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Enamel decalcification in primary schoolchildren

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SUMMARY

To serve as a baseline for a future study of enamel decalcification in relation to orthodontic treatment, the prevalence and severity of decalcification was determined in 204 schoolchildren who had not received orthodontic treatment (mean age 12,3 years), and who lived in a fluoride deficient area. The severity of decalcification indicated by a Decalcification Index (DI) was calculated using a scoring system applied to the cervical, middle and incisal thirds of the vestibular and lingual surfaces of all the permanent teeth, excluding second and third molars. A total of 84 per cent of the children showed some decalcification, this occurred more frequently on the vestibular, compared to the lingual surface. The cervical third of the teeth was the most frequently affected third. A similar pattern was observed for the Decalcification Index. The individual teeth most affected were the permanent first molars. From this study it can be seen that decalcification was common in primary schoolchildren not undergoing orthodontic treatment, particularly in the cervical third of the permanent first molar teeth.

OPSOMMING

Die voorkoms en mate van glasuurontkalking is in 204 skoolkinders bepaal om as grondslag vir 'n toekomstige studie van glasuurontkalking as gevolg van ortodontiese behandeling te dien. Die groep kinders het nie ortodontiese behandeling ontvang nie (gemiddelde ouderdom 12,3 jaar) en woon in 'n fluoried-gebrekkige gebied. Die mate van ontkalking is deur 'n ontkalkingsindeks (D.I.) bepaal wat deur 'n puntestelsel bereken is. Dit is toegepas op die nek, middel en insisale derdes van die vestibulêre en linguale vlakke van al die permanente tande, behalwe die tweede en derde molare. 'n Totaal van 84 per sent van die kinders het 'n mate van ontkalking getoon. Dit het meer dikwels op die vestibulêre as die linguale vlakke voorgekom. Die nek derde van die tande is die meeste aangetas. 'n Soortgelyke patroon is vir die ontkalkingsindeks waargeneem. Die individuele tande wat die meeste aangetas is, is die eerste permanente molare. Uit hierdie studie blyk dit dat ontkalking in primêre skoolkinders wat nie ortodontiese behandeling ondergaan nie dikwels voorkom, veral in die nek derde van die permanente eerste molaar tande.

INTRODUCTION

The presence of clinically detectable enamel decalcification following the removal of orthodontic bands, has for many years been accepted as one of the hazards of orthodontic treatment (Graber and Swain 1975). It is considered to be the precursor, or early lesion of enamel caries (Noyes 1937, Darling 1956) and is due primarily to the surface action of acid which during orthodontic treatment may come from two sources, namely, the cement used for retaining the orthodontic bands and the breakdown products of food debris.

The liquid portion of zinc phosphate cement contains 40 to 50 per cent free phosphoric acid (Paffenbarger, Sweeny and Isaacs 1933, Nixon 1962), so that 3 minutes after the start of mixing, the pH of zinc phosphate cement is approximately 3,5 (Phillips 1973). The high acid content led Lefkowitz and Bodecker (1938) to suggest that dental cements had a decalcifying effect on the enamel under orthodontic bands. This view, particularly in regard to a thin cement mix, has since been supported by further studies (Lefkowitz 1940, Costello *et al* 1948, Docking and Newbury 1953, Seniff 1962). In contrast zinc phosphate cement used in a medium consistency mix has been shown not to have a decalcifying action on enamel (Docking and Newbury 1953, Wisth 1970).

The presence of fixed orthodontic appliances in the mouth undoubtedly predisposes to the accumulation of plaque. Two favoured sites for such accumulation are around the cervical margins of the teeth and under the bands in areas where the cement has been washed out.

A number of workers have documented significant increases in oral bacteria during orthodontic treatment (Bloom and Brown 1964, Dikeman 1962, Owen 1949, Adams 1967). They believed that orthodontic therapy made good oral hygiene more difficult, modified the oral environment and increased caries activity as measured by increased salivary concentrations of lactobacilli, which is a source of acid for enamel decalcification.

In spite of the above evidence and the presumed association between orthodontic therapy and enamel decalcification, a review of the literature reveals little evidence to either prove or disprove the association.

Myers (1952) compared decalcification on unprotected teeth and on teeth protected with varnish. He showed that 27,4 per cent of the unprotected teeth showed new areas of decalcification when the bands were removed, compared to 5,9 per cent of the protected teeth.

