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Dental Erosions in Subjects Living on a Raw Food Diet

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Erosion · Epidemiology · Raw food diet

Abstract
The aim of the study was to investigate the frequency and severity of dental erosions and its association with nutritional and oral hygiene factors in subjects living on a raw food diet. As part of a larger dietary study 130 subjects whose ingestion of raw food was more than 95% of the total food intake were examined. The median duration of the diet was 39 (minimum 17, maximum 418) months. Before the clinical examination, the participants answered questionnaires and recorded their food intake during a 7-day period. Dental erosions were registered using study models. As a control 76 sex- and age-matched patients from our clinic were randomly selected. The raw food diet records showed the median daily frequency of ingesting citrus fruit to be 4.8 (minimum 0.5, maximum 16.1). The median intake of fruit was 62% (minimum 25%, maximum 96%) of the total, corresponding to an average consumption of 9.5 kg of fruit (minimum 1.5, maximum 23.7) per week. Compared to the control group subjects living on a raw food diet had significantly ($p \leq 0.001$) more dental erosions. Only 2.3% of the raw food group (13.2% of the controls) had no erosive defects, whereas 37.2% had at least one tooth with a moderate erosion (55.2% of the controls) and 60.5% had at least one tooth with a severe erosion (31.6% of the controls). Within the raw food group no significant correlation was found between nutrition or oral health data and the prevalence of erosions. Nevertheless, the results showed that a raw food diet bears an increased risk of dental erosion compared to conventional nutrition.

Erosion differs from caries in that it is defined as superficial mineral loss caused by a chemical process not involving microorganisms [Pindborg, 1970]. Causative agents are acids originating from intrinsic or extrinsic sources. Intrinsic sources include recurrent vomiting or regurgitation of gastric contents [Scheutzel, 1996]. Extrinsic sources may be environmental exposures, for instance exposure to acid mists in the workplace air [Petersen and Gormsen, 1991], some medicines such as chewable vitamin C tablets [Giunta, 1983] and in particular, dietary sources due to acidic drinks or foods. In vitro experiments using acidic drinks like cola, orange juice or sport drinks [Meurman et al., 1987; Rytömaa et al., 1988; Lussi et al., 1995] have clearly proved the erosive potential of dietary acids. Additionally, the association of dietary habits with dental erosion has been shown in prevalence studies [Linkosalo and Markkanen, 1985; Lussi et al., 1991; Sherfudhin et al., 1996] and in case reports [Muenninghoff and Johnson, 1982; Graehn, 1995].

During the first decades of our century various philosophies developed which intended to bring people's lives closer to nature. With this, the idea to live on a 'natural diet' followed as a fundamental aspect. All processed foodstuffs were stated as unnatural and therefore unwholesome whereas uncooked and unprocessed food was recommend-

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Fig. 1. Facial and incisal erosions (laterotruded position): tooth 13 and 12 – facial erosion grade 2, incisal erosion grade 1 (note the nonocclusion and diverging edges of the anterior teeth); tooth 44 – facial erosion grade 1; tooth 14 and 45 attrition (note the corresponding facets).

Fig. 2. Occlusal and oral erosions: tooth 15, 14, 13, 12 – erosions grade 2.

ed as natural and salubrious [Harvey and Harvey, 1985; Wandmaker, 1991]. These forms of nutrition, although they are not necessarily vegetarian, contain plenty of citrus fruit and thus may bear an increased risk of dental erosions.

Therefore, the aim of the study was to investigate the frequency and severity of erosions in a group of subjects living on a raw food diet and to correlate it with nutrition and oral hygiene data.

Materials and Methods

The sample consisted of 130 (64 female and 66 male) subjects out of a larger group of individuals participating in a dietary study performed by the Institute of Nutrition Science, Justus Liebig University, Giessen. Subjects were selected by means of a dietary and health questionnaire and were included when: (1) the ingestion of uncooked food was more than 95% of the total food intake and (2) the duration of the diet was at least 1 year.

