

Original Article

Dental Erosion in Workers Exposed to Sulfuric Acid in Lead Storage Battery Manufacturing Facility

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Received 27 January, 2010/Accepted for Publication 24 February, 2010

Abstract

Dental erosion, and specifically its symptoms, has long been studied in Japan as an occupational dental disease. However, in recent years, few studies have investigated the development of this disease or labor hygiene management aimed at its prevention. As a result, interest in dental erosion is comparatively low, even among dental professionals. Our investigation at a lead storage battery factory in 1991 found that the work environmental sulfuric acid density was above the tolerable range ($1.0\text{mg}/\text{m}^3$) and that long-term workers had dental erosion. Therefore, workers handling sulfuric acid were given an oral examination and rates of dental erosion by tooth type, rates of erosion by number of working years and rates of erosion by sulfuric acid density in the work environment investigated. Where dental erosion was diagnosed, degree of erosion was identified according to a diagnostic criterion. No development of dental erosion was detected in the maxillary teeth, and erosion was concentrated in the anterior mandibular teeth. Its prevalence was as high as 20%. Rates of dental erosion rose precipitously after 10 working years. The percentages of workers with dental erosion were 42.9% for 10–14 years, 57.1% for 15–19 years and 66.7% for over 20 years with 22.5% for total number of workers. The percentages of workers with dental erosion rose in proportion to work environmental sulfuric acid density: 17.9% at 0.5–1.0, 25.0% at 1.0–4.0 and 50.0% at 4.0–8.0 mg/m^3 . This suggests that it is necessary to evaluate not only years of exposure to sulfuric acid but also sulfuric acid density in the air in factory workers.

Key words: Dental erosion—Occupational health—
Battery manufacturing facility—Sulfuric acid—Oral health

Introduction

Dental erosion can be an occupational

hazard in work environments where acid gases or mists act directly on the tooth, causing surface decalcification, clouding and impairment.

Table 1 Diagnostic criteria for dental erosion*

Degree of dental erosion	Definition
First degree:	Only the tooth surface is impaired.
Type 1:	The enamel is slightly opaque.
Type 2:	Impairment is within the enamel, not reaching the dentin.
Second degree:	Impairment reaches the dentin, with exposure of the dentin showing characteristic yellow.
Type 1:	Wedge-shaped impairment is deepened.
Type 2:	The outer layer of the dentin on the lip side has been exfoliated.
Type 3:	The whole tooth, especially the cusp of mandibular incisor, has been impaired, or has been subjected to attrition by decalcification. Dental erosion 3rd degree:
Third degree:	The dentin is completely exposed from impairment, which almost reaches the pulp or reaches the pulp itself. Approximately 50 percent of the crown has been impaired.
Fourth degree:	More than 2/3 of the crown has been impaired.

* Diagnostic criteria based on "Industrial Dental Hygiene" presented by Japan Dental Association

In other words, dental erosion develops when the surface of the tooth enamel has failed to adapt to the environment. In this process, exposure to abnormal levels of acid density makes normal maintenance of the tooth enamel impossible.

Yoshizawa¹²⁾ classified degrees of tooth impairment as a diagnostic criterion. Morimoto also proposed a diagnostic criterion in the *Journal of Dental Health* in 1969⁷⁾. Then, the Japan Dental Association published "Industry Dental Hygiene", in which it introduced its own diagnostic criterion. Morimoto reported that multiplying work environmental acid density by exposure time allowed prediction of dental erosion⁷⁾. However, continuous sampling of the work environment and ascertaining exposure time in each worker makes this difficult to achieve in practice. In the lead storage battery factory we selected for investigation, the work environmental sulfuric acid density was above the tolerable range (1.0 mg/m^3)⁵⁾ and long-term workers had dental erosion. Therefore, workers handling sulfuric acid were given an oral examination and rates of dental erosion by tooth type, rates of erosion by number of working years and rates of erosion by sulfuric acid density in the work environment investigated. Where dental erosion was diagnosed, degree of erosion was identified according to a diagnostic criterion.

Materials and Methods

1. Subjects

In June 1991, we cross-sectionally examined 40 workers at a battery charging workshop in a lead storage battery manufacturing facility (sex: male, average age: 42.4, average working years: 8.8, below described as "sulfuric acid-treating workers").

Dental examination for dental erosion was carried out on a total of 40 workers. Items examined were dental erosion and dental caries, in terms of damage to intra-oral hard tissues, and oral mucosal disease, periodontal disease and tartar adherence, in terms of damage to intra-oral soft tissues. For this examination, intra-oral photographs were taken. Dental check-ups at the manufacturing facilities normally covered dental caries and periodontal disease. Since the present report focuses on the development of dental erosion through the work environment, dental erosion due to the development of dental caries or periodontal disease was excluded.