Bach (1953, 1954) recorded a 6 per cent increase in decalcified areas in excessive carbohydrate consumers, compared to 4,7 per cent in minimum carbohydrate consumers following orthodontic treatment. In his survey Bach (1953, 1954) included the interproximal tooth surfaces, although it is doubtful that the presence or absence of enamel decalcification on the interproximal surfaces can be accurately recorded in a fully erupted dentition.

Ingervall (1962) compared the differences in caries frequency between 60 children who had received treatment with fixed orthodontic appliances and 60 children in a control group. He concluded that caries frequency was significantly higher among those children who had received orthodontic treatment. If, however, precarious lesions were excluded, then the caries increase was smaller and not of statistical significance. He interpreted this to mean that the effect of orthodontic appliance was principally to produce an increase in the number of initial carious lesions, i.e. enamel decalcification. His results further indicated that teeth, fitted with full bands, have a lower caries frequency than corresponding teeth in the control group.

More recently, Zachrisson and Zachrisson (1971) reported that orthodontic treatment did not appreciably increase the prevalence of caries but the localisation of the lesions was significantly different in treated and untreated persons. The appliances caused a shift of caries from interproximal to vestibular and lingual areas. They recorded enamel decalcification in their scoring of dental caries and showed that the majority of decalcified lesions (scores 1 and 2) in the control group were found on the maxillary and mandibular permanent first molars.

Data from other investigations have indicated that the incidence of carious lesions was not necessarily increased because of orthodontic treatment (Noyes 1937, Quin 1956, Dolce 1950, Bach 1953 & 1954, Muhler 1970, Zachrisson 1976, Wisth and Noord 1977). From the views reported above, it can be seen that the association between orthodontic treatment, enamel decalcification and dental caries is still controversial. As yet there are no reports of any studies carried out specifically for the purpose of determining the relationship of enamel decalcification to orthodontic treatment.

With this in mind an investigation is being undertaken to determine quantitatively the amount of enamel decalcification in samples of white South African children. These will include matched groups of children not undergoing orthodontic treatment, children receiving orthodontic treatment and children in whom orthodontic treatment has been completed. It is a long-term project which will involve both cross-sectional and longitudinal studies.

This first report is of a cross-sectional study concerned with establishing the amount of enamel decalcification in 204 schoolchildren who have not received orthodontic treatment.

MATERIALS AND METHODS

The sample for this study was chosen with the intention of using it at a later date, as a control group with which to compare the extent of decalcification in patients referred for orthodontic treatment. It was drawn from pupils attending two primary schools in the town of Springs, one of several in the Witwatersrand mining and industrial area with a white population of 58,000. Springs is situated 50 kms east of Johannesburg and draws its water supply from the Rand Water Board which supplies the Witwatersrand, including the city of Johannesburg, with water containing 0,20 ppm fluoride (mean yearly average).

The schools were selected on the basis of representing a middle to higher socio-economic population group, the same groups that predominate in private orthodontic practice in the area. Guidance in the selection of the schools was obtained from the senior dentist of Springs Dental Clinic, a body responsible for dental health inspections and education of all schoolchildren (±11 000) in the area.

The sample of 204 consisted of 102 pupils (51 boys and 51 girls) from each of the two schools (4 374 teeth). Within each school the pupils were drawn at random from Standard V classes (the final year in primary school) to give a group of children in the late mixed and early permanent dentition. This group would correspond with the age group at which most patients start orthodontic treatment, i.e. 12,4 years (Mizrahi 1977).

Prior to examination each subject was given a toothbrush and toothpaste and asked to brush all the teeth. No specific instructions were given regarding brushing technique.

The patient was then seated in an upright chair and examined with the aid of a Welch-Allen headlamp, a dental mirror, tweezers and a pledget of cotton wool. No attempt was made to do a prophylaxis or to dry the teeth with compressed air. The cotton wool pledget was used to wipe away any residual food debris that may have been present. Specially designed computer recording forms were completed by an assistant. The age of the patient to the nearest quarter of a year, the presence or absence of a history of topical fluoride application as well as all deciduous and absent permanent teeth were noted. Permanent second molars were disregarded. Teeth were recorded using the two digit system adopted by the F.D.I. in 1970.

The vestibular surfaces of the teeth were examined from

upper right to upper left and lower left to lower right. The same procedure was used for the lingual surfaces. No attempt was made to examine the interproximal surfaces of the teeth.

