CASE WESTERN RESERVE UNIVERSITY

GRADUATE STUDIES

We hereby approve the thesis of

HENRY FREDERICK NEUMANN

candidate for the MASTER OF SCIENCE

degree.

Signed: _____ (Chairman)

_____

_____

_____

_____

Date May 14, 1974

A CLINICAL EVALUATION OF DECALCIFICATION UNDER ORTHODONTIC BANDS FOLLOWING PRETREATMENT WITH ACIDULATED PHOSPHATE-FLUORIDES AND ADHESIVE PLASTIC COATINGS

by

HENRY FREDERICK NEUMANN

Submitted in partial fulfillment of the requirements

for the Degree of Master of Science

Department of Orthodontics

SCHOOL OF DENTISTRY

CASE WESTERN RESERVE UNIVERSITY

June 1974

A CLINICAL EVALUATION OF DECALCIFICATION UNDER ORTHODONTIC BANDS FOLLOWING PRETREATMENT WITH ACIDULATED PHOSPHATE-FLUORIDES AND ADHESIVE PLASTIC COATINGS

Abstract

by

HENRY FREDERICK NEUMANN

Decalcification secondary to failure of band-cement is a vexing orthodontic problem. In order to investigate and compare the effects of two acidulated phosphate-fluorides and two plastic adhesive coatings in resisting decalcification, each first premolar in twenty-four orthodontic extraction cases were assigned randomly combinations of the following treatments: ("Luride") acidulated phosphate-fluoride (1.23 percent), ("Thera-Flur") acidulated phosphate-fluoride (0.5 percent), ("Nuva-Seal") and ("Protecto") both hybrid epoxy enamel coatings.

The agents were applied to the buccal surfaces of the teeth following manufacturer's instructions and well-adapted bands were seated with cement on all but the buccal surfaces.

Twelve weeks later the bands and protective agents were removed, and ninety-six hours later the teeth were extracted. The extent of decalcification was scored blindly and independently by four observers and, as indicated by Friedman's blocked, non-parametric analysis of variance, there was a significant ($p<.01$) overall difference among treatments. The adhesive plastics, as a group, produced a greater resistance to decalcification and, specifically, Protecto was associated with the least amount of decalcification.

The samples were observed further with the scanning electron microscope because it was felt that this would elucidate the nature of the lesions which were ranked clinically. However, it was concluded that this is an inappropriate tool to evaluate the clinical appearance of incipient decalcification.

It was suggested that the adhesive plastics be employed in high-risk cases that exhibit poor oral hygiene, high caries index or existing zones of decalcification prior to orthodontic therapy.

ACKNOWLEDGEMENTS

The author expresses his sincerest gratitude to the following:

Dr. Lysle E. Johnston, Associate Professor and Chairman of the Department of Orthodontics, School of Dentistry, Case Western Reserve University, who, as Chairman of my thesis committee and my chief advisor, gave more than just hours of help, advice, and constructive criticism; he gave sincerity, friendship, and guidance throughout my entire graduate education.

Dr. David Swedlow, Instructor in Oral Biology, School of Dentistry, Case Western Reserve University, who, in addition to being a member of my committee, gave many hours of help and insight into the scanning electron microscope phase of my research.

Dr. Joel Wisotzky, Professor of Oral Biology and Medicine and Director of Dental Research, School of Dentistry, Case Western Reserve University, for his interest in this project, being a member of my committee, for expediting considerations by the Human Involvement Committee and for his patience as an observer.

Dr. Robert Scheffer, Associate Professor of Anesthesia and Oral Surgery, School of Dentistry, Case Western Reserve University, for his words of encouragement, being a member of my committee, and particularly for developing the extraction technique.

Dr. Sanford Neuger, Associate Clinical Professor of Orthodontics, School of Dentistry, Case Western Reserve University, for

being a member of my committee, a patient observer and a guiding influence upon my future.

Dr. Edward Rossi, Associate Professor and Chairman of Oral Pathology, School of Dentistry, Case Western Reserve University, for his time as an observer and his refreshing attitude even under academic strains.

Mr. Doug Johnston, for his excellent photography and preparation of the plates.

Mrs. Linda Nicholl, for her quick, precise typing and proofreading.

Mr. Bill Martin, for the preparation of the graphic illustrations; Miss Marcia Bolton, for her assistance during the application of the pretreatment agents; Miss Helen Geleb, for her expert sectioning technique; Mr. James Simmelink, for his assistance on the light microscope section of this research; and to all the first year Orthodontic graduate students, Drs. Behrents, Berkowitz, Bernabei, Kossoff, and Rhodes, for their cooperation in patient acceptance under extenuating circumstances.

The author also expresses his gratitude to the following companies for providing information and materials:
Unitek Corporation, Monrovia, California; Davies Rose Hoyt, Needham, Massachusetts; Lee Pharmaceutical Inc., South El Monte, California; L. D. Caulk Company, Division Dentsply, Milford, Delaware.

DEDICATION

Dedicated to my parents, whose guidance and seemingly endless energies have made my education possible, and to my wife for her conscientious attitude towards my continuing education.

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ACKNOWLEDGEMENTS	iv
DEDICATION	vi
LIST OF TABLES	viii
LIST OF ILLUSTRATIONS	ix
CHAPTER	
I. INTRODUCTION	1
II. REVIEW OF THE LITERATURE	2
III. MATERIALS AND METHODS	10
IV. RESULTS	18
V. DISCUSSION	20
VI. SUMMARY AND CONCLUSIONS	36
APPENDIXES	
I. INDIVIDUAL RANKINGS BY OBSERVERS	38
II. SEM PHOTOMICROGRAPHS OF SUBJECT 24	46
III. COLOR PHOTOGRAPHS OF SUBJECTS 24 and 7	50
IV. INDUCED MICROSCRATCHES AND ENAMEL-ADHESIVE INTERFACE	54
V. PATIENT CONSENT FORM	56
LITERATURE CITED	58

LIST OF TABLES

Table Page

I. Treatment Protocol. 11

II. Combined Decalcification Ranks as Seen by Four Observers. 19

III. Comparison of Rankings--Visual and SEM for Five Subjects 22

LIST OF ILLUSTRATIONS

Page

FIGURE

1. Sectioning Technique for Scanning Electron Microscope Observations. 15

2. Bar Graph Comparison of Pretreatment Agents. 33

PLATE

I. Comparison of Perikymata--Acidulated Phosphate-Fluoride versus