Subjects with eating disorders or gastrointestinal disturbances were excluded. The median age of the participants was 43 (minimum 18, maximum 63) years and the median duration of the diet was 39 months (minimum 17, maximum 418).

The examinations were performed in public facilities in 24 cities in Germany and in one city in France. All subjects were clinically examined but, since the premises for the clinical examination were unfavorable, impressions were made from each of the participants and dental erosions were registered using study models.

Analysis of the Study Models

Erosions were recorded on vestibular, oral and occlusal surfaces. Modified from the scoring system of Linkosalo and Markkanen [1985] the criteria were defined as follows.

Vestibular/oral surfaces: grade 0: no visible erosion; grade 1: moderate erosion less than half of the surface, shallow concavities whose breadth greatly exceeds their depth; grade 2: severe erosion with deep concavities or shallower concavities more than half of the surface (fig. 1, 2).

Occlusal/incisal surfaces: grade 0: no visible erosion; grade 1: moderate erosion, small pits and slightly rounded cusps, fissures flattened, incisal edges of the anterior teeth with grooves (fig. 1); grade 2: severe erosion, depression of the cusps with severe cupping and grooving, restoration margins raised above the tooth level, incisal edges of the anterior teeth with deep grooves (fig. 2).

For comparing control and raw food groups and for relating dental erosions with nutrition data an 'erosion index' (EI) was determined for each subject:

$$EI = \frac{\Sigma \text{ of number of eroded surfaces}}{\Sigma \text{ of the total surfaces at risk}} \times 100$$

The control group consisted of 76 randomly selected study models from age- and sex-matched patients from our clinic. The clinical examination and the analysis of the study models were performed by the same examiner, who was calibrated by 2 independent examiners. The Kappa values for interexaminer reliability ranged between 0.75 and 1, for intraexaminer reliability between 0.72 and 1.

Nutrition Data

A few weeks prior to the clinical examination 112 of the 130 subjects precisely recorded their food intake during a 7-day period. This was facilitated by means of a small booklet containing detailed instructions followed by a list of foodstuffs that included 20 types of drinks, 61 kinds of fruit, some sorts of dried fruit and nuts, 49 kinds of vegetables and some kinds of fish, meat and other food. Exemplary photographs of portions of food that specified weight or indicated the average weight of the food (e.g.: 1 tomato, medium-sized = 50 g) allowed the participants to estimate the quantity of the food ingested.

This booklet was developed by the Institute of Nutrition Science. From these dietary records and from the dietary questionnaire the duration of the diet, eating frequency, frequency of the intake of citrus fruit, quantity of the total food intake and quantity of the intake of citrus fruit were determined. There were no nutrition data available for the control group.

Oral Health Oral Hygiene Questionnaire

Prior to the clinical examination, all participants answered a questionnaire dealing with dental health habits. It consisted of questions regarding common aspects of dental health, a self-assessment of oral health, complaints such as pain or hypersensitivity of teeth and changes of oral health during the raw food diet. Answers were marked with a cross in the corresponding box. With respect to oral hygiene habits, tooth brushing technique and frequency, hardness of the toothbrush bristles and the use of fluorides were recorded.

Statistics

All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS 7.5). Since most of the data were not normally distributed, nonparametric tests were used. Erosion indices of the subjects in the control and raw food group and erosion indices in relation to oral hygiene aspects were analyzed using the Mann-Whitney U test. The correlation between nutrition data and erosion indices was performed using Spearman correlation coefficients; additionally multiple regression analysis was applied including intake frequency of fruit, duration of the diet and percentage of fruit of the total intake.

Results

Analysis of the Study Models

Compared to the control group subjects living on a raw food diet had significantly ($p \leq 0.001$) more dental erosions. Only 2.3% of the raw food group (13.2% of the controls) had no erosive defects, whereas 37.2% had at least one tooth with erosions grade 1 (55.2% of the controls) and 60.5% with erosions grade 2 (31.6% of the controls).