For the purpose of scoring the presence and extent of enamel decalcification both the vestibular and lingual surfaces of the crown were divided into a cervical, middle and incisal third. The lesion on each third was scored from 0 to 3, depending on the extent of the area covered. Zero represented no decalcification, score of 1 for decalcification of one third or less, score of 2 for decalcification of one third to two thirds and score of 3 for decalcification of two thirds and over. With the vestibular and lingual surfaces each contributing a maximum score of 9, the total possible score for any one tooth was 18.
For the purpose of this study the term "enamel decalcification" refers to the clinical presence of a white enamel opacity and is not based on any histological assessment.

Two types of lesions may appear as a white opacity on teeth. One is due to a developmental disturbance in enamel formation which may vary in appearance from a mild mottling to severe hypoplasia (Small and Murray 1978). The other is enamel decalcification due to the surface action of acid.

Severe enamel hypoplasia and marked decalcification are easily distinguished from each other. However, in certain instances mild localised developmental mottling may closely resemble mild enamel decalcification. Therefore it is accepted that in surveys of either mottled enamel (Dean 1934, Jackson 1961) or decalcification of enamel, as in the present study, some overlap of diagnosis is inevitable.

As all clinical examinations were carried out by one examiner, and intra examiner variability was monitored, it would be reasonable to assume that any error due to the possible inclusion of mild lesions of developmental origin would be a constant factor applicable to all the sample groups in the study.

The recorded data was processed in an IBM 370/158 computer using the standard programmes, including the Statistical Package for the Social Sciences (Nie *et al* 1975), from which two broad groups of information were derived.
(a) Scores for decalcification occurring on the different surfaces examined, i.e. the mean surface score or decalcification index – DI, for the sample, as well as the frequency of decalcification occurring on the different surfaces.

Values were calculated for the following surfaces:

1. All surfaces, vestibular and lingual surfaces of each tooth (Decalcification Index DI)
2. Vestibular surface only of each tooth
3. Lingual surface only of each tooth
4. The cervical third of the vestibular and lingual surfaces of each tooth.
5. The middle third of the vestibular and lingual surfaces of each tooth
6. The incisal third of the vestibular and lingual surfaces of each tooth
7. The cervical third of only the vestibular surface of each tooth
8. The middle third of only the vestibular surface of each tooth
9. The incisal third of only the vestibular surface of each tooth
10. The cervical third of only the lingual surface of each tooth
11. The middle third of only the lingual surface of each tooth
12. The incisal third of only the lingual surface of each tooth.

In order to calculate the mean sample values for each of the above surfaces, it was necessary to first calculate the mean score for each patient, i.e.

$$\frac{\text{surface score}}{\text{number of surfaces}}$$

and then divide this figure by the number of patients in the sample.

(b) Scores for decalcification on the different surfaces of individual teeth, i.e. the mean tooth score or Decalcification Index (DI) for each tooth as well as the frequency of decalcification on each tooth.

In order to calculate these values the scores of the different surfaces for each tooth in the sample were added and then divided by the number of teeth in the sample:

e.g.
$$\frac{\text{the sum of the surface score for all upper right first molars}}{\text{number of upper right first molars}}$$

All examination and scoring was carried out by one examiner. The examiner reliability was tested on a random group of thirty patients re-examined after a four week interval. Duplicated examinations were also conducted during the course of the survey as recommended by the World Health Organisation (1977). Scores on different surfaces of the same teeth were tested statistically using Student's paired t test. For independent groups Student's t test was used for scores and the Chi-square test for frequencies. The level of statistical significance chosen was $p<0,01$.

As the data did not appear to have a strictly normal distribution, the use of the mean as a true representation of central tendency may be questioned and consequently the results of the Student's t test should be interpreted with caution. Other measures of central tendency are being investigated.

RESULTS

A quantitative analysis of the amount of decalcification and the frequency of occurrence, i.e. the percentage of the sample showing decalcification with regard to the different surfaces examined, is shown graphically in Figures 1 and 2 respectively.

The first column in Fig. 1 reflects the level of decalcification for all the surfaces examined. The mean patient score was 0,26 (standard error of the mean 0,02), this figure represents the level of decalcification for this sample or the DI. The corresponding column in Fig. 2 indicates that 84 per cent of the sample showed some degree of decalcification.

