# Examining Relationship between Occupational Acid Exposure and Oral Health in Workplace

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# Abstract

**Objectives:** Acid mist can suspend in the air and enter the body via skin contact, the respiratory tract, or even oral intake, which pose various health hazards. Previous studies have shown that occupational exposure to acid mist or acidic solutions is a major risk factor for oral diseases. However, the findings are inconsistent and do not consider individual factors and lifestyles that may cause the same oral diseases. Therefore, we conducted a comprehensive oral health survey and collected detail information to confirm the effect of acidic solution exposure on worker's oral health.

**Methods:** The study selected enterprises in the metal surface treatment or electroplating industries in Taiwan that employed 300 or more employees and were willing to participate in this survey. Each enrolled subject underwent a questionnaire and comprehensive teeth and oral mucosa examination by a team of qualified and uniformed trained dentists. Oral clinical mirrors and community periodontal index (CPI)-type millimetric probe clinical data were collected according to the World Health Organization (WHO) dental caries diagnostic criteria. In this cross-sectional study, a total of 309 subjects participated was surveyed.

**Results:** The results showed that acid exposure was correlated with soft oral tissue injury rather than hard oral tissue in our survey. Besides, halitosis and age were positive associated with periodontal disease and use of dental floss reduced the risk of periodontal disease. After correcting for major factors, such as age, sex, smoking, drinking, and chewing areca, acid exposure was still statistically related to periodontal disease in LA (loss of attachment) index by 3.27-fold ($p = 0.00$, CI 1.69 - 6.34).

**Conclusion:** This study showed that occupational acid exposure during acidic solution work was an independent risk factor for periodontal disease. It is important to strengthen occupational hazard control, educate workers on oral disease and related factors, and raise the awareness of oral hygiene.


# Introduction

Acidic solution work generally refers to any work where workers may be exposed to acidic substances or related derivatives. Acidic solutions may be present in the air in three different forms: mist, vapor, and gas. Mist refers to a liquid aerosol formed by vapor condensation or liquid atomization. Vapor is a gaseous form of liquid or solid at normal temperature and pressure. Among common acidic solutions, nitric acid, sulfuric acid, and phosphoric acid can be present in the form of mist or vapor in the air in addition to their liquid form; however, because of their low volatility and relatively high hydrophilicity, they are present in the air mainly as mist [1, 2]. The causes of acid mist vary with the manufacturing process and method. Industries exposed to acidic solutions include manufacturing (phosphate fertilizers, isopropyl alcohol, ethanol, sulfuric acid, nitric acid, and lead-acid batteries), construction, petroleum and coal products, oil and gas extraction, printing and publishing, paper-making, and leather manufacturing. In addition, if metal materials or metal-related compounds are used in the manufacturing process, such as smelting copper, electroplating, pickling and other metal surface treatment industries, the workers are more likely to be exposed to metal-containing acid mist. Acid mist can suspend in the air and enter the

body via skin contact, the respiratory tract, or even oral intake, which pose various health hazards, such as skin disease [3], respiratory irritation [4], oral lesions, periodontal disease [5], and tooth erosion [6], and may even increase the risk of lung [7] and laryngeal cancer [8]. Dental illnesses are common, but important health problems tend to be overlooked. Common dental problems can be categorized as soft or hard tissue diseases. Soft tissue diseases include problems of the gums, cheeks, lips, tongue, and palate; hard tissue diseases include tooth and bone problems. The most commonly diagnosed diseases include periodontal disease, tooth decay, missing teeth, and tooth erosion.

In addition to affecting chewing and eating, dental diseases may cause or worsen chronic diseases over the long term [9, 10]. For example, periodontal disease may increase the risk of cardiovascular [11] and neurodegenerative diseases [12], affect glycemic control [13], and increase the risk of infants with a low birth weight [14]. Previous studies have shown that occupational exposure to acid mist or acidic solutions is a major risk factor for tooth, periodontal, and oral mucosal lesions [6, 15–21]. However, the findings are inconsistent and do not consider individual factors and lifestyles that may cause the same oral diseases. In this study, we conducted a comprehensive oral health survey and collected information about each subject's dietary habits, occupational exposure time, exposure environment, and their personal history of illnesses with a questionnaire. Based on this study, we confirmed the effect of acidic solution exposure on worker's oral health and provided recommendations on how to reduce the risk of chronic diseases in the future.

