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The Evolving Decline in Industrial Dental Erosion and It's Revised Detection and Management

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Summary

Japanese occupational safety and health laws require dental examinations for workers who have workplace exposure to strong acids and specific special chemicals. This study's dental examinations have been performed over the past eight years. Data in the form of annual images were collected during exams at a modern chemical production facility which uses various concentrations of nitric, hydrochloric and sulfuric acids with area ventilation and worker environmental chemical protection for those substances. Images of the front teeth and tongue were obtained once a year to monitor and improve detection of subtle dynamic changes in tooth surfaces and oral mucosa. Dental information concerning acid workers has reported a marked decline in the incidence of moderate to severe dental erosion in the past few decades. An innovation in the exam methods led to several interesting findings. Dental erosion in a reduced form was identified in about half of the workers, which suggests that erosion is still occurring even at a modern production facility. Dental erosion was most likely to be identified in plant workers with historical and routine exposures to acid quantities in excess of 100Kg. of acid exposure. In some workers, a subtle progression of dental erosion, not previously diagnosed through the normal on site visual exams, has been identified through digital dental images taken chronologically.

Introduction

Japanese occupational safety and health laws for employers require dental examinations every 6 months, but only require a cursory visual examination of teeth and supporting tissue to gauge exposure effects of acids, phosphorus, hydrogen fluoride and other work place chemicals classified as hazardous. The examination which generally includes the tongue, jaw and face, is usually performed by a dentist. During previous decades, reports of moderate to severe erosion were commonplace in these facilities where acids are routinely used in production or commercial processes[1,2]. But reports have declined significantly in the past few decades since the law took effect and additional economic changes have made significant improvements in production methods and other working conditions. These factors also have significantly decreased worker exposures to hazardous chemicals at manufacturing plants. This was evident in our interesting findings at the eighth year of an ongoing study

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which included the addition of annual photo studies of the workers dental health at a small modern chemical production plant.

Materials and Methods

Condition of facility

The study was performed at a 10 year old very modern production facility which later received ISO 9001 and 14001 compliance certification. The facilities' management has developed an elevated social and environmental awareness of conditions in and near their plant. Such high awareness has not been routinely found at other similar companies of this size.

The main production includes various laboratory reagents, chemicals for the pharmaceutical industry and other chemical products. Many organic solvents and chemicals legally defined as part of the special chemicals group are used for on–site production of their products. Various concentrations of nitric, hydrochloric and sulfuric acids are also used. Worker exposures to chemicals, solvents and acids varied by amount, duration, concentration and type as they rotated between job positions or other work locations at the plant. Exposure ranged from several hundred liters to small amounts (less than 100Kg).

Production involves the transfer, mixing and drying of various quantities of chemicals relative to the batch requirements. Each of the steps may provide exposure risks. Preparing measured quantities of materials normally requires transfer from a large storage container to a smaller one. It then requires transfer to a mixer or reaction vat and later transfer for packaging. These steps are done manually in many cases which requires close contact with chemicals and their associated mists and vapors even in a properly ventilated area.

The total number of workers at the plant varied from year to year, reaching a total of 36 currently. Our target number of workers for the study was 13 to 17 (annual average 14.9). Their ages ranged from 23 to 46 in 1996 and from 26 to 54 in 2004. For example, dental examinations were required by law for 15 of the workers in 2004. Their length of employment at that time ranged from 5 to 30 years. Some transferred to this newer location from similar jobs and responsibilities at other plants. 10 of the workers were continuously included in all of the study's last 8 years at this facility.

Workers who directly handle chemicals or are directly involved in the production process are classified as acid workers. About 20 are classified as non acid workers. About 1/3 works of them in production areas, but without handling acids routinely on the job. Another 1/3 are in quality control where they test products for content and purity, but only occasionally use acid quantities considered very small. Another 1/3 works in plant administration offices. The 20 workers are not specifically required to have dental examinations.

Examination Methods

During the study, a normal examination (legally defined) was performed approximately twice a year by the same dentist over 8 years. Patients were evaluated in accordance with J.D.A. standards [3] (Table 1). There were no control groups examined as part of the study to evaluate possible erosion through other causes. The study was not conducted to determine or identify any possible correlation between any specific environmental concentrations of acids or chemicals in the work place and any incidence of dental erosion. Thus no environmental measurements were attempted or taken. The photo study was performed in conjunction with the required dental examinations needed to keep the

Table 1 : Acid Dental Erosion Classifications (Japan Dental Association)[3]

Class	Symptom
±	mild or slight erosion of enamel surfaces or indeterminate level
E 1	erosion confined to enamel
E 2	erosion confined to dentine
E 3	erosion with near total dentin loss
E 4	erosion with largely lost crown (generally more than 2/ 3 of crown)

company in compliance with specific laws which primarily require monitoring of dental erosion in a company's chemical workers.