The median erosion index in the raw food group was 24.2 (minimum 0.0, maximum 64.3) compared to 7.4 (minimum 0.0, maximum 48.4) in the control group ($p \leq 0.001$). In the control group, showing a skewed distribution, low erosion index values were most frequent with a tail towards higher values. In contrast, erosion indices in the raw food group were distributed relatively evenly.

In both groups (raw food vs. control) the risk of erosive defects was highest on occlusal surfaces (grade 1: 37.5 vs. 18.2%, $p \leq 0.001$; grade 2: 18.0 vs. 4.2%, $p \leq 0.001$), next highest on vestibular surfaces (grade 1: 13.2 vs. 2.1%, $p \leq 0.001$; grade 2: 3.2 vs. 0.4%, $p \leq 0.001$) and least on oral surfaces (grade 1: 4.7 vs. 1.2%, n.s.; grade 2: 1.6 vs. 0.4, n.s.).

Regarding the tooth surfaces affected, the distribution pattern of erosive defects was very similar in both groups. On occlusal surfaces, erosions were distributed relatively evenly with a peak for severe erosions at lower first molars in the raw food group. Vestibular erosions were most frequent in the anterior region of the upper jaw and in canines and premolars in the lower jaw. On oral surfaces erosive defects could be found only in the maxillary and mandibular anterior region. The percentage of erosive defects on surfaces at risk is shown in detail in figure 3.