# Materials And Methods

### Study population

Based on the directory of factories and manufacturers from the Ministry of Economic Affairs of the Republic of China, we selected enterprises in the metal surface treatment or electroplating industries in municipalities and counties in Taiwan that employed 300 or more employees and were willing to participate in this survey. In this study, we used judgmental (non-randomized) sampling. From the parent source, we selected acidic solution factories willing to collaborate. The factories were in Northern Taiwan, and the workers may have been exposed to different acidic solutions, including hydrochloric acid, sulfuric acid, and nitric acid.

We contacted the factory managers or supervisors, who in turn contacted and confirmed which study subjects were willing to participate. We then conducted the survey at the time of a routine health check at each factory. The subjects were enrolled at 1:1 ratio into the exposure group (people engaging in acid mist work) and the control group (people working in the same work environment without exposure to acid mist; or people engaging in non-acid mist work, such as other production line workers). The study was reviewed and approved by the Institutional Review Board (IRB) of the Tri-Service General Hospital (TSGHIRB No.: 1-105-05-080) before the study began. Each subject signed the informed consent form at the time of enrollment.

### Study questionnaire

This was a cross-sectional study. The study subjects were 20 years of age or older. The exposure group included workers engaging in acid mist work, such as electroplating and metal surface treatment. The control group included workers without exposure to acid mist, such as administrative staff, or workers engaging in non-acid mist work. The subjects who declined to participate were excluded from this study.

The study questionnaire included the subject's basic demographics, as well as potentially important variables and confounders on tooth erosion according to relevant literature, including the subjects' dietary habits with acidic foods, occupational exposure time, exposure environment, and their personal illness history.

## Oral examination

Each enrolled subject underwent a comprehensive examination of their teeth and oral mucosa by a team of qualified and uniformed trained dentists to minimize the variation caused by different dentists. The detailed results were recorded in the subject's medical records for subsequent data analysis. To reduce error, the dentists were unaware of each subject's occupational exposure. A mouth mirror and a probe were used to record the DMFT index. The decayed teeth were recorded as (D), missing teeth as (M) and filled teeth as (F) according to WHO criteria [22]. The CPITN (community periodontal index) and LA index was measured for assessment of periodontal status, by using a mouth mirror and a specifically designed periodontal probe [23]. The measured variables included tooth erosion (Keels-Coffield clinical severity scale [24]) (Table 1), tooth abrasion, tooth decay (decayed, missing, and filled teeth (DMFT) index), and periodontal disease (the WHO community periodontal index of treatment needs [CPITN] [23]) index and loss of attachment [LA] index).

## Data analysis

The DMFT index, which corresponds to the average number of decayed, missing, and filled permanent teeth, was the outcome analyzed. The WHO CPI [25] and LA [26] levels were used to assess periodontitis (Hu-Friedy PCP11.5B CC SE probe 3.5-5.5-8.5-11.5). Periodontitis was defined as a CPI or LA value greater than or equal to 1 (Table 2). The index teeth numbers were 11, 16, 17, 26, 27, 31, 36, 37, 46 and 47. A CPITN was used at the gingival margin as a reference to measure the periodontal pocket. During the measurement, the probe was aligned with the long axis of the tooth and the total extent of the pocket was explored. The results were recorded as follows: 0: the 1$^{st}$ marking of probe remained completely visible, without bleeding after probing - healthy gum; 1: the 1$^{st}$ marking of probe remained completely visible, with bleeding after probing - gingivitis; 2: the 1$^{st}$ marking of probe remained completely visible, with dental calculus (including supra-or subgingival calculus); 3: the 2$^{nd}$ marking of probe remained completely visible - shallow pocket; and 4: the 3$^{rd}$ marking of probe remained completely visible - deep pocket. An LA was used at the cemento-enamel junction (CEJ) as a reference to measure the periodontal pocket. During the measurement, the probe was aligned with the long axis of the tooth and the total extent of the pocket was explored. The results were recorded as follows: 0: CEJ was within the first

marking; 1: CEJ reached the second marking; 2: CEJ reached the third marking; 3: CEJ reached the fourth marking; and 4: CEJ reached beyond all markings (Table 1).