Further examination of Figs. 1 and 2 shows that, with

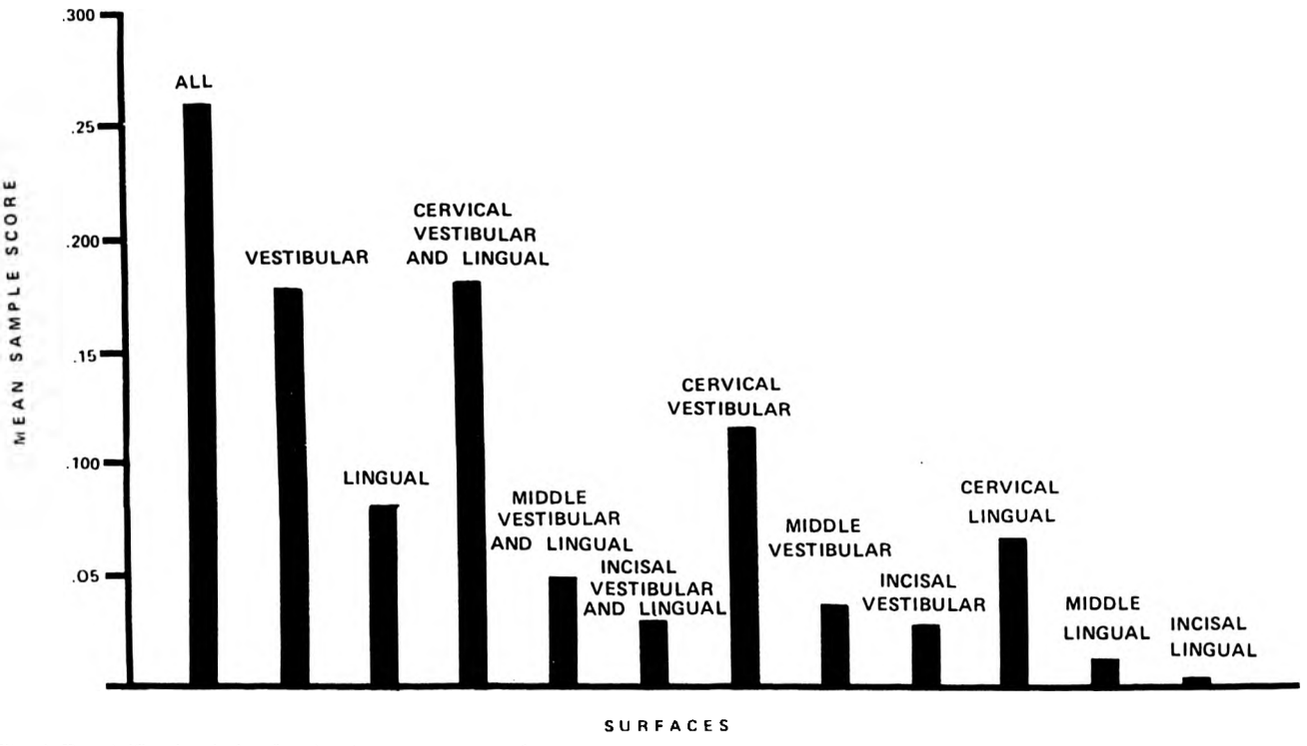


Fig. 1 Decalcification index for the different tooth surfaces.