The photo study approach was adopted in 1996. Photo images (front teeth and tongue) were taken on an annual basis to get a more comprehensive record of workers' oral condition, although they were not legally required. Initially, a film based camera was used to record the images taken between 1996 and 1998. Later, a digital camera was introduced and used from 1999 to 2004. The images were stored in a trial health check card which utilized a photo database (Microsoft Access TM). Digital worker dental images, documenting their condition over time, have been cataloged by ID card number. They were used both for monitoring symptoms and in the education of both the workers and health care workers.

Results

General conditions

The general interior environmental conditions of this facility are very good, although a slight chemical odor has occasionally been detected in the production room. Entry is restricted in a few areas, so no direct evaluation is possible. At the perimeter, there is no obvious odor or vapor evident. Overall, the conditions both inside and outside of the plant are above average and well maintained.

Prevalence of dental erosion

Table 2 shows the number of workers diagnosed with dental erosion each year. Dental erosion was identified in 5–10 workers (an annual average of 48.2% in routine examinations and 50.2% in photo examinations). Chemical workers who presented identifiable dental erosion were employed in jobs which had acid exposure ranging from 5 to 30 years. Other workers without identifiable dental erosion also had similar job based exposures of similar duration to acids and chemicals, but no direct correlation between the incidence of dental erosion and worker job responsibilities was obvious. The data and observations provided no indication that any direct relationship exists between exposures and the incidence of dental erosion in these workers.

Table 3 shows acid quantities in historical use per exposure and the number of workers identified with dental erosion. Exposure ranges could be divided by exposure level ; more than one hundred–kilogram (large quantity group) and the less than 100Kg. (small quantity group). Although the acid types were limited to 3, (nitric acid, hydrochloric acid and sulfuric acid)the concentrations in use varied widely. A larger number of workers with dental erosion had usual exposure to more than 100 Kg. of acid than workers with exposure of less than 100Kg. acid (χ^2 test, $p< 0.01$). Details of acid quantities were gathered in worker interviews during routine six month examinations. The kinds and concentrations of acids were not considered in the comparisons because each exposure uniquely

Table 2 : Yearly prevalence of dental erosion among acid workers ; ordinary exam vs photo exam

date	ordinary exam*	photo exam*	(workers total : T)
1996.05	6	7	(16)
1996.11	6	—	(16)
1997.05	7	10	(15)
1997.12	8	—	(15)
1998.05	8	9	(17)
1998.12	5	—	(13)
1999.06	5	5	(15)
1999.12	6	—	(13)
2000.07	8	7	(15)
2000.12	8	—	(14)
2001.07	8	7	(14)
2002.01	7	—	(14)
2002.09	9	8	(16)
2003.03	9	—	(16)
2004.03	8	7	(15)
Average	7.2	7.5	(15)
* / T %	48.2%	50.2%	

Notes) Ordinary exam was performed every six months, but photographed annually.
Whole diagnosed grades are not over ± (mild or slight erosion of enamel surfaces or indeterminate).
Normal 2003.9 month exam was unavailable due to events of scheduling at the facility.

Table 3 : Industrial chemical workers and acid quantities at histrical usual use (2004)

Dental erosion	Acid amount in historical regular use		Total
	≧100Kg*	<100Kg	
Without	0	8	8
With	5	2	7
Subtotal	5	10	15

*Workers with usual exposure to more than 100Kg of acid had an increased incidence of dental erosion (χ^2 test ; $p<0.01$)

varied by location and the specific job performed.

Diagnostic differences between routine exams and photo examinations

The 1997 photo examination identified 3 additional workers with dental erosion than were identified and diagnosed through routine examination. In other years a similar number of workers were also identified that had not been diagnosed through standard routine examinations. All incidents of dental erosion were diagnosed as grade (mild or indeterminate level). Erosion at this low grade level makes any specific cause difficult to determine without a strict control group since unidentified causes could be a contributing factor. None was used or required as the specific causes were not a goal or of interest in this study.

