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ORIGINAL ARTICLE

Wear of teeth due to occupational exposure to airborne olivine dust

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Abstract

Objectives. To clarify whether high tooth wear of employees in a mining industry that extracts the mineral olivine could be associated with airborne dust exposure in their working environment. ***Method.*** The cumulative exposure to airborne mineral dust for the workers in the company was calculated on the basis of their period of employment multiplied by the airborne olivine-dust concentrations, which have been monitored continuously during the past 20 years for all divisions of the company. After invitation, 85% of the employees ($n = 191$) were examined clinically and their dentitions were photographed and duplicated in plaster casts. Four clinicians, working independently, examined the sets of casts/photographs for tooth wear and ranked these from most to least. Two groups of employees were compared with regard to tooth wear, i.e. the 30% with the highest (case) and the lowest (control) estimated dust exposure levels. Tooth wear in the case and control groups was compared using a non-parametric test based on rankings (Mann-Whitney test). ***Results.*** Tooth wear differed significantly between the workers in the low and the high mineral dust exposure groups ($p < 0.001$). The differences were also apparent within three age subsets, although statistical significance was reached only in the 34–44 years subset ($p = 0.002$). Considerable individual variation was noted within the three exposure groups. ***Conclusion.*** Workers with high exposure to airborne olivine dust may contract considerable tooth wear.

Key Words: *Dentistry, mining, occupational health, tooth attrition, tooth erosion*

Introduction

Tooth wear is a natural process and is normally of little concern. However, severe tooth wear in some individuals usually requires complex and expensive restorative therapy to prevent pulpal pain and avoid endodontic complications. Identifying the causative factors for severe tooth wear is difficult, as there are multiple factors that may contribute, and usually more than one factor is involved. The individual's age must always be considered primarily, because teeth demonstrate physiological wear caused by corrosion, friction, and intra-tooth stress. Dramatically augmented loss of tooth substance has been seen in individuals with extensive intake of acidic food and drink, gastro-oesophageal reflux disease and eating disorders. Other important individual risk factors are the quality of the enamel and of the saliva, the daily dietary composition, parafunctional orofacial muscular activities, number of occluding tooth pairs, use of some medications that interfere with oral conditions, and so on. There are also indications that exposure to environmental acids and abrasive dust may contribute to tooth wear. Several analytical studies using multivariate regression statistics have failed to identify the relative and synergetic effects of independent variables on tooth wear [1]. Hence, the processes that lead to tooth wear are complex and probably highly dependent on individual conditions.

Excessive tooth wear has also been linked to abrasive airborne particles in epidemiological studies in countries with desert sands [2–4], and in a limited number of studies carried out in occupational working environments [5–9]. A tentative explanatory mechanism is that hard abrasives in the air enter the oral cavity and adhere to the saliva-coated mucosa and tooth surfaces, causing abrasion of the occluding teeth during swallowing and mastication [1].

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Dentists in a small community on the Norwegian west coast reported in 1999 to the Norwegian social insurance authorities that many of the workers employed at a local mining company had extensive tooth wear. The mining company operates an open cast mine extracting olivine. Olivine is a naturally occurring magnesium-iron silicate mineral used in the metallurgic industry—hardness 6.5–7.0 on Moh's hardness scale. It was therefore theorized that the tooth wear could be caused by exposure to airborne dust in the employee's working environment. The Norwegian Labor Inspection Authority therefore requested a clinical investigation to find the possible association. The present study aimed to determine whether the employees in this particular mining company demonstrated more extensive tooth wear than usual, and whether this could be associated with the exposure to olivine dust in the work environment.

Material and methods

The concentrations of airborne olivine dust in the working environment had been monitored regularly for more than 20 years by the mining company in accord with stipulations in Norwegian labour protection law. All measurements had been contracted to an external and independent company (SINTEF, Trondheim, Norway). The purpose of the measurements was to ensure that the administrative norm for airborne olivine dust exposure in the working environment was not exceeded, i.e. 10 mg/m^3 total dust [10]. During the past 20 years, the levels of dust exposure have decreased in general, ranging between 15 mg/m^3 and less than 0.5 mg/m^3 total dust. The airborne olivine-dust concentrations in the mining company have averaged between 7.5 and <0.5 mg/m^3 total dust, depending on the physical location of the workplace (Table I).