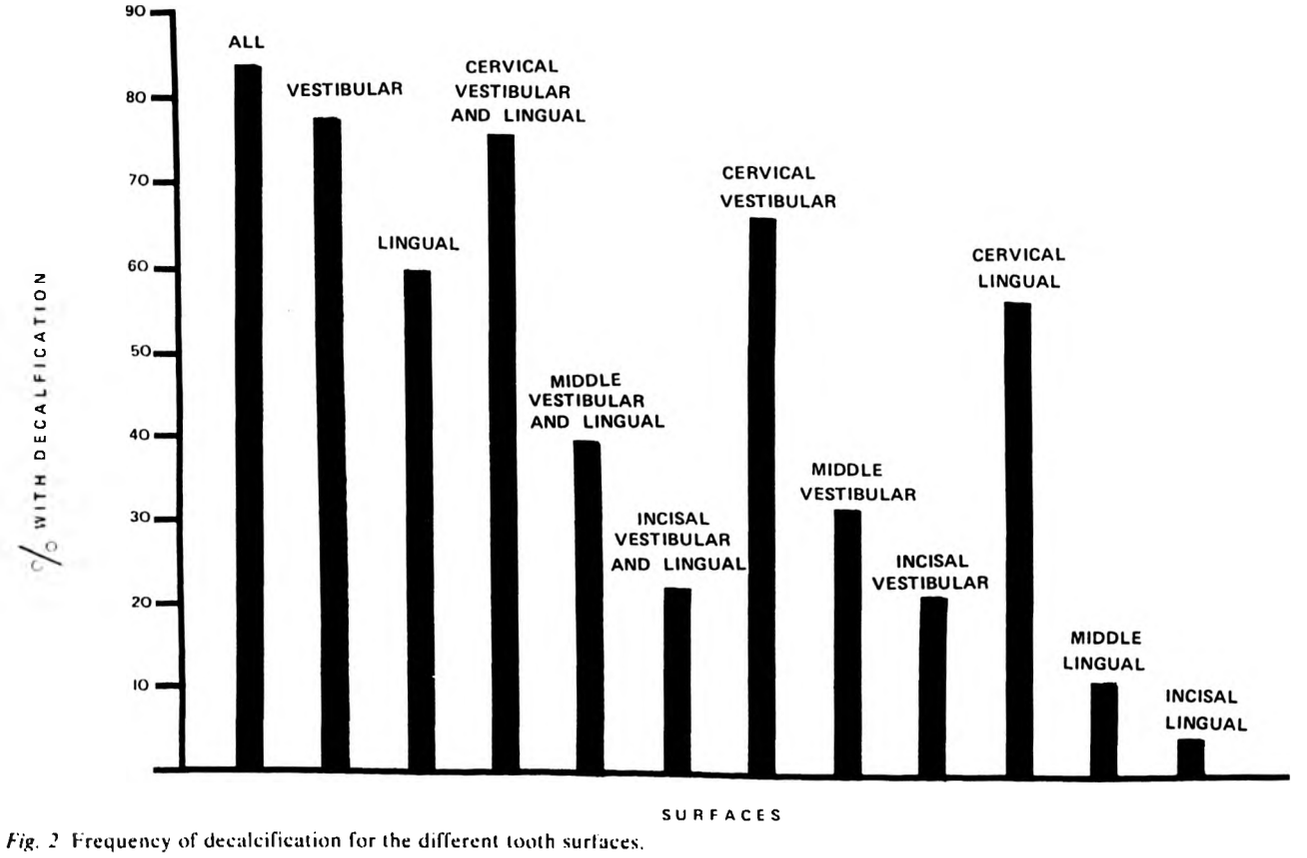


Fig. 2 Frequency of decalcification for the different tooth surfaces.

respect to both score and frequency, the vestibular surfaces of the teeth exhibited significantly more decalcification than the lingual surfaces ($t = 7{,}63$ $p < 0{,}001$; $X^2 = p<0{,}001$).

Consideration of the cervical, middle and incisal thirds (vestibular and lingual combined) shows that the cervical third exhibited more decalcification than the middle or incisal third. Differences between these 3 surfaces (cervical – middle, cervical – incisal, and middle – incisal) were statistically significant in respect of scores ($p<0{,}001$) and frequencies ($p<0{,}001$).

Examination of the data for the cervical, middle and incisal thirds when the vestibular and lingual aspects were considered separately shows that the same pattern exists. However, there was no significant difference between the scores of the middle and incisal thirds on the

vestibular surface and no significant difference between the frequency of decalcification on the middle and incisal thirds of both the vestibular and lingual surfaces.

Analysis of the data for the score and the frequency of decalcification in males and females showed that males scored higher and had a higher frequency of decalcification in respect of all the surfaces examined. However the sex difference was significant only for the all surface groups ($t = 2,57$ $p<0,005$).

In the case of the frequency values the sex difference was significant only at the 5 per cent level in the case of the all surface group ($X^2 = 4,3$).

The mean age of the sample was 12,33 years (SD 0,71). An analysis of the data for patients below 11,75 years and those above 11,75 years showed no statistically significant difference for either scores or frequencies.

Table I presents the details of frequencies and scores for enamel decalcification on each tooth. Taken as a group there was no significant difference in the frequency of decalcification between the upper and lower teeth or between the left and right side of the mouth. An examination of the data shows that the tooth most frequently and most severely affected was the lower permanent first molar followed by the upper permanent first molar and then the upper central and lateral incisor teeth. The difference in frequency between the lower molar, upper molar and the remaining teeth was statistically significant ($p<0,001$). There was also a significant difference ($p<0,01$) between the upper incisors and all the remaining teeth except for the upper lateral incisors and upper first premolars. Between the upper centrals, laterals and first premolars there was no significant difference.