Very subtle changes in the surfaces of teeth

Progression of erosion had not been evident in routine examinations, although some variations oc-

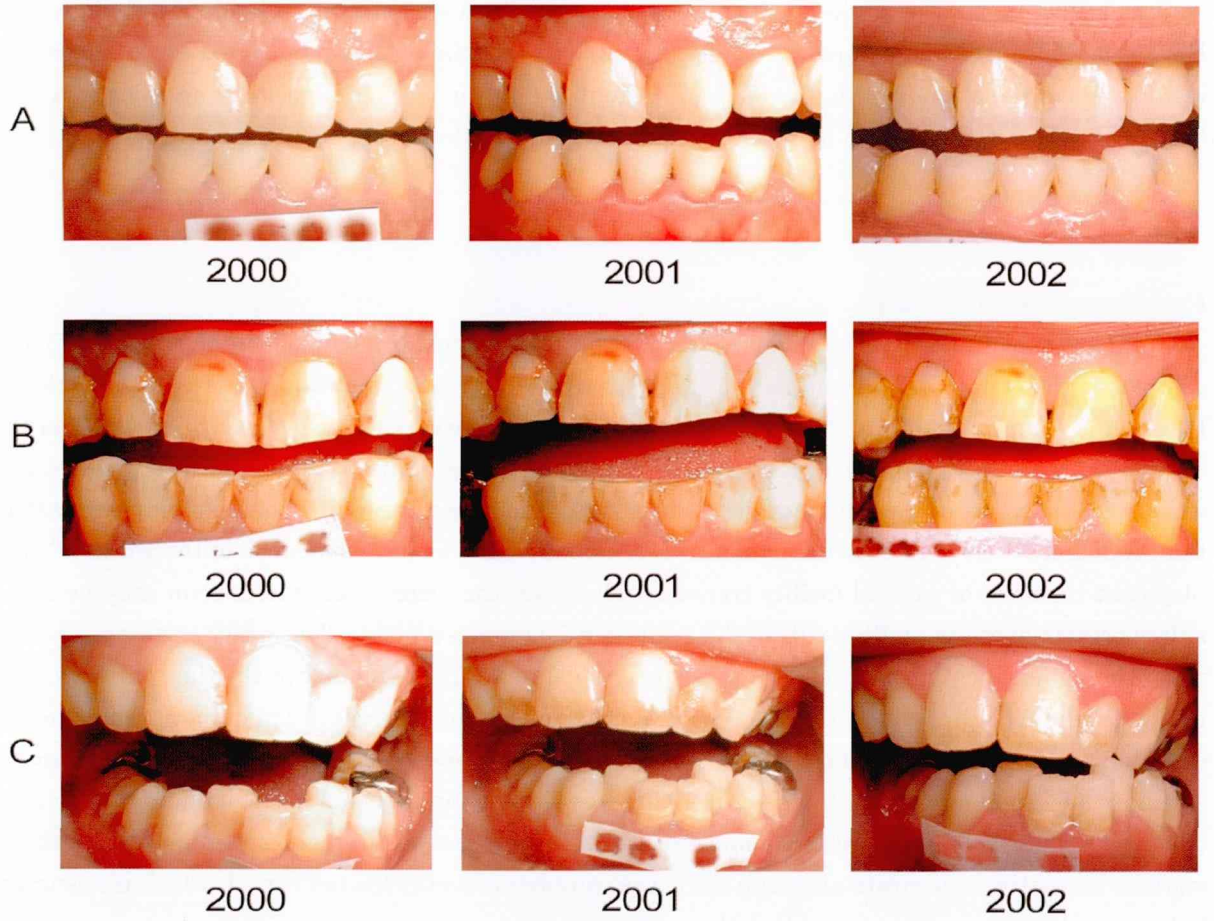

Fig. 1：Examples of yearly progressive changes in teeth (Case A, B and C)
Case A with slightly increased notched edge and slightly decreased surface luster of teeth.
Case B with flattened edge and slight exfoliation of upper right incisor surface at year 2002.
Case C with slight loss of luster on lower tooth surfaces. (the changes can be seen are selected during 8 years.) All three cases had historical exposure to an environment which included acid quanitities more than 100 liters per exposure.

curred in the number of teeth effected in one worker. Changes in those variations were not always evident in the routine exams. In photo examinations, in which even subtle changes in progression are relatively easy to identify, a progression of erosion was identified in some workers which had not been identified during the regular routine examinations (Fig.1). All of those identified had historical exposure to more than 100Kg. of acid per incident. During an inquiry in case A, of working conditions during 2002, he mentioned he had been strongly conscious of exposures to environmental acids during very busy times in production. In another case, identified as B, the worker sometimes used large quantities of nitric acid to wash vessels without the protection of a draft chamber. In case C, he described a period about 10 years prior, when hot hydrochloric acid was used almost daily in production. The types and concentrations of acids to which they have contact or exposure vary according to the company's production needs.