In a letter sent from the dental study team in Oslo, all employees of the mining company were invited to take part in this study. They were informed that they would undergo a clinical examination to appraise tooth wear, which included intra-oral photographs and an impression of their teeth. They were also asked to provide information on a questionnaire about their past work place in the company, in addition to questions focused on possible other causative factors for tooth wear. The number of employees at the time of the investigation was 224, and 191 persons (85%) (18 F and 173 M) consented to participation. No attempts were made to clarify whether the reasons for non-participation were due to general disinterest, embarrassment due to poor oral health, or whether other reasons prevailed.

The questionnaire was sent, along with the appointment letter, about 14 days prior to the clinical examination. Questions were asked about age and gender, place of employment and employment history. Additional questions focused on special dietary habits, prior or present history of bruxism, self-assessment of drug- or non-drug-related xerostomia, gastro-oesophageal reflux disease and any other possible aspects that could explain any tooth wear.

The questionnaires were collected at the clinical examination, which was carried out in a dental clinic situated in the local community. Each participant was examined for about 30 min by a trained senior dental student. The teeth were photographed from the front and occlusally with a Pentax M.D. IMAGE II camera equipped with a Pentax GA Makro 2,8/100 lens fitted with Kodak Portra 160 NC color film. In addition, casts of both dentitions were made in hard stone from alginate impressions (Alginoplast; H. Kulzer GmbH, Hanau, Germany) (Figure 1). All 191 participants attended their clinical appointment, i.e. there were no patient drop-outs.

Assessment of tooth wear was based on an examination of 191 pairs of casts in combination with triplets of 12×18 cm size color prints. The wear was assessed independently by three faculty clinical professors and one senior dental student at the University of Oslo using an identical procedure. All the combined casts/photographs dentitions were ranked from the most to the least regarding overall general

Table I. Number of examined employees within the different divisions of the mining company and the average dust exposure in the divisions ranked according to mg/m^3 total dust levels

Divisions	Employees	mg/m^3
Cleaning, electro-engineering, administrative office, research & development (R&D)	40	0.5
Fire-resisting factory, machinery work shop, purchase office	30	1
Construction machinery, construction, welding, mechanic production	71	1.7–3.3
Open cast mine, quay, sand plant	50	5–7.5
Total	191	

Figure 1. Example of two sets of plaster cast of dentitions being compared for extent of tooth wear (left set judged as showing more tooth wear).

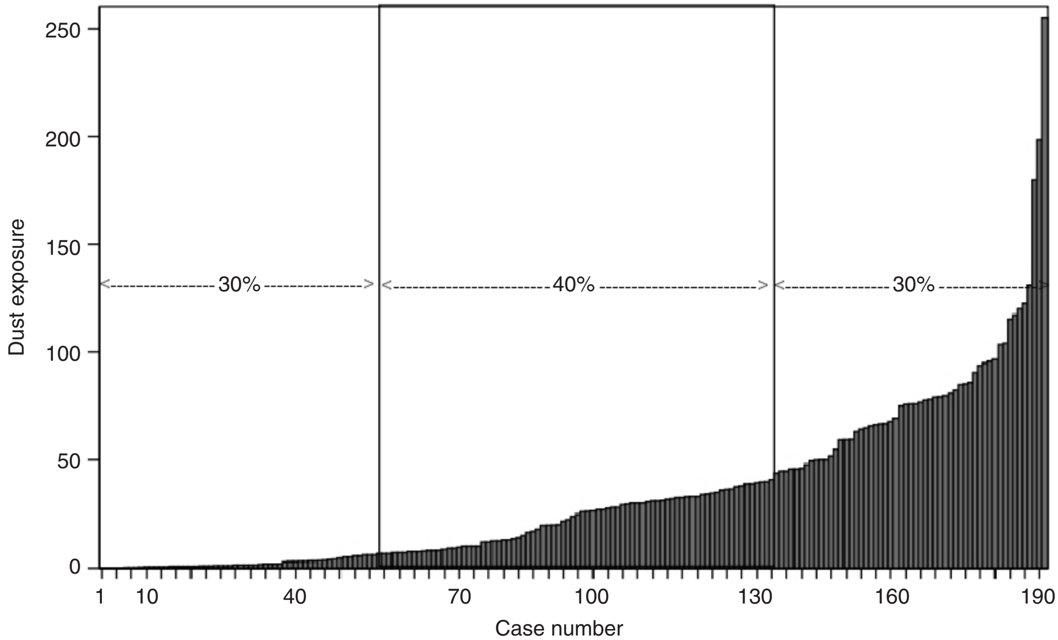

Figure 2. Estimated cumulative exposure to airborne olivine dust for all employees ranked from the lowest to the highest. Each vertical bar represents one employee sorted by increasing exposure. The vertical axis represents the sums of a composite of average dust exposure multiplied by years working experience. The vertical lines represent the borderlines between the participants with the lowest 30% and the highest 30% estimated exposure levels, i.e. the defined control and case groups.