Acidic foods were defined as foods where the pH value was ≤ 6 [27]. For dietary habits with acid foods, a type of acidic food was only considered when the subject consumed that acidic food more than once per week. The data for each type of acidic food were pooled for analysis. Owing to the absence of data regarding dietary habits with acidic foods, we pooled each type of acidic foods and categorized into four groups (Q1 to Q4).

### Statistical analysis

IBM SPSS Statistic v20 was used for statistical analysis. For incomplete questionnaires, the mean values were used for analysis. For descriptive analyses, the t-test, one-way analysis of variance (ANOVA), and chi-square test were performed for comparative analyses of the demographics. Moreover, the frequency, ratio, and the severity of tooth erosion, DMFT, CPITN and LA scores were analyzed. For inferential analyses, a regression model was used to investigate the relationship between credible exposure and disease by correcting for potential interfering factors. Moreover, logistic and linear regression analyses were performed to investigate the effect of age, dietary habits, occupational exposure time, exposure environment, and personal illness history on the oral health of people engaging in acid mist work in factories.

## Results

At baseline, a total of 315 subjects were included. Based on our inclusion criteria, 5 of control group and 1 of exposed group were excluded. A total of 309 subjects (157 in control and 152 in exposed group) participated in this study. The basic demographics are shown in Table 3. In the control group, 26.8% of the subjects were women and 73.2% were men. In the exposure group, 17.1% were female and 82.9% were male. The control group was aged 37.76 ± 10.06, and the exposure group was aged 30.08 ± 6.43. The subjects in the control and exposure groups had worked 10.41±10.80 and 2.24±2.42 years, respectively. In the control group, the body mass index (BMI) values were 24.47 ± 4.16, and the BMI values in the exposure group were 23.70 ± 3.58. In the control group, 34.5% of the subjects completed secondary education or below (≤ 12 years) and 65.5% completed tertiary education or above (> 12 years). The 47.2% and 52.8% of the exposure group subjects completed secondary and tertiary education, respectively. These differences were statistically significant.

The single variate analysis of hard tissue damage levels showed that in the control group (no acid exposure), being female, higher age, long worked years, high educational level, no smoking, drinking, no chewing areca, no mask use, no history of gastroesophageal reflux, history of gastric ulcer, brushing teeth twice a day or more, no mouthwash use, dental floss use, no mouth breathing, and halitosis were potential risk factors for tooth erosion, although only sex and age were statistically significant risk factors (Figure 1A). Analysis of the DMFT index showed that in the control group (no acid exposure), being male, higher age, long work history, high educational level, smoking, drinking, chewing areca, no mask use,

brushing teeth twice a day or more, no mouthwash use, dental floss use, no mouth breathing, and no halitosis were associated with a high DMFT index (Figure 1B). Among these factors, acid exposure, age, worked years, education, dental floss use, mouth breathing, and halitosis were statistically significant factors.

The single variate analysis of soft tissue damage levels showed that in the exposure group (acid exposure), being female, lower age, short work history, low educational level, no smoking, no drinking, no chewing areca, mask use, no history of gastroesophageal reflux, no history of gastric ulcer, brushing teeth twice a day or more, mouthwash use, no dental floss use, mouth breathing, and halitosis were associated with a high CPITN index (Figure 1C). Of these, acid exposure, dental floss use, mouth breathing, and halitosis were statistically significant factors. Analysis of the LA index showed that in the exposure group (acid exposure), being female, higher age, short work history, low educational level, no smoking, no drinking, chewing areca nut, mask use, no history of gastroesophageal reflux, no history of gastric ulcer, brushing teeth twice a day or less, mouthwash use, no dental floss use, mouth breathing, and halitosis were associated with a high LA index (Figure 1D). Of these, acid exposure, sex, age, dental floss use, and mouth breathing were statistically significant factors.

The single variate analysis showed that acid exposure was related to oral hard and soft tissue damage. Next, we incorporated the related and statistically significant variables into a multivariate regression analysis (Figure 2). In oral hard tissue, the results showed that only age increased the risk of tooth erosion by 1.05-fold per year ($p = 0.00$, CI 1.04-1.08).