Chemical effects on limited face, tongue and oral soft tissues

Many organic solvents were in routine use (specifically toluene, xylene, hexane and trichloroethylene). Metabolic substances were identified in many of the worker's urine samples (ex.16 of 25 organic solvents workers in 2004). All of the levels were within the first distribution grade of Japanese organic cabinet regulation limits. Various chemicals, legally defined as special chemicals, are in use

at the plant. Some of the workers presented symptoms which varied from individual to individual. However, the causes and symptoms could not clearly be attributed to chemical exposure. Over the last 8 years of the study, nothing unusual was identified in the faces, tongues and or other oral soft tissues of workers which could be speculated as due to or an effect of chemical exposure.

Discussion

Prevalence of dental erosion

Ordinary examinations over eight years (Table 2) provided little evidence of any significant changes in the overall dental condition of workers who were required to undergo the examinations. During the examination term, there were variations in the workers who were identified with dental erosion, as well as variations in the overall number of participants. Also during the term, some workers' job responsibilities changed and others left the company through normal employment attrition. A diagnosis error in classifying dental erosion may exist as a consequence of the workers' employment turnover or normal facility transfers. However, the primary diagnosis error may be a result of erosion diagnosis falling within the grade of mild or questionable. This grade is an ambiguous zone where identification depends primarily on the feelings of the examiner at the time of the examination. Eight of the acid workers have been diagnosed as having dental erosion of more than 3 years duration (underwent more than 6 examinations). The incidence of erosion in these workers can be calculated as about 49% (overall incidence). This was close to the expected norm of dental erosion incidence as routinely diagnosed in chemical workers. It indicates that diagnosis of dental erosion in workers is relatively accurate although the actual number of teeth effected varied, which is assumed to be caused by diagnostic error within the grade.

Workers with a history of routine exposure to large quantities of acid ($\geqq$100Kg per exposure) have a greater tendency to be diagnosed with dental erosion than workers exposed to lower quantities ($\geqq$ 100Kg a time, $p< 0.01$), (Table 3). The number of eroded teeth identified in each worker varied little and the number of workers identified with dental erosion remained relatively stable. This incidence of dental erosion is strongly suggested to be due to environmental exposure to acid. Although incidence and severity of dental erosion have been declining, it still exists in a very mild form, even at a very modern facility.

Surface changes in teeth evaluated annually

Cases A, B and C in Fig.1 are typical examples of year on year changes in the surfaces of teeth. All 3 of the workers identified through photo comparison had historical exposures to more than 100Kg. of various acids (mainly nitric and hydrochloric acid) per exposure. However, there is no clear evidence of damage attributable directly to environmental exposure to acids. Monitoring with accurate measurement of environmental acid concentration is desirable and could provide important data concerning the incidence in contrast to the severity of identified worker erosion. There were no environmental acid concentration measurements taken during this study which would quantify workplace exposures, however the dental erosion identified in workers can not be directly discounted through other incidental non work place factors. The subtle changes identified in the surfaces of teeth were not found in routine exams but rather through image comparison. In detecting or identifying subtle annual dynamic changes in teeth, the photos were indispensable. Since the 1980's, respiratory cancer attributed to sulfuric acid exposure has been receiving a lot of attention[4–13]. It can be

assumed that early identification of subtle changes in the surfaces of teeth might be a correlatable indication of possible cumulative respiratory damage through acid exposure.

The incidence could have contributing factors. Cylindrical pipe area ventilators are usually used in handling hazardous chemicals. When workers use the cylindrical pipe area ventilators (about f 100mm), the fixed intake ports prevent optimum placement due to their fixed position. They are inflexible to the needs of a situation or work being performed. In addition, the intake ports are not flanged to allow a larger effective area. Even when using protective masks, exposure to high concentrations can occur which may lower the masks protection. This is one possible reason why dental erosion is still evident even at this modern facility.

Since organic solvents are the most frequently used chemicals, worker's masks are routinely equipped with filters specific to that solvent. They usually exchange filters to provide specific protection as their work environment changes. However, in past records of worker interviews during regular exams, workers' statements of their using environment specific filters for protection were inconsistent. When their environments included a combination of both acids and solvents as production required, a few workers failed to exchange filters to match the new working conditions. This could also be a contributing factor in cases of dental erosion.