tooth surface loss using reiterative stepwise comparisons. Eight persons with full jaw removable or fixed full jaw dentures were excluded from this ranking. Moreover, one person with severe tooth surface loss explained this by an extensive period of frequent vomiting and was therefore also excluded. Thus, a ranking order of the dentitions' wear severity from 1 to 182 was made on the basis of the casts and photographs combined. The rankings of the four assessors correlated between 0.84 and 0.87 according to Spearman correlation tests. Since this was considered satisfactory, the average of the four individual rankings was used as the measure for tooth wear in the statistical analyses.

Each participant's accumulated level of exposure to dust was estimated by simply multiplying the years of service employed in the different divisions by the average concentrations of airborne olivine dust measured in the respective divisions throughout the years. As it was acknowledged that there are several methodological and biological possibilities for confounding and risk of both recollection and measurement bias, we decided to focus this investigation on the 30% of participants who had the highest and the lowest levels of estimated exposure to airborne olivine dust (Figure 2). The remaining 40% of participants were therefore ignored, which signifies that this study has a case-control study design. The case group consists of the 30% of employees with the highest exposure to dust, while the control group is the 30% of employees with the lowest exposure.

As expected, there was a marked association between the estimated accumulated dust exposure level and age (chi square $= 61$, d.f. $= 4$, $p < 0.001$) (Table II). To adjust for age in the comparisons between the case and control groups with regard to tooth wear, three age subsets of approximately equal sizes were made, i.e. 18–33 years, 34–44 years, and > 44 years (Table II). Only one female belonged in the case group and four in the control group, so no separate analyses for gender were carried out.

The rankings of the tooth wear of the participants in the control group, i.e. the lowest estimated dust exposures, were compared with the rankings of the individuals in the case group, i.e. with the highest exposure, for the whole study sample as well as within the three age subsets. A non-parametric test based on ranks was applied to detect statistically significant differences (Mann-Whitney test).

Tooth wear was also categorized according to a commonly used and validated 4-scale grading for occlusal tooth wear [11]. This classification system includes a score 0 = no wear or negligible wear of enamel; score 1 = obvious wear of enamel or wear through the enamel to the dentin in single spots; score

Table II. Number of participants categorized according to estimated exposure to airborne olivine dust and age subset

	Age subsets (years)			
Exposure groups	18–33	34–44	>44	Total
Controls "low exposure levels"	39	13	5	57 (30%)
"Medium"	20	33	24	77 (40%)
Cases "high exposure levels"	3	22	32	57 (30%)
Total	62	68	61	191

2 = wear of the dentin up to one-third of the crown height; and score 3 = wear of the dentin more than one-third of the crown height.

Results

The extent of tooth wear, represented by the subsets' rank summaries, was clearly related to increased cumulative exposure to airborne dust (Figure 3). Statistically significant differences in tooth wear were found between the control and case groups using the Mann-Whitney test ($n = 109$, $n = 57$ in the control group versus 52 in the case group, $p < 0.001$). Corresponding statistical analyses within each age subset demonstrated higher tooth wear for the individuals in the case compared to the control group, although a statistically significant difference was only reached in the 34–44 years' subset ($n = 34$, 13 versus 21, $p = 0.002$) (Figure 3).

Considerable variations in tooth wear were noted within all exposure groups as well as within the age subsets (Figure 3).

No relationship was seen between tooth wear and number of remaining teeth and occluding pairs.

The information from the questionnaires did not reveal specific reasons to expect any excessive tooth wear for any participant beyond the single person who was excluded from the analyses. Nine persons, evenly distributed between the exposure groups, were aware of a habit of nocturnal clenching of teeth. Thirteen claimed that they drank more than three liters of carbonated soft drinks per day, but there was no indication of increased tooth wear among them. Thirty-nine individuals reported that they had had gastro-oesophageal reflux disease. A majority of these were older participants and in the case (high exposure level) group ($n = 19$).