An examination of the frequencies and scores for decalcification occurring on the cervical, middle and incisal thirds in relation to each tooth (Table II) confirmed the pattern shown in Figs. 1 and 2.

DISCUSSION

The first bar in Fig. 1 represents the Decalcification Index for the entire sample. It is an indication of the level of decalcification when the vestibular and lingual surfaces of all teeth are considered together and will be used as a baseline for comparisons in future studies.

Analysis of the differences in the Decalcification Index between the sexes revealed that males scored significantly higher than females ($t = 2,57$ $p<0,005$).

The first bar in Fig. 2 indicates that 84 per cent of subjects in the sample showed some evidence of enamel decalcification. The difference between the frequency of decalcification in males and females was not as significant ($X^2 = 4,3$ $p<0,05$) as in the case of the Decalcification Index. This suggests that not only do more males than females show evidence of enamel decalcification but, more important, the amount of decalcification in males is significantly greater than in females. This finding may be related to a difference in the level of oral hygiene practised by males and females. Further studies are being undertaken to investigate this relationship.

The vestibular surfaces of teeth in the sample were significantly more susceptible to enamel decalcification than the lingual surfaces (Figs. 1 and 2). The results also showed that the cervical third of the tooth was significantly more prone to decalcification than either the middle or incisal third and the middle surface, in turn, was more susceptible than the incisal third. This pattern was also apparent when the vestibular and palatal surfaces were examined separately except that the difference in score between the incisal and middle third

Table I Details of frequency of decalcification and mean tooth scores for maxillary and mandibular teeth

Tooth	n	Percentage with Decalcification	Mean Tooth Score	Standard Error of the Mean
16	203	44.8	0.68	0.06
15	154	6.5	0.10	0.03
14	174	12.1	0.17	0.04
13	149	4.7	0.10	0.05
12	201	9.0	0.12	0.03
11	203	13.8	0.20	0.04
21	203	15.3	0.21	0.04
22	203	12.8	0.16	0.03
23	150	5.3	0.08	0.03
24	174	7.5	0.14	0.04
25	146	3.4	0.05	0.02
26	201	43.8	0.69	0.08
36	200	58.0	1.21	0.11
35	134	5.2	0.07	0.03
34	179	8.4	0.11	0.03
33	190	3.2	0.05	0.02
32	204	4.9	0.06	0.02
31	203	4.4	0.05	0.02
41	204	1.5	0.02	0.01
42	204	2.9	0.03	0.02
43	187	4.8	0.06	0.02
44	176	6.2	0.08	0.03
45	133	5.3	0.09	0.05
46	199	59.3	1.20	0.10

Table II Details of frequency of decalcification and mean tooth scores for cervical, middle and incisal thirds of maxillary and mandibular teeth

Tooth	n	Cervical			Middle			Incisal		
		(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
16	203	33.5	.42	.05	15.3	.19	.03	4.9	.07	.03
15	154	1.9	.02	.01	3.9	.05	.02	1.9	.03	.02
14	174	6.3	.07	.02	1.7	.02	.01	5.2	.09	.04
13	149	2.0	.03	.02	1.3	.02	.02	2.0	.05	.04
12	201	5.5	.07	.02	1.0	.02	.01	3.0	.04	.02
11	203	6.9	.09	.02	3.0	.05	.02	3.9	.06	.02
21	203	8.9	.13	.03	3.0	.04	.02	3.9	.04	.02
22	203	7.4	.11	.03	2.5	.03	.01	3.0	.04	.02
23	150	2.0	.03	.02	1.3	.01	.01	2.0	.04	.03
24	174	4.6	.07	.03	2.3	.03	.02	3.4	.04	.02
25	146	1.4	.01	.01	1.4	.01	.01	2.1	.02	.01
26	201	33.3	.46	.06	13.9	.20	.04	2.5	.03	.01
36	200	56.5	1.06	.09	7.5	.13	.04	2.0	.03	.01
35	134	5.2	.05	.02	.7	.02	.02	0	0	
34	179	6.1	.07	.02	.6	.01	.01	2.2	.03	.02
33	190	1.6	.02	.01	.5	.02	.02	1.6	.02	.01
32	204	2.0	.02	.01	.6	.01	.01	1.6	.02	.01
31	203	1.5	.02	.01	1.5	.02	.01	1.5	.02	.01
41	204	0.5	.01	.01	.5	.01	.01	.5	.01	.01
42	204	1.5	.02	.01	.5	.01	.01	1.0	.01	.01
43	187	5.2	.02	.01	1.1	.03	.02	2.1	.02	.01
44	176	5.7	.06	.02	.6	.01	.01	1.1	.02	.01
45	133	4.5	.05	.02	1.5	.03	.02	.8	.01	.01
46	199	57.3	1.03	.08	9.0	.16	.04	1.0	.02	.01