Dental erosion through non work related causes

According to some references the prevalence of patients with erosion through unknown causes was 6.3 to 37.7% (with an average incidence of 14%) [2,14–17]. In this study, a similar number of workers or about 14% of those diagnosed could be expected to have dental erosion through unidentified causes. Even when taking into consideration dental erosion caused by non work reasons (about 14%), a clear relationship still exists between exposures to larger acid quantities and the diagnosis of erosion in workers who were exposed (Table 3). This strongly suggests that the majority of dental erosion at this facility is through environmental acid or chemical exposure.

Chemicals effects on limited face and oral soft tissues

Organic solvents and various legally defined special chemicals are used at this facility. Exposure to these chemicals brings a high probability that workers will develop symptoms in soft tissues such as oral mucosa. However, no special symptoms were detected in oral areas other than teeth during the 8 years of this study. Although oral mucosa soft tissue has good recovery characteristics from minor acid irritation, teeth have no such characteristics and so environmental acid exposures produce the subtle changes that were seen in workers' teeth, and there are relatively long lasting evidence of possible exposures. In photos, comprehensive images of limited face, lip, oral mucosa and tongue fine details can be easily seen.

Comparison of between photo examination and routine examination

The area of dental imaging, especially in field studies, has seen only very limited general use of photographic images for diagnosis, primarily because a patient's current oral condition is relatively easy to inspect directly without any additional special apparatus. Digital photography has eliminated nearly all of the film based imaging problems and extra costs. In 1997, when this study began, film based imaging was the most viable option. Initially there were differences between routine exams and the photo exams. This may have been due to a diagnostic error in the quality and clarity of those early photo images. Now, even normal consumer grade digital cameras have more than suffi-

cient resolution, ease of use in taking close up images and have a very low cost per image. The photo images can be easily stored digitally on a computer using database software which is also well suited to health care worker assistance in quickly locating images for comparison. Progression of tooth surface change has not been routinely identified through normal examination cards which record routine grading and diagnosis. Digital dental card records are useful in managing dental erosion and can be highly recommended for use by industrial dentists.

Conclusion

At a small modernized chemical production facility, the management of dental erosion in workers has been photo documented with digital images over the last 8 years. Dental erosion at a mild or indeterminate level has been identified in some workers over the last 8 years. A correlation between workers with dental erosion and acid amounts in use ($\geqq$100Kg. per exposure) was significant ($p<0.01$). Dental erosion still exists at a modernized facility, although in a declining form. In some of the workers with dental erosion, subtle changes in teeth were only identified through their yearly digital photo images. The cause was considered to be environmental acid exposure, through quantities in use and statistical expectations for workers. No symptoms were identified in oral areas other than dental erosion in workers who used organic solvents and various other special chemicals. Health check cards utilizing popular database software have been useful in identifying subtle time based progression of erosion in teeth and also in worker education. Awareness of the earliest stage of dental erosion or earlier identification of subtle changes in the surfaces of teeth could not only help prevent additional dental erosion, but could also be an indicator of respiratory damage by acids.

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抄録：軽症化する歯の酸蝕症とその管理

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小規模化学工場において，労働安全衛生法に基づく特殊歯科健康診断を行っている．その8年間の経過の中でいくつかの興味ある所見が得られた．この事業場は10年ほど前に設立され，近代化された局所排気装置等を備えている．主に各種試薬類，医薬品基剤等を製造しており，有機溶剤，特定化学物質等が多種使用され，酸は硝酸，塩酸，硫酸が多く扱われている．歯科特殊健康診断の対象者は毎年，約16名（労働者総数約36名）であった．「歯の酸蝕症」診断は日本歯科医師会基準にしたがって行われた．6ヶ月毎の通常診断とは別に，年に一回，一部顔面を含めた舌および前歯の写真を撮影し，その動的観察を行った．これらの診断は8年間，同一歯科医師が行った．「歯の酸蝕症」を有すると診断された者は毎年7名程度あり，酸蝕度はいずれも±の範囲であった．酸取扱い経験量の少ない者に対して，多量の酸取扱い者に「歯の酸蝕症」を有する者が多く見られた（$p<0.01$）．また，多量の酸に暴露される数名において，歯の表面に酸によると思われる微細な経年変化が写真上で見られた．このような変化は通常診査（視診）では認められなかった．近年，職業性「歯の酸蝕症」は見られなくなったという認識が広まっている．しかし，今回，近代化された作業環境において，なお「歯の酸蝕症」の存在が認められ，また数例については，それらが進行する状況も認められた．微細な歯の表面変化の把握は，「歯の酸蝕症」のみならず，酸による呼吸器系障害等の予防にもつながると期待された．