin color – 0 = white, 1 = black/mulattoes; education – 0 = college, 1 = less than college; monthly wage in US$ – 0 = high (over 579.00), 1 = low 105.00–579.00; alcohol consumption – 0 = no/occasionally; 1 = moderate/heavy (2–7 days a week); smoking – 0 = no/ex-smoker, 1 = current smoker; time after the last dental visit – 0 = 6 or more months; 1 = less than 6 months; oral hygiene measured by the frequency of daily tooth-brushing – 0 = poor (less than three times), 1 = good (three or more times per day); daily dental flossing – 0 = no, 1 = yes. Oral prosthesis – 0 = no, 1 = yes.

oral mucosal lesions. Moreover, daily dental flossing was a protective factor (OR 0.56; 90% CI 0.37–0.85) for this type of oral lesion, but surprisingly, a negative association between frequent alcohol consumption and red lesions was also observed (OR 0.60; 90% CI 0.40–0.91).

Discussion

Results from this study suggest that acid mists may be a risk factor for oral mucosal lesions among workers with no lip sealing. Absence of lip sealing may increase the intensity of acid mists

Table 4. Odds ratios and 90% Wald test based confidence intervals from logistic regression for oral mucosal lesions, according to lips sealing

Variables in the final model	Lips sealing	
	Absent [OR (90% CI)]	Present [OR (90% CI)]
Referent	1.00	1.00
Exposure time to acid mists[a]		
Six or less years	1.82 (0.81–4.09)	1.09 (0.70–1.70)
Over 6 years	2.96 (1.23–7.16)	0.91 (0.60–1.39)
Sociodemographic		
Age in years[a]		
35–44	0.55 (0.25–1.25)	0.92 (0.60–1.39)
44–65	1.26 (0.53–3.02)	1.00 (0.64–1.57)
Low education (less than high school)	–	1.54 (1.12–2.13)
Oral health-related factors		
Tooth-brushing three or more times daily	–	0.70 (0.50–0.98)
Oral prosthesis	–	2.21 (1.44–3.38)

Periodontal score – 0 = low (<3) and 1 = high (≥3).
OR, odds ratio; CI, Wald confidence interval.
[a]To analyze exposure time to acid mists and age, dummy variables were created taking as referent category never exposed, and age of 18 to 34 years, respectively. Other variables were coded as: Skin color – 0 = white, 1 = black/mulattoes; education – 0 = college, 1 = less than college; monthly wage in US$ – 0 = high (over 579.00), 1 = low 105.00–579.00; alcohol consumption – 0 = no/occasionally; 1 = moderate/heavy (2–7 days a week); smoking – 0 = no/ex-smoker, 1 = current smoker; time after the last dental visit – 0 = 6 or more months; 1 = less than 6 months; oral hygiene measured by the frequency of daily tooth-brushing – 0 = poor (less than three times), 1 = good (three or more times per day); daily dental flossing – 0 = no, 1 = yes. Oral prosthesis – 0 = no, 1 = yes.

Table 5. Odds ratios and 90% Wald test-based confidence intervals from logistic regression for red oral mucosal lesions, according to lips sealing

Variables in the final model	Lips sealing	
	Absent [OR (90% CI)]	Present [OR (90% CI)]
Referent	1.00	1.00
Exposure time to acid mists[a]		
Six or less years	2.99 (0.98–9.14)	0.82 (0.46–1.46)
Over 6 years	2.39 (0.83–6.86)	1.09 (0.68–1.76)
Sociodemographic		
Age in years[a]		
35–44	1.03 (0.36–2.98)	1.25 (0.75–2.10)
44–65	2.00 (0.67–5.98)	1.37 (0.79–2.38
Low education (less than high school)	–	1.98 (1.33–2.94)
Low monthly wage (US$105.00–579.00)	0.36 (0.14–0.94)	–
Life style		
Moderate/heavy drinking (drink 2 to 7 days a week)	–	0.60 (0.40–0.91)
Oral health-related factors	–	–
Daily dental flossing	–	0.56 (0.37–0.85)
Oral prosthesis	5.30 (1.77–15.85)	5.51 (2.85–10.67)

Periodontal score – 0 = low (<3) and 1 = high (≥3).
OR, odds ratio; CI, Wald confidence interval.
[a]To analyze exposure time to acid mists and age, dummy variables were created taking as referent category never exposed, and age of 18 to 34 years. Other variables were coded as: Skin color – 0 = white, 1 = black/mulattoes; education – 0 = college, 1 = less than college; monthly wage in US$ – 0 = high (over 579.00), 1 = low 105.00–579.00; alcohol consumption – 0 = no/occasionally; 1 = moderate/heavy (2–7 days a week); smoking – 0 = no/ex-smoker, 1 = current smoker; time after the last dental visit – 0 = 6 or more months; 1 = less than 6 months; oral hygiene measured by the frequency of daily tooth-brushing – 0 = poor (less than three times), 1 = good (three or more times per day); daily dental flossing – 0 = no, 1 = yes. Oral prosthesis – 0 = no, 1 = yes.

exposure (10, 18). In this study, oral mucosal lesions were mainly of the ulcerative type. Among workers without lip sealing, prevalence of red oral mucosal lesions was also higher among those exposed to acid mists though the association was of borderline statistical signifi-

cance. Conclusions about the association of acid mists exposure and vesiculo-bullous mucosal lesions are limited because of the small number of cases. No associations were observed between acid mists exposure and a high periodontal change score.