In the oral soft tissue, the results showed that halitosis but not acid exposure was related with periodontal disease (CPITN index) by 5.73-fold ($p = 0.01$, CI 1.58 - 20.81), and the use of dental floss reduced the risk of periodontal disease by 0.29-fold ($p = 0.03$, CI 0.09 - 0.88). Interestingly, the LA index, another measure of periodontal disease, showed that acid exposure increased the loss of attachment (LA index) by 3.27-fold ($p = 0.00$, CI 1.69 - 6.34). Moreover, the risk of loss of attachment (LA index) increased by 0.09-fold with each year of increased age ($p = 0.00$, CI 1.05 - 1.13). Therefore, oral soft tissue was more easily damage by acidic exposure and poor oral hygiene.

# Discussion

Oral diseases are generally not immediately life-threatening and can be easily overlooked. Poor oral health is often associated with individual behaviors, but sometimes the effect of environmental or occupational factors are overlooked. Strong inorganic acids, such as hydrochloric acid, nitric acid, and sulfuric acid, are essential materials used in industrial processes, and the output or use of these minerals is often regarded as an important indicator for the development of a nation’s related industrials. Recent studies showed that acidic solutions in the work environment increase the risk of oral soft tissue (oral mucosa and periodontal tissue) diseases, such as mucosal ulcers, which can increase the risk of periodontal disease, oral fibrosis and stomatitis, leading to periodontal pocket induction and loss of attachment [5, 15, 28]. Studies on the relationship between acidic solution work environments and soft

tissue disease showed that age, work history, and oral hygiene habits may further increase the risk of soft tissue disease in workers exposed to acid mist [29]. Periodontal disease is a common and most important oral soft tissue diseases that affect oral health. Periodontal disease is characterized by periodontal tissue inflammation, including the gums, alveolar bone, and the periodontal ligament. The gums are affected first. They become inflamed and swollen, which leads to periodontal pocket induction between the teeth and gums. As inflammation progresses, periodontal pockets become bigger and deeper, which destroy alveolar bone and eventually causes tooth loss.

In addition to analyzing the effects of occupational acid mist exposure on oral health, we also analyzed several other factors that may affect oral health, including personal oral hygiene (the frequency of brushing per day, use of mouthwash and dental floss, and mouth breathing), personal health (halitosis, history of gastroesophageal reflux, and history of gastric ulcer), poor personal oral habits (smoking, drinking, chewing areca, frequency of consuming acidic foods), and mask use. After controlling for these potential interfering factors, the results showed that acid exposure and age increased the risk of severe periodontal disease (periodontal pockets detected by LA). These results were consistent with the findings of a Finnish study, which included fewer interfering factors. The results from the Finnish study showed that among workers with occupational exposure to sulfuric acid, 36.9% developed periodontal pockets; the ratio was only 30.9% in the control group. Moreover, the periodontal pocket incidence in the exposure group increased significantly with age [30]. Interestingly, halitosis was related with periodontal disease (CI 1.58 - 20.81, $p = 0.01$) and the use of dental floss reduced the risk of periodontal disease (CI 0.09 - 0.88, $p = 0.03$); however, these two factors were not risk factors for loss of attachment. A study of workers in metal processing plants in Brazil showed that after controlling for interfering factors, such as age, drinking, and smoking, the odds ratio for periodontal disease was 1.77 between workers with more than six years of exposure and those with no exposure, but these results applied only to workers who did not use dental floss [15]. The Finnish study, on the other hand, showed no significant correlation between periodontal disease and exposure [30]. These results showed that for workers with acid exposure, oral hygiene helped to prevent mild periodontal disease and had no significant prophylactic role for more severe periodontal diseases, such as loss of attachment, suggesting that acid exposure may interact with other oral factors that directly or indirectly result in severe periodontal problems. Therefore, we infer that acidic solutions can cause oral soft tissue lesions by one or more of the following mechanisms: 1) acidic solutions directly irritate soft oral tissue, such as the gums and periodontal tissue, and can directly disrupt cell function and arrangement of the soft tissue [5]; 2) acidic solutions may suppress the immune-protective components of saliva, thus indirectly affecting gingival or periodontal immunity, resulting in persistent gingival or periodontal inflammation, and aggravating periodontal disease; and 3) acidic solutions may damage the ability of saliva to balance the pH, resulting in an acidic oral environment, which, together with poor personal oral hygiene, smoking, drinking, and chewing areca, may cause bacteria to grow, thereby damaging the gums or periodontal tissue [31]. On the other hand, some researchers investigated periodontal tissue health and found that occupational acid exposure was not significantly related to periodontal disease [5, 21]. As a result, more long-term follow-up studies are

needed to clarify the relationship between different occupational acid exposures and oral soft tissue damage.