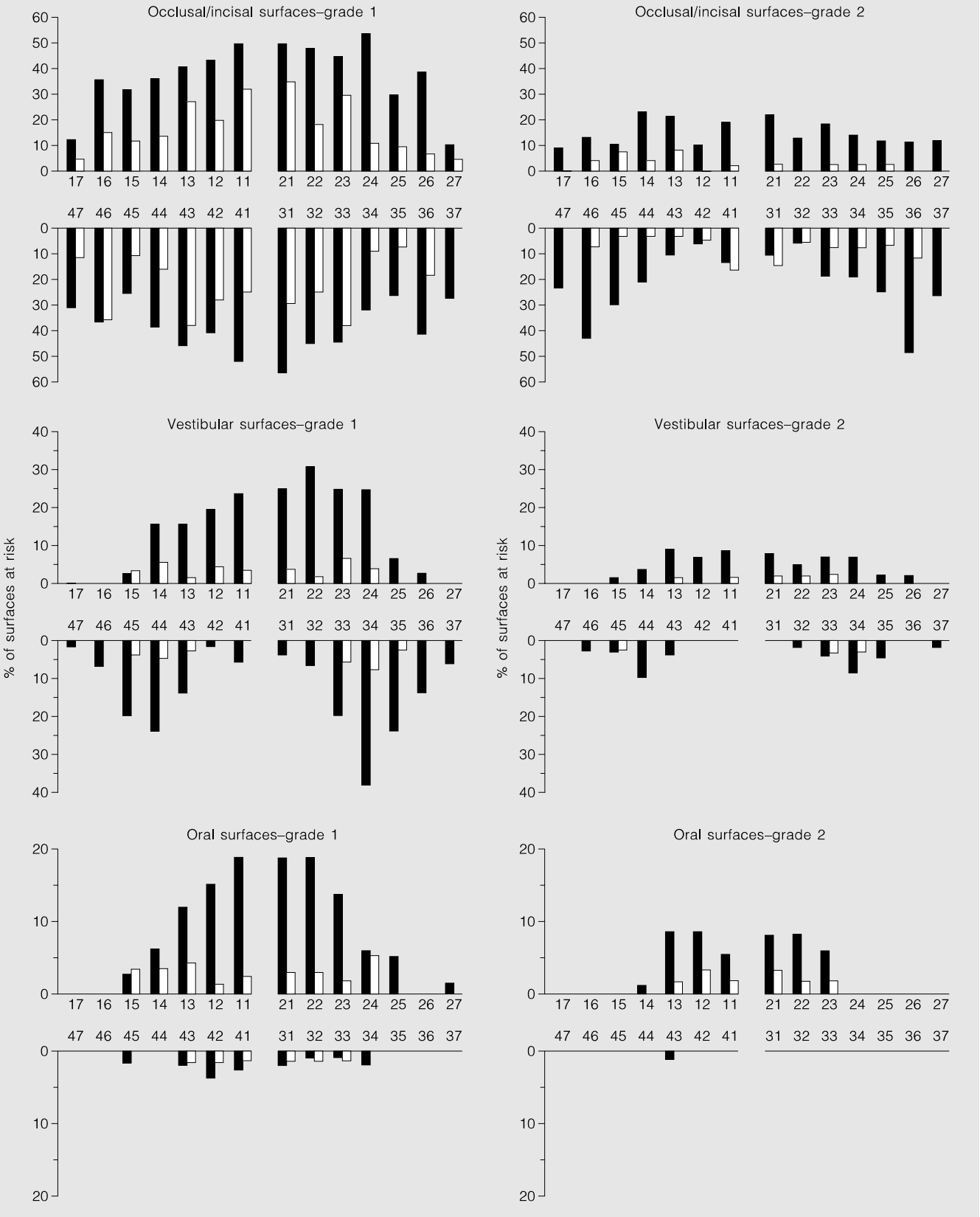
Nutrition Data

The analysis of the dietary records showed a median daily frequency of ingesting food of 12.7 (minimum 1.5, maximum 28) with a frequency of ingesting citrus fruit of 4.8 (minimum 0.5, maximum 16.1). The median weekly consumption of uncooked food was 12.9 kg (minimum 2.4 kg, maximum 40.4 kg). The median intake of fruit was 62% (minimum 25%, maximum 96%) of the total. This corresponded to a median consumption of 8.9 kg of fruit (minimum 1.5 kg, maximum 23.7 kg) per week. The quantity of soft drinks, fruit juice or herbal tees was negligible. Since the participants drank water almost exclusively, beverages were excluded from the nutrition data. Relating nutrition factors to the individual erosion index, no significant correlation could be found (fig. 4). Even multiple regression including important factors such as the duration of the diet, the frequency of the intake of citrus fruit or the percentage of the intake of citrus fruit from the total intake showed no significant results.

Oral Health Oral Hygiene Questionnaire

Forty-six percent of the participants assessed their oral health as good, 43% as fair and 7% as poor. On the raw food diet 45% observed an improvement of their oral health (less calculus and improved periodontal health) but 14% observed a change for the worse with gingival bleeding and hypersensitivity of the teeth. Nine percent of the subjects reported not cleaning their teeth, 36% brushed once and 51% twice or more per day. Only 6% used a fluoridated toothpaste. Twenty-three percent brushed their teeth immediately after meals. Most of the participants (76%) brushed vertically or with circling movements and only 7% brushed horizontally. Fifty-nine percent used toothbrushes with bristles of medium hardness, 22% with soft and 10% with rigid bristles. In all, oral hygiene habits showed no influence on the erosion index.

Fig. 3. Distribution pattern of dental erosions for occlusal, vestibular and oral surfaces expressed as percentage of eroded surfaces of surfaces at risk. The black columns represent the raw food group, the shaded columns the control group.