Periodontal changes

Absence of an association between acid mists and periodontal health has been reported in some studies (2, 18, 19). However, other reports found that acid mists were associated with periodontal pockets >4 mm (5, 8) and gingival bleeding (8, 9), which are symptoms of periodontal diseases. Such associations are consistent with the irritating effects of inorganic acids on dermal or mucosal tissues (1). Irritants may affect oral soft tissues, such as the gingiva surrounding the teeth. Acid exposure may also affect immunologic defenses or protective components of the saliva which play an important role in the pathogenesis of periodontal diseases (6). In contrast, acid exposures may decrease the pH level in the oral cavity, creating an unfavorable environment for microbial growth, a strong predictor of periodontal disease (6). In addition, low normal pH can diminish supragingival or subgingival plaque and calculus accumulation, both periodontal disease risk factors (6). As in other studies (5, 18), nonoccupational factors appeared to be more relevant for periodontal disease than acid mist exposures, exemplified by the relatively strong associations between low wage (20) among individuals without lip sealing, and older age (15) among those with lip sealing. Low monthly wages may be a proxy for higher exposure, since they are paid to less qualified and more heavily exposed workers. Although smoking is a well-known risk factor for periodontal disease, negative associations with gingival bleeding, edema and other inflammatory signs have been reported, and explained as a possible consequence of reduced blood flow due to vasoconstriction caused by nicotine (21, 22). Consistent with other studies, results reported here suggest that frequent dental visits and daily dental flossing protect against periodontal disease (20, 23), and age is associated with periodontal change. Results do not suggest that acid mists are associated with periodontal changes, but it is also possible that the sample size for this study was too small to detect true associations. In sum, the results of this study support the hypothesis that age and low wage are associated with periodontal changes, but the putative role of acid mists requires further evaluation.

Oral mucosal lesions

Acid mists exposure appears to be a potential risk factor for oral mucosal lesions, similar to the results of higher prevalence of oral mucosal lesions among workers exposed to acid mists, particularly red (RP 4.04; 95% CI 1.37–11.87) or ulcerative lesions (RP 14.53; 95% CI 3.17–66.56) (10). These results conflict with a Finnish study that did not observe an increased prevalence of oral mucosal lesions among workers exposed to inorganic acid (5). Exposure to inorganic acids can cause soft-tissue irritation, and the association observed between exposure to acid mists during six or more years suggests a chronic manifestation. The lip sealing-related difference in the magnitude of the acid mist association with oral mucosal lesions is consistent with the hypothesis that higher intensity of exposure occurs among workers without lip sealing. The association between oral prosthesis and red lesions was the only result independent of lip sealing, a finding supported by the known association of dentures with denture stomatitis which is usually a form of oral candidosis (24, 25).

Low education and oral prosthesis were the nonoccupational factors most strongly associated with oral mucosal lesions among workers with lip sealing, while frequency of toothbrushing was protective within this group of workers. In contrast with other studies, age was not positively associated with oral mucosal lesions (24, 25). Low education and oral prosthesis were positively associated with red lesions among workers without lip sealing. A potential protective factor was dental flossing. Also, among workers with lip sealing present, a negative association between frequent consumption of alcoholic beverages and red oral mucosal lesions was found, which may be a result of a presumable underreporting of alcohol consumption of active workers related to self-reporting. It is worth noticing that all workers having oral problems received appropriate treatment as part of the oral health promotion program.

Findings of this study need to be taken with caution because of its cross-sectional design. Clinical findings were limited to the time at the interview, so it was not possible to confirm that exposure preceded the effect. At the time when the study was carried out, the CPITN was recommended by

WHO, and it was the choice of the dental team that considered it a simple, fast and feasible strategy to be used in a large scale oral health promotion program (11). Nevertheless, it has been criticized because only teeth indices are used (26). Important clinical parameters are not considered such as bone and attachment losses (27, 28) and for those considered they are registered taking a hierarchical approach (29).

In addition, the odds ratios reported here may not be unbiased estimators of prevalence ratios, since the oral health outcomes studied are relatively common. Some socially undesirable behaviors such as smoking and alcohol consumption would also be underreported in this active worker population, which is engaged in a known risky industrial activity.

Strengths of this study included on-site dental exams and interviews, which allowed high worker participation. Occupational history data were complete for each worker's entire employment time in the plant. Exposure assessment can be problematic in occupational epidemiology. Multiple exposures are common in industrial environments, so it is not always possible to know which are responsible for an observed effect. This study benefits from the use of a job exposure matrix, which has been recognized as a good resource for exposure assessment in epidemiological studies (30). However, use of duration of exposure to acid mists only may be confounded by exposure to copper or high temperatures, which were simultaneously present in this metallurgical plant (7). Despite limitations of the data, our results suggest that lip sealing should be considered when studying the effect of airborne exposures on oral health. Although our results do not support the hypothesis that acid mists cause periodontal changes, it remains possible that longer or higher intensity of exposure than that observed in our study could cause these health outcomes.

Studies of the etiology of periodontal changes and oral mucosal lesions are scarce. Future studies should consider specific histological types of oral mucosal lesions, and more appropriate periodontal disease measures to analyze associations with environmental or occupational exposures. The modifying effect of lip sealing on exposure should also be considered. This study suggests that acid mists could be a hazard to oral mucosal lesions, and supports the implementation of oral health promotion programs already in effect in high-risk industries in several countries.

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