Previous studies showed that besides periodontal disease, occupational exposure to acid mist and acid solution may cause tooth damage [6, 15-21], especially tooth erosion [5]. In 2010, a Japanese study showed that the mean prevalence rate of tooth erosion among battery factory workers was 22.5%, which was also proportional to work history. In a report by Chikte et al [32], clinical examination showed that among electroplating workers, 60% had toothache and sensitivity, 76% had varying degrees of loss of tooth structure, and 25% had occupational tooth loss [32]. Petersen et al [20] reported that due to exposure to sulfuric acid mist, 56% of battery factory workers had tooth thinning and tapering, 29% reported tooth shortening, and 31% had tooth erosion; however, this study did not confirm the effect of occupational acid exposure on tooth erosion. In 1984, Gamble et al [33] showed a strong correlation between exposure to sulfuric acid mist and tooth erosion; tooth damage occurred as early as 4 months after a mean sulfuric acid exposure of 0.23 $mg/m^3$. In this study, the mean sulfuric acid exposure in the factories included in the survey was less than 0.066 $mg/m^3$, which may be related to more advanced engineering control of occupational acid mist exposure, the awareness of oral hygiene, and the use of protective equipment, resulting in a great reduction in occupational hazards. As a result, this study showed no significant correlation between acid exposure and tooth erosion.

In the evaluation of acidic exposure related dental caries, we found the mean DMFT score was 9.29±6.41 in control group and 6.65±5.57 in exposed group ($p<0.001$). A mean decayed tooth (untreated caries teeth) was 1.26±2.01 in control group and 1.68±2.39 in exposed group ($p=0.097$) (data not show). Compare with national oral survey, the Taiwan adult and elder oral health survey found a mean DMFT score was 11.51±6.22 and a mean decayed teeth (D) was 1.74±2.90 in the 18-34 years age group [34]. As a result, dental caries was not correlated with acidic exposure in our study population. The same results were also found in the UK [21], Japan [35] and Brazil [6] caries experience studies in acid workers.

Another interesting point in our study was the use of masks did not significantly reduce the risks. Personal protective equipment is a worker's last line of defense against workplace hazards, especially when all other controls set up to minimize risk and protect the worker have been exhausted. However, the efficiency of personal protective equipment is significantly reduced if it is worn incorrectly or if it does an inadequate selection. Employees need to be adequately educated the potential hazards and trained in how to wear protective equipment in workplace.

The limitation of our study included a cross-sectional study design and reporting bias of self-reported questionnaire. Diabetes would be an important factor for CPI. However, there were only 5 diabetes patients in our study population (data not show). The reason might be due to related young adult. Therefore, history of diabetes was not considered as a confounder for CPI.

# Conclusion

This study showed that occupational acid exposure during acidic solution work was an independent risk factor for periodontal disease. Even after correcting for dietary habits, occupational exposure time, exposure environment, and personal illness history, acid exposure was still related to oral health changes. It is important to strengthen occupational hazard control, educate workers on oral disease and related factors, and raise the awareness of oral hygiene, which are all the best solutions to improve the oral health of these workers.

# Declarations

**Ethics approval and consent to participate:** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Consent for publication:** N/A

**Competing interests:** The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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**Authors' contributions:** Wei-Liang Chen contributed to the design of the study, was responsible for the management and retrieval of data, contributed to initial data analysis and interpretation, drafted the initial manuscript. Wei-Liang Chen, Yuan-Yuei Chen, Wei-Te Wu, Ching-Huang Lai, Yu-Shan Sun, and Chung-Ching Wang decided upon the data collection methods. Wei-Liang Chen and Chung-Ching Wang were also responsible for the data analysis decisions. Chung-Ching Wang conceptualized and designed the study, supervised all aspects of the study, critically reviewed and revised the manuscript, and approved the final manuscript as submitted. All authors meet the ICMJE criteria for authorship.