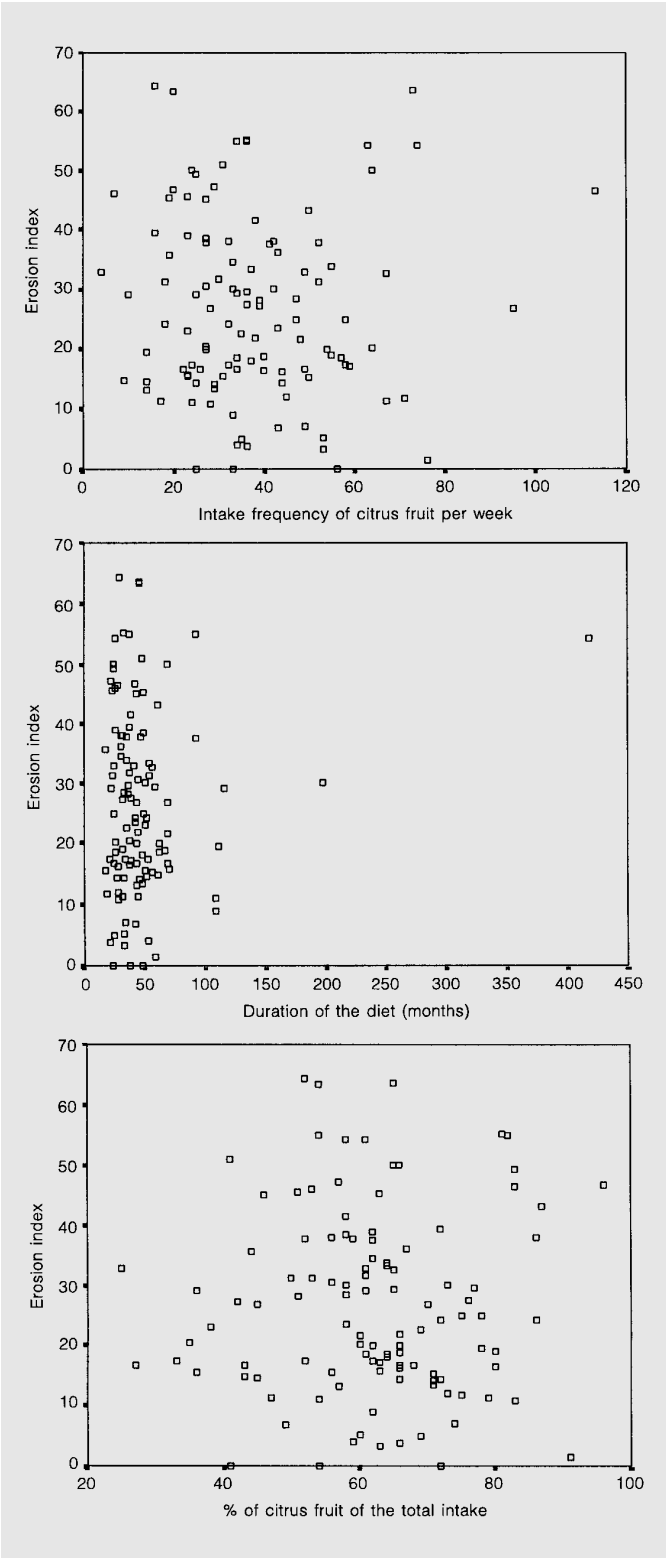


Fig. 4. Correlation between the erosion index of subjects of the raw food group and their nutrition data (n = 112).

Discussion

Different forms of noncarious mineral loss occur on tooth surfaces. Attrition is defined as a destructive process due to tooth-to-tooth contact, abrasion as a substance loss due to foreign objects or substances and demastication as wear due to a mechanical action between food and teeth. In contrast, erosion is defined as a solely chemical process [Imfeld, 1996a]. Nevertheless, since the oral cavity is a multifunctional ecological system, tooth wear in general should be looked at as a multicausal process. Therefore, erosive and mechanical substance loss may occur simultaneously all the more so because eroded and hypomineralized surfaces are more susceptible to mechanical wear [Davis and Winter, 1980; Ganss et al., unpublished data]. But since there are different patterns of wear, one of the aforementioned processes is in the fore in most cases and a differential diagnosis may be possible.

For a clinical diagnosis of erosive lesions, teeth should be thoroughly cleaned and dried and good illumination should be available. Since the premises for the clinical examination were unfavorable and the time for the examination was restricted, we decided to use study models. The clinical signs of erosion were defined by Lussi [1996]. In this study, only clearly visible lesions which definitely fulfilled the defined criteria were classified as erosions above grade 0. On occlusal surfaces, even areas with clear-cut borders and with corresponding antagonistic facets were diagnosed as attrition and could easily be distinguished from erosions. However, it remains still unclear which pattern of substance loss results from demastication. It is conceivable that abrasive foodstuffs can cause concavities without corresponding substance loss of the antagonists similar to erosive lesions especially if the dentine is involved. On vestibular surfaces, defects with sharp rims and with their depth exceeding their breadth were diagnosed as abfraction whereas smoothly bordered flat-spread lesions were diagnosed as erosion.