2. Identification of dental erosion

A 3-degree diagnostic criterion was used to identify dental erosion. However, application of this criterion to occupation-induced dental erosion may fail to detect certain clinical symptoms. As workplace management is advanced,

Table 2 The examination results about dental erosion for each worker

Subject	Working period	E1-1	E1-2	E2-1	E2-2	E2-3	E3	E4
A	16yr. 10m.		1					
B	10yr. 6m.		2					
C	16yr. 2m.		3					
D	12yr. 11m.		2			2		
E	23yr. 1m.		2			2		
F	10yr. 0m.				1	2		
G	19yr. 0m.					4		
H	18yr. 5m.		1			1		1
I	23yr. 0m.					1	4	1

Notes: E1-1: dental erosion 1st degree type 1; E1-2: dental erosion 1st degree type 2; E2-1: dental erosion 2nd degree type 1; E2-2: dental erosion 2nd degree type 2; E2-3: dental erosion 2nd degree type 3; E3: dental erosion 3rd degree; E4: dental erosion 4th degree



Fig. 1 Subject A



Fig. 2 Subject B

we were able to adopt a diagnostic criterion that allows early detection of early symptoms of dental erosion. This criterion (Table 1) was based on “Occupational dental health” presented by the Japan Dental Association⁴⁾.

The values obtained were statistically analyzed with the Mann-Whitney *U*-tests to identify significant differences between *x* workers with dental erosion and workers with no dental erosion. In this study, the data analysis and graphic preparations were performed using the SPSS 17.0J (SPSS Japan Inc., Tokyo, Japan) and Microsoft Excel 2007.

Results

1. Examination results on dental erosion

The examination results on dental erosion for each worker are shown in Table 2. In addition,



Fig. 3 Subject C

the diagnosis is described in Figs. 1–9. The photograph shows the location of erosion (A–I). Examination results for 9 workers are shown in Table 2, including degree of dental erosion and number of teeth. The attached images indicate why dental erosion was diagnosed.



Fig. 4 Subject: D



Fig. 5 Subject: E



Fig. 6 Subject: F



Fig. 7 Subject: G

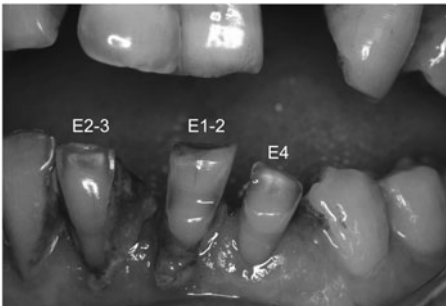


Fig. 8 Subject: H



Fig. 9 Subject: I

2. Percentage of dental erosions by tooth type

Figure 10 shows the percentage of dental erosions by tooth type. No development of dental erosion was identified in the maxillary teeth. Erosion was concentrated in the anterior mandibular teeth. Prevalence of erosion in the mandibular central incisors was especially high: 20%.

3. Percentage of workers with dental erosion by number of working years

Figure 11 shows the percentage of workers with dental erosion by number of working years. Rates rose precipitously after 10 working years. The percentages of workers with dental erosion by number of working years were 42.9% for 10–14 years, 57.1% for 15–19 years and 66.7% for over 20 years, with 22.5% for

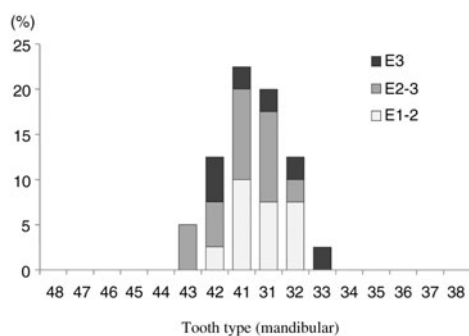


Fig. 10 Percentage of dental erosion by tooth type in mandible in lead storage battery factory workers exposed to sulfuric acid

E1-2: dental erosion 1st degree type 2; E2-3: dental erosion 2nd degree type 3; E3: dental erosion 3rd degree

total number of workers. A statistical comparison of working years between workers with dental erosion and workers with no dental erosion revealed that number of working years was significantly longer in the former group ($p < 0.05$).

4. Percentage of workers with dental erosion by environmental sulfuric acid density

Figure 12 shows the percentage of workers with dental erosion by environmental sulfuric acid density. The rates of workers with dental erosion rise in proportion to work environmental sulfuric acid density: 17.9% at 0.5–1.0, 25.0% at 1.0–4.0 and 50.0% at 4.0–8.0 mg/m^3 .