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# Tables

**Table 1. Diagnostic criteria of oral health in the study**

Criteria of the Keels-Coffield clinical severity scales for dental erosion

| Level | Description |
|---|---|
| 0 | No erosion |
| 1 | Mild: Only the cusp tips are affected; shallow moon craters are present. |
| 2 | Moderate: Deep moon craters or depressions are preset and may coalesce. |
| 3 | Severe: Teeth are slick with little or no anatomy present; possible pulpal exposures. |

Criteria of CPITN score for periodontal disease

| Score | Description |
|---|---|
| 0 | The 1st marking of probe remained completely visible, without bleeding after probing |
| 1 | The 1st marking of probe remained completely visible, with bleeding after probing |
| 2 | The 1st marking of probe remained completely visible, with dental calculus (including supra-or subgingival calculus) |
| 3 | The 2nd marking of probe remained completely visible |
| 4 | The 3rd marking of probe remained completely visible |

Criteria of LA score for loss of attachment in periodontal disease

| Score | Description |
|---|---|
| 0 | CEJ was within the first marking |
| 1 | CEJ reached the second marking |
| 2 | CEJ reached the third marking |
| 3 | CEJ reached the fourth marking |
| 4 | CEJ reached beyond all markings |

CEJ: Cemento-enamel junction

**Table 2. The oral hard/soft tissue indices for study survey**

| Oral hard tissue | | | |
|---|---|---|---|
| Tooth erosion | | Dental caries | |
| No | Yes | No | Yes |
| Level 0 | Level 1 to 3 | DMFT=0 | DMFT>0 |
| Oral soft tissue | | | |
| Periodontal disease | | Loss of attachment | |
| No | Yes | No | Yes |
| CPITN=0 | CPITN>0 | LA=0 | LA>0 |

**Table 3. Distribution of demography characteristic in the study population between exposed and control group**

| | Variable | Control group N=157 | Exposed group N=152 | *p*-value |
|---|---|---|---|---|
| Sex | | | | 0.04* |
| | Female | 26.8% | 17.1% | |
| | Male | 73.2% | 82.9% | |
| Age | | 37.76±10.06 | 30.08±6.43 | <0.01* |
| Worked years | | 10.41±10.80 | 2.24±2.42 | <0.00* |
| #BMI | | 24.47±4.16 | 23.70±3.58 | 0.09 |
| Education | | | | 0.03* |
| | ≤ 12 years | 34.5% | 47.2% | |
| | > 12 years | 65.5% | 52.8% | |
| Smoking | | | | 0.92 |
| | No | 60.3% | 60.8% | |
| | Yes | 39.7% | 39.2% | |
| Drinking | | | | 0.08 |
| | No | 65.2% | 55.2% | |
| | Yes | 34.8% | 44.8% | |
| Chewing areca | | | | 0.01* |
| | No | 87.1% | 95.8% | |
| | Yes | 12.9% | 4.2% | |
| Mask use | | | | <0.00* |
| | No | 26.5% | 4.2% | |
| | Yes | 73.5% | 95.8% | |
| History of gastroesophageal reflux | | | | <0.01* |
| | No | 87.1% | 97.2% | |
| | Yes | 12.9% | 2.8% | |
| History of gastric ulcer | | | | <0.01* |
| | No | 92.3% | 99.3% | |
| | Yes | 7.7% | 0.7% | |
| Teeth brushing | | | | <0.00* |
| | Less than twice a day | 88.5% | 55.0% | |
| | Twice a day or more | 11.5% | 45.0% | |
| Mouthwash use | | | | <0.01* |
| | No | 78.8% | 62.4% | |
| | Yes | 21.2% | 37.6% | |
| Dental floss use | No | | | <0.00* |
| | Yes | 34.8% | 87.2% | |
| | | 65.2% | 12.8% | |
| Mouth breathing | | | | 0.12 |
| | No | 61.5% | 52.7% | |
| | Yes | 38.5% | 47.3% | |
| Halitosis | | | | 0.10 |

**p< 0.05 by t-test or chi-square test between exposed and control groups**

| | | | |
|---|---|---|---|
| No | 50.0% | 59.5% | |
| Yes | 50.0% | 40.5% | |
| ##Dietary habits with acidic foods （Q1 VS Q4） | | | <0.000* |
| Q1 | 24.8% | 31.1% | |
| Q2 | 36.3% | 17.4% | |
| Q3 | 22.9% | 15.9% | |
| Q4 | 15.9% | 35.6% | |

p< 0.05 by one-way analysis of variance (ANOVA) for dietary habits with acidic foods.