Using study models, the optical properties of the tooth surfaces could not be assessed and the diagnosis of very early stages of vestibular or oral erosions was difficult. This may have resulted in a slight underestimation of erosions of smooth surfaces. On the other hand, the study models allowed an analysis of the occlusal situation facilitating the diagnosis of occlusal surfaces. The involvement of dentine, which is an important criterion for grading in most indices, could only be supposed. Therefore, the grading scale was reduced to two grades, which were based on the extent of the lesion only. Since dental erosions involve tooth surfaces only, study models seem to be an appropriate aid for assess-

ment, documentation and follow-up, but further research should focus on the improvement of the grading scheme.

Regarding the prevalence of dental erosions in populations, epidemiological surveys are few in number and they are difficult to compare since international standards defining diagnostic parameters and grading of erosive lesions have not been established. Some of the first data to be published was that of Sognnaes et al. [1972]. They examined 10,000 extracted teeth and found approximately 18% with erosive lesions. Mandibular teeth had a somewhat higher frequency of erosions than the corresponding maxillary teeth. Incisors and premolars were mostly affected, followed by canines and finally molars, which had the lowest percentage of erosive lesions. A study performed in Boston and Los Angeles [Xongha and Valdmanis, 1983] revealed that nationwide 25% of individuals may be affected with an erosive type of tooth wear. A more recent study carried out in Switzerland [Lussi et al., 1991] focused on randomly selected subjects between 26 and 30 and between 46 and 50 years of age. Using a similar grading, they found that regarding moderate lesions 9.6% of the participants in the age-group 46–50 years had at least one tooth with a facial, 40.1% with an occlusal and 6.1% with an oral erosion. In our control group (median age 43 years) 23.6% of the subjects had at least one tooth with a facial, 86.8% with an occlusal and 9.2% with an oral lesion. Concerning severe erosions, Lussi et al. [1991] found 13.7% with at least one tooth with a facial, 42.6% with an occlusal and 2.0% with an oral erosion, whereas in our control group 2.6% of the subjects revealed at least one tooth with a facial, 26.3% with an occlusal and 3.9% with an oral erosive defect. The most striking difference between the two studies was a relatively high prevalence of moderate erosions on occlusal surfaces found in our control group. This was due to a high number of subjects revealing grooves in their lower incisors (fig. 3). Apart from that, we found a greater percentage of moderate and a lower percentage of severe erosions. This may on the one hand be due to the somewhat younger group of subjects of the control group but on the other hand the analysis of study models may have underestimated severe erosions if they are defined as an involvement of dentine. Nevertheless, signs of erosion seem to be common but one should keep in mind that moderate lesions should not be looked at as pathological.