Six percent of the participants ($n = 11$) showed wear of dentin amounting to more than one-third of the crown height, 18% ($n = 33$) had wear of dentin up to one-third of the crown height, 53% ($n = 96$) had obvious wear of enamel or wear through the enamel to the dentin in single spots, and 23% ($n = 41$) had no wear or negligible wear of the enamel.

Discussion

Measuring tooth wear reliably is fraught with difficulty and several concepts for registration and indices for

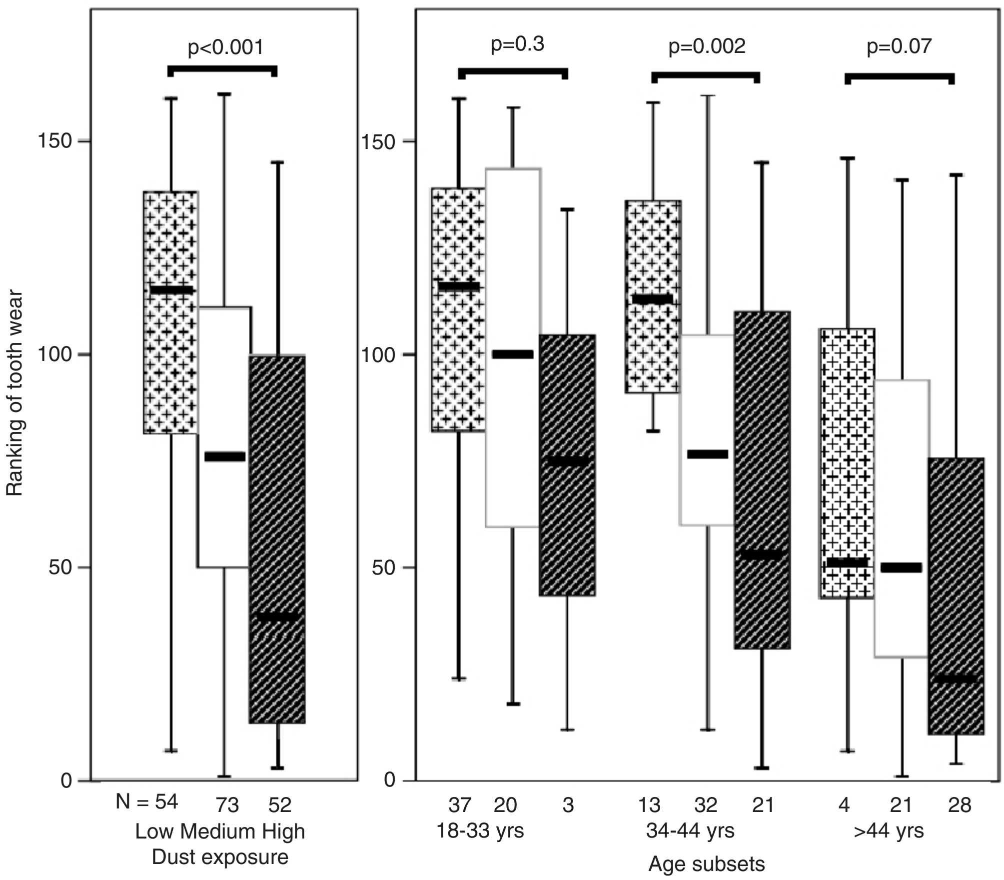

Figure 3. Box-plot illustrating the rankings of tooth wear for the three estimated dust exposure groups. The upper and lower edges of the boxes represent the 25% and 75% quartiles, the horizontal lines represent the mean, and the box whiskers the 5% and 95% range of rankings for tooth wear. Low-ranking values represent extensive tooth wear; higher-ranking values signify less wear. *P*-values for statistical differences between the case and control groups calculated with Mann-Whitney tests, while the medium exposure group data are included for illustrative purposes only.

categorization have been presented in the literature [11–13]. Most are based on categorical scales. The usability and reliability of various indices will vary depending on whether they are applied for clarifying etiological mechanisms, determining minimum thresholds for required therapy, or for purely descriptive purposes in cross-sectional population studies. We believe that most of these problems are avoided by the procedure used in this investigation. By having each examiner arrange the models and photographs according to a general impression of the collective wear of the dentition, taking into account the uneven distributions of remaining teeth in the jaws, high inter-examiner agreement was reached. The procedure allowed a more sensitive discrimination between cases with subtle differences, which was often the case, than would be achieved by classifying according to a rough categorical index. A similar analytical approach has been used for examining wear and deterioration of restoration margins of amalgam fillings [14].