# BMI: Body mass index

## The total number of types of acidic food which subjects consumed more than once per week. We separated the data into 4 Quarter (Q1 to Q4) for analysis.

*p<0.05

# Figures

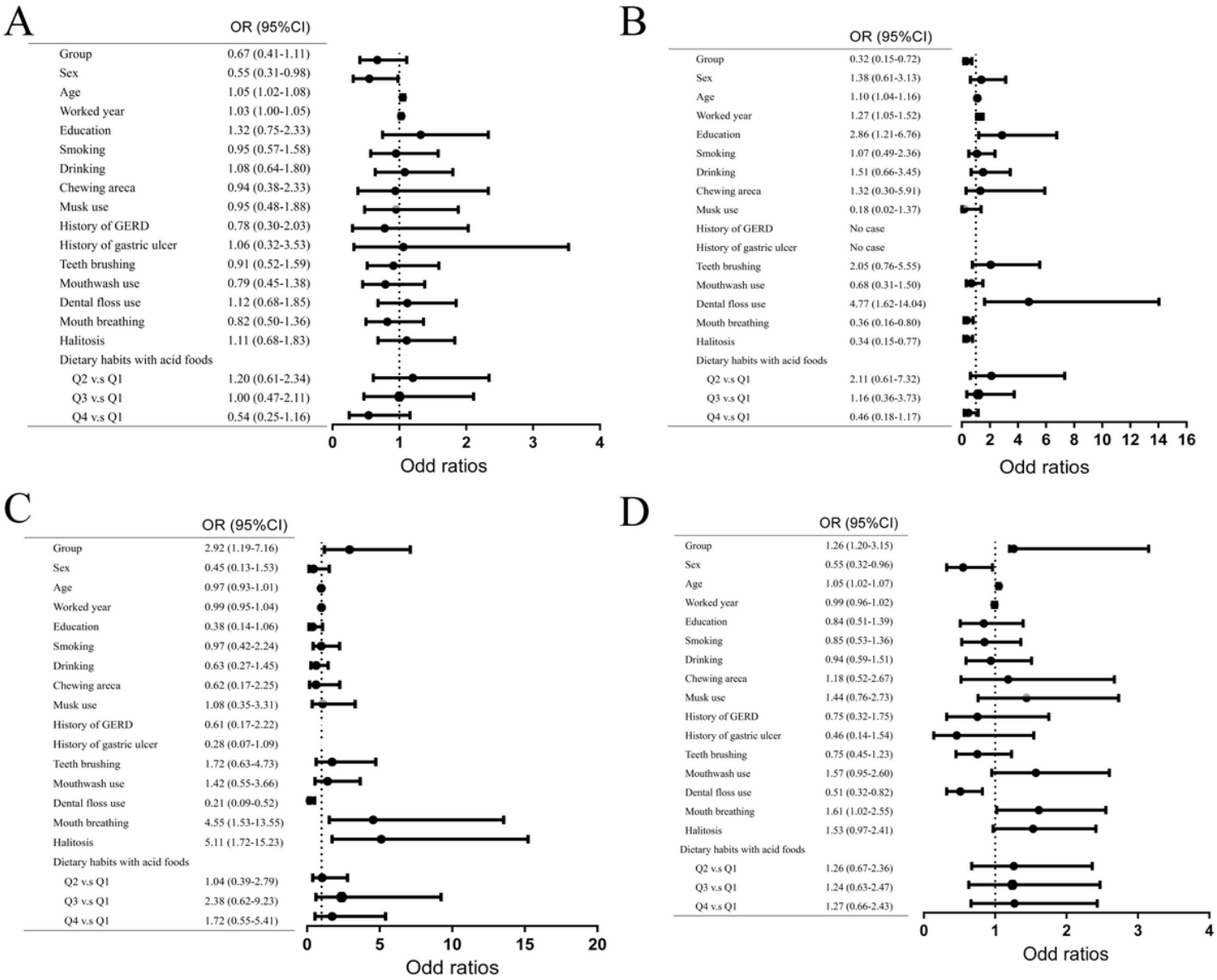
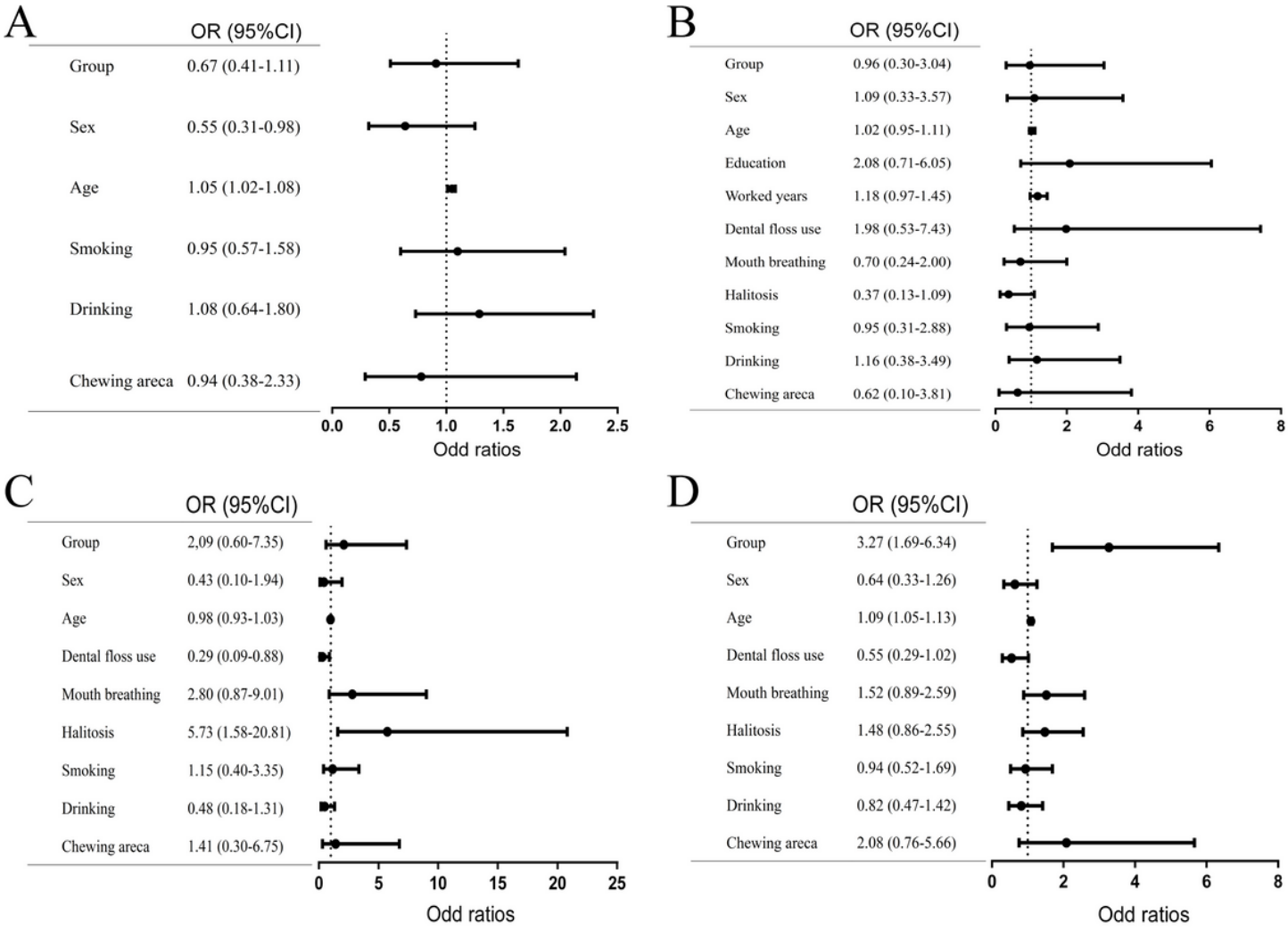



Figure 1

Significant factors associated with (A) tooth erosion, (B) DMFT, (C) CPITN, and (D) LA




## Figure 2

Multivariate logistic regression model of the association between exposed status and demography characteristic on (A) tooth erosion, (B) DMFT, (C) CPITN, and (D) LA