The results of our study indicated that subjects living on a raw food diet had significantly more erosions than their controls; 97.7% had erosive defects and severe erosions occurred twice as often as in the controls. Similar results were obtained from a prevalence study in Finnish vegetarians [Linkosalo and Markkanen, 1985]. Using a comparable index, the authors found 76.9% of the subjects affected with dental erosions. Of these, 26.9% had incipient lesions but 50% had erosions involving the dentine. The main nutritional factors influencing the occurrence of dental erosions were the consumption of vinegar and vinegar conserves, citrus fruit and acidic berries. However, the nutrition behavior of the participants was evaluated by means of an interview only, whereas dietary recordings allow one to obtain a more differentiated view. In this study the participants were informed about the aim of the nutrition study in great detail. Within a period of several weeks before the clinical examination the subjects were free to choose the most favorable time to begin the 7-day recording of their nutrition. They were instructed not to change their nutritional habits during this recording period and to describe this in detail. Due to their uncommon dietary habits they were interested in improving their knowledge of the influence of nutrition on health and well-being and therefore were motivated for compliance. In all, the nutrition recordings in combination with the nutrition questionnaire were likely sufficient to give an accurate reflection of the participants' dietary habits. Since the collection of the nutrition data was very complex and time-consuming, it seemed to be unrealistic to motivate subjects from the control group to record their nutrition in the same way. A group of randomly selected subjects may exhibit a common nutrition pattern and therefore we decided to leave the nutrition data out. The analysis of the dietary recordings showed an eminent quantity of fruit taken in: 50% of the individuals ate from 9.0 up to 23.5 kg fruit per week. This correlates, for example, to the ingestion of 25 bananas, 22 apples, 50 kiwis and 55 oranges. Additionally, 52.7% of the subjects ate fruit from 5 up to 16 times a day. A high frequency of fruit intake has been indicated as a risk factor in erosion occurrence [Linkosalo and Markkanen, 1985; Järvinen et al., 1991; Lussi et al., 1991] but it is still unclear if the quantity of fruit eaten or the duration of a vegetarian or raw food diet influences dental erosions. Unexpectedly, in our group of 130 subjects, dental erosion occurrence was far beyond correlation with any of the nutrition data. Obviously, even the lowest intake frequency, lowest quantity of fruit eaten or the shortest duration of the diet already expressed a maximum dietary risk factor for dental erosions. This corresponds with the finding that consuming citrus fruit more than twice a day may increase the risk of erosions 37-fold [Järvinen et al., 1991]. The frequency or severity of the lesions observed in this study may therefore have solely been related to dietary independent factors such as the quantity and characteristics of saliva or the susceptibility of tooth substances to demineralization.

Other aspects influencing the occurrence of erosions may be oral hygiene habits. Some in vitro studies revealed a protective effect of fluoride [Sorvari et al., 1994; Attin et al., 1997; Hughes et al., 1997] but it is still unclear if this holds true in vivo as well or which fluoridation measure should be recommended [Imfeld, 1996b]. The evaluation of the oral health questionnaire showed that most of the subjects did not use fluorides, which is attributed to their 'back to nature' philosophy. Since only 6% of the participants used a fluoridated toothpaste, a correlation with erosion occurrence could not be performed. Tooth brushing was common among the participants but most of them had 'low risk' brushing habits while using vertical or circling techniques and brushes with medium or soft bristles. However, 24% of the subjects brushed immediately after meals. Brushing immediately after an acid attack may increase substance loss [Davis and Winter, 1980; Scheutzel, 1996] while a sufficient remineralization period after acid etching may not totally prevent, but clearly decrease mineral loss due to tooth brush abrasion [Ganss et al., unpublished data]. However, no significant difference could be found between subjects brushing immediately after the meals and subjects brushing between meals or subjects never brushing their teeth. Perhaps even 'immediately', which in fact means a couple of minutes later, may imply a sufficient remineralization period giving a protective effect on tooth substances.

Despite the high prevalence of severe erosive defects, only 14% of the subjects complained of tooth hypersensitivity and 10% reported that it occurred after the onset of the raw food diet. This corresponds to the results of a prevalence study of wedge-shaped abrasion defects and hypersensitivity performed in Switzerland. Eighty-four percent of subjects with wedge-shaped abrasion defects suffered from hypersensitivity but only 16.9% of subjects with facial erosions complained of it [Lussi et al., 1993]. Therefore, hypersensitivity seems to be related to mechanical rather than to chemical substance loss.

In conclusion, this study shows that living on a raw food diet bears an increased risk of dental erosion. In the raw food group the median erosion index (percent of affected surfaces of surfaces at risk) was 24.2 compared to 7.4 in the control group. Subjects living on special nutrition forms consisting of plenty of fresh fruit and vegetables should be informed of the risk of tooth damage, but it is still unclear which prophylactic measure should be recommended.

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