Key: (a) Percentage with decalcification
(b) Mean tooth score
(c) Standard error of the mean

was not significant on the vestibular surface and in the case of the frequencies the difference was not significant in either the vestibular or the lingual surface. The cervical third of the vestibular surface of the mandibular permanent first molar was the most susceptible and most severely affected site. At present there appear to be no other studies with which to compare these results.

Examination of the data in relation to the individual teeth indicates very clearly the greater susceptibility of the permanent first molars to decalcification. Table I shows that 57 per cent of lower molars and 45 per cent of upper molars exhibited some degree of involvement. In 1953 Bach stated that he "did not find one permanent first molar in over 2000 cases that did not present a decalcified line on the buccal and lingual surfaces upon first examination". In other words, 100 per cent of permanent first molars exhibited some decalcification. More recently Zachrisson and Zachrisson (1971) showed that 43–49 per cent of permanent first molars (Zachrisson's caries index score 1 and 2) in his control group showed some evidence of decalcification. It is possible that more widely accepted and practised preventive dental health measures in use today could be responsible for the difference between the result of Bach's (1953, 1954) survey carried out 25 years ago and the present survey. The children in Zachrisson and Zachrisson's (1971) control group had their teeth brushed with sodium fluoride three times a year during their years at school. The children in the present survey received no special co-ordinated preventive dental treatment.

In spite of differences in time and geographical situation, between the surveys of Bach (1953, 1954), Zachrisson and Zachrisson (1971) and the present study, there is a close similarity in the distribution of decalcification within individual teeth in each dental arch. The teeth in decreasing order of susceptibility, are:

1. mandibular first molars
2. maxillary first molars
3. maxillary central incisors
4. maxillary lateral incisors
5. maxillary first premolars
6. maxillary and mandibular canines, second premolars
7. mandibular incisors

It is interesting to note that the distribution and prevalence of enamel decalcification differs from the figures on the prevalence of enamel opacities of intrinsic origin as recorded in a table compiled by Small and Murray (1978) in which the percentages of subjects affected ranged from 8 to 83,5 per cent with most of the surveys reporting frequencies between 30 and 40 per cent. Furthermore the teeth that Small and Murray (1978) reported showing most mottling were the maxillary central incisors and maxillary first molars. This suggests to us that, in spite of the confusion that may exist in recognising mild mottling or decalcification, it would appear that severe lesions are clinically distinguishable.

CONCLUSIONS

This study has shown that decalcification, as the term is used clinically, is common in primary schoolchildren living in a fluoride deficient area and not undergoing orthodontic treatment. The decalcification occurs most commonly in the cervical regions of the permanent first molars. In view of the high prevalence of decalcification in the population sample studied, the generally held

belief that orthodontic treatment is responsible for a high prevalence of decalcification is open to question, and requires further investigation.

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REFERENCES

Adams, R.J. (1967) The effects of fixed orthodontic appliances on the cariogenicity, quantity and microscopic morphology of oral lactobacilli. *Journal of Oral Medicine*, **22**, 88-98.

Bach, E.N. (1953) Incidence of caries during orthodontic treatment. *American Journal of Orthodontics*, **39**, 756-778.

Bach, E.N. (1954) Report of "Orthodontic Children" covering a period of twenty five years. *American Journal of Orthodontics*, **40**, 83-108.

Bloom, R.H. & Brown, L.R. (1964) A study of the effects of orthodontic appliances on the oral microbial flora. *Oral Surgery, Oral Medicine, Oral Pathology*, **17**, 658-667.