Discussion

1. Percentage of dental erosion by tooth type

Most reports in Japan regarding location of dental erosion have focused on the mandibular teeth^{1-3,6-9}. The present study also found that development of erosion was focused on the mandibular teeth, and specifically the anterior teeth. Dental caries is generally rare in this location, indicating that development of erosion was probably environmentally induced by exposure to airborne sulfuric acid. On the other hand, some of the maxillary and mandibular posterior teeth which were judged clear of erosion at the time of

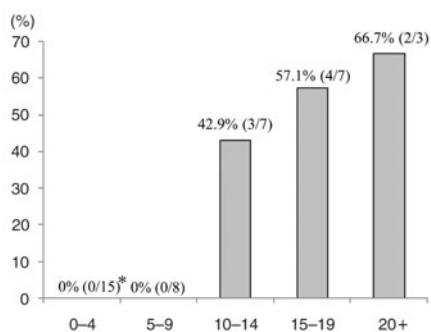


Fig. 11 Percentage of workers with dental erosion by number of working years in lead storage battery factory

* (No. of subjects with dental erosion/no. of subjects examined)

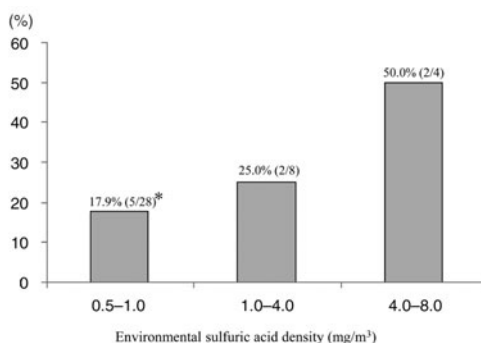


Fig. 12 Percentage of workers with dental erosion by environmental sulfuric acid density measured in factory workshop

* (No. of subjects with dental erosion/no. of subjects examined)

this examination may have had symptoms of dental erosion previously but been treated. Specifically, although 3 out of the 9 workers received dental treatment for the maxillary anterior teeth, it is unknown as to whether this was for caries or erosion. One-time investigations such as the present one are unable to monitor long-term tooth changes, indicating the importance of continuous monitoring.

2. Percentage of workers with dental erosion by number of working years

Since the percentage of workers with dental erosion rose precipitously after 10 working

years, measures for workers with approximately 10 years' or more years' exposure are important. The percentage of workers with dental erosion among total number of workers was 22.5%, which was lower than the 31.3% reported by Nishimura *et al.*⁸⁾ in a study dealing with a dye manufacturing facility. The sulfuric acid density in the work environment in the dye manufacturing facility was 44.0–88.0 mg/m³, more than 10 times that reported in the present study, which suggests that dental erosion is significantly related to sulfuric acid density in the work environment.

It is possible that the development of dental erosion was hidden by prior treatment of dental caries in the maxillary anterior teeth in this study.

There are a number of reasons why erosion rarely occurs in the anterior maxillary teeth. It has been reported that erosion is likely to occur in the anterior mandibular teeth. A possible reason is that, as Figs. 1–9 shows, the mandibular anterior teeth, and especially their tips, are likely to incur damage through friction to the enamel during occlusal contact with the maxillary anterior teeth, particularly if the amount of saliva is insufficient to provide buffering. As a result, the enamel may receive considerable damage before re-mineralization can occur. These factors are believed to explain the high prevalence of dental erosion in the mandibular anterior teeth.

3. Percentage of workers with dental erosion by environmental sulfuric acid density

In earlier studies, the percentage of workers with dental erosion rose in proportion to work environmental sulfuric acid density, indicating the importance of monitoring sulfuric acid density in the air^{8–11)}. Few studies have investigated the relationship between dental erosion and sulfuric acid density in the air, indicating the usefulness of the present results. It is necessary to evaluate not only length of exposure, but also density of sulfuric acid in the air.

For hygienic prevention of dental erosion, reduction of exposure time and wearing of protective masks are effective. Mouth rinsing

with drinking water during working hours and rest periods is also considered to be effective for removal of intra-oral sulfuric acid. The results suggest that the management of facilities in which workers are likely to be exposed to sulfuric acid should take steps to keep such exposure to a minimum, for example, through automation of manufacturing processes, as this is likely to be the best way to prevent dental erosion.

Conclusion

Where dental erosion was diagnosed, the degree for each case was identified according to a diagnostic criterion. The results were as follows:

1. No development of dental erosion was detected in the maxillary teeth. Erosion was concentrated in the mandibular teeth, especially anteriorly.

2. Prevalence of dental erosion caused by sulfuric acid gases and mists was as high as 20%. Rates of dental erosion rose precipitously after 10 working years.

3. The percentages of workers with dental erosion were 42.9% for 10–14 years, 57.1% for 15–19 years and 66.7% for over 20 years, with 22.5% for total number of workers. The percentage of workers with dental erosion rose in proportion to work environmental sulfuric acid density: 17.9% at 0.5–1.0, 25.0% at 1.0–4.0 and 50.0% at 4.0–8.0 mg/m³.

These results suggest that it is necessary to evaluate not only length of exposure, but also density of sulfuric acid density in the air.

Acknowledgements

We would also like to thank Professor Masao Nishimura, Tokyo Dental College.

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