Tooth wear seemed to be more obvious anteriorly than in the posterior segments in most cases where extensive wear was observed. Attempts have been made to correlate the relative wear areas intra-orally with the most probable etiology [15]. Currently, there is only weak evidence that the intra-oral location of the most pronounced wear may give an indication of etiology, although it may be stated that there is a tendency for palatinal wear in the upper anterior teeth among bulimic patients, palatinal wear in the upper teeth among patients with gastro-oesophageal disease, and incisal loss of the anterior teeth in individuals with bruxism [16].

The estimates of accumulated doses of exposure were calculated by multiplying the average concentrations of airborne olivine dust and years of service. This may be debatable, because it can be translated as defining these two factors as proportional. It is acknowledged that an exponential or non-linear calculation between year of employment and dust exposure may be just as appropriate. However, the literature gives no indication of what is the most appropriate proportional relationship.

The participants were considered representative for the employees of the mining company, including the employees exposed to airborne olivine dust. Eight participants were not assessed for tooth wear because they had full jaw removable or fixed dentures. None of these belonged in the control group. No attempts were made to retrospectively appraise the reasons for extraction and/or need for extensive rehabilitative therapy due to risk of recollection bias. On the other hand, it is not irrelevant to speculate on whether there has been a relationship between extensive tooth wear—occupationally caused or otherwise—and extensive rehabilitation/tooth extraction.

The estimated accumulated exposure to olivine dust was based on average measurements over several years. The decreasing trend of the dust levels over time, probable local variations of dust levels within the divisions and unknown measurement errors, affects the precision of the individual's dust exposure levels. Moreover, the individual's employment periods in the different divisions were according to the participant's memory, which may be prone to memory bias. It would have been preferable to have had access to written documentation of their employment history, but such records were not available. We believe that the consequences of possible memory bias and inaccuracies of exposure levels are reduced by focusing only on the 30% of participants with the lowest and highest dust exposures. On the other hand, Figure 3 shows that the 40% of participants not included in the analyses demonstrated tooth wear somewhere between the low and the high exposure groups, supporting a dose/response relationship between dust exposure and tooth wear. This finding is consistent with previous reports of occupational exposure of Swedish miners [7] as well as dust-exposed workers in the granite industry in Denmark [8].

There was a consistent trend in tooth wear depending on exposure in all three age groups (Figure 3). Although a statistical difference was only seen for the 34–44 year group, it is assumed that the failure to reach a statistically significant level was because the low age group included only three high-exposed individuals and the oldest group only five low-exposed individuals, i.e. a possible type 2 error.

The 6% of participants with wear of dentin amounting to more than one-third of the crown height is higher than in a Swedish study on 585 randomly selected participants aged between 20 and 80 years, where the prevalence was approximately 2% [11]. Tooth wear among the workers in the present study thus seems higher compared to this Swedish population.

The extent of tooth wear varied markedly within the different dust exposure groups and even within the age subsets (Figure 3). Whether this is caused by other etiological factors or individual susceptibility to tooth wear apart from dust exposure cannot be determined in a study with a cross-sectional design. No clear patterns were found in the questionnaires that could account for high extent of tooth wear among any participants, except the single female participant with a history of frequent vomiting. Few individuals reported bruxism, and these were evenly distributed among the exposure groups. However, the validity of the data from the questionnaire can be questioned because relatively few [9] reported nocturnal clenching of teeth relative to as many as 36 reported a gastro-oesophageal reflux disease. Since the occurrence of reflux problems was based on self-assessment and not by a physician's diagnosis, the validity and reliability of this finding remain uncertain.

The correlations between tooth wear and exposure/age do not say much about the dynamics of the process. Nor is it known when the actual tooth wear took place.

Dust levels in the working environment have improved over the years according to the routine measurements. One might perhaps expect less wear in the future. It is therefore uncertain whether the differences between the low and highly exposed workers will be so apparent in the future as is the case for the present participants.

Individuals at risk for occupational dust exposure should be made aware of the situation to possibly avoid future extensive and expensive tooth rehabilitation. It is also important that industries with dust problems become aware of the possible oral health risk for the workforce. Although personal respiratory filters are effective, they are cumbersome and restrict breathing, and therefore fall into disuse. A simple and perhaps more effective preventive intervention would be to provide employees with plentiful and easy access to fresh chilled water to rinse away accumulated dust.

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