Costello, I., Massler, M., Monteleone, U.L. & Suher, T. (1948) Effect of zinc oxyphosphate cement on enamel. *American Journal of Orthodontics*, **34**, 271-277.

Darling, A.I. (1956) Studies of the early lesion of enamel caries with transmitted light, polarised light and radiography. Part I. *British Dental Journal*, **101**, 289-297. Part II. *British Dental Journal*, **101**, 329-341.

Dean, H.T. (1934) Classification of mottled enamel diagnosis. *Journal of the American Dental Association*, **21**, 1421-1426.

Dikeman, T.L. (1962) A study of acidogenic and aciduric microorganisms in orthodontic and non orthodontic patients. *American Journal of Orthodontics*, **48**, 627. (Abstract).

Docking, A.R. & Newbury, C.R. (1953) The effect of orthodontic cement on tooth enamel. *Australian Dental Journal*, **57**, 139-149.

Dolce, J.J. (1950) Caries incidence in relation to orthodontic therapy. *American Journal of Orthodontics*, **36**, 534-545.

Graber, T.M. & Swain, B.F. (1975) *Current Orthodontic Concepts and Techniques*, 2nd ed., p. 10, 33, 476. London: W.B. Saunders.

Ingervall, B. (1962) The influence of orthodontic appliances on caries frequency. *Odontologisk Revy*, **13**, 175-190.

Jackson, D. (1961) A clinical study of non-endemic mottling of enamel. *Archives of Oral Biology*, **5**, 212-223.

Lefkowitz, W. & Bodecker, C.F. (1938) Concerning the vitality of the calcified dental tissues. II. The permeability of enamel. *Journal of Dental Research*, **17**, 453-463.

Lefkowitz, W. (1940) Histological evidence of the harmful effect of cement under orthodontic bands. *Journal of Dental Research*, **19**, 47-55.

Meyers, M.J. (1952) Protectism of enamel under orthodontic bands. *American Journal of Orthodontics*, **38**, 866-874.

Mizrahi, E. (1977) Retention of the conventional orthodontic band. *British Journal of Orthodontics*, **4**, 133-137.

Muhler, J.C. (1970) Dental caries - orthodontic appliances - SnF_2. *Journal of Dentistry for Children*, **37**, 34-37.

Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K. & Bent, D.H. (1975) *Statistical Package for the Social Sciences*, 2nd ed., New York: McGraw-Hill.

Nixon, G.S. (1962) Zinc phosphate cement. *Dental Practitioner*, **12**, 322-326.

Noyes, H.J. (1937) Dental caries and the orthodontic patient. *Journal of the American Dental Association*, **24**, 1243-1254.

Owen, O.W. (1949) A study of bacterial counts (lactobacilli) in saliva related to orthodontic appliances - A preliminary report. *American Journal of Orthodontics*, **35**, 672-678.

Paffenbarger, G.C., Sweeney, W.T. & Isaacs, A. (1933) A preliminary report on the zinc phosphate cements. *Journal of the American Dental Association*, **20**, 1960-1982.

Phillips, R.W. (1973) *Skinner's Science of Dental Materials*, 7th ed., p. 473. Philadelphia: W.B. Saunders.

Quin, G.W. (1956) The progress of dental caries beneath orthodontic bands. A clinical study. *American Journal of Orthodontics*, **42**, 793. (Abstract).

Seniff, R.W. (1962) Enamel surface change caused by oxyphosphate cement. *American Journal of Orthodontics*, **48**, 219-220. (Abstract).

Small, B.W. & Murray, J.J. (1978) Enamel opacities: prevalence, classification and aetiological considerations. *Journal of Dentistry for Children*, **6**, 33-42.

Wisth, P.J. (1970) The role of zinc phosphate cement in enamel surface changes on banded teeth. *The Angle Orthodontist*, **40**, 329-333.

Wisth, P.J. & Noord, A. (1977) Caries experience in orthodontically treated individuals. *The Angle Orthodontist*, **47**, 59-64.

World Health Organisation (1977) *Oral Health Surveys. Basic Methods*, 2nd ed., p. 20. Geneva.

Zachrisson, B.U. & Zachrisson, S. (1971) Caries incidence and orthodontic treatment with fixed appliances. *Scandinavian Journal of Dental Research*, **79**, 183-192.

Zachrisson, B.U. (1976) Cause and prevention of injuries to teeth and supporting structures during orthodontic treatment. *American Journal of Orthodontics*, **69**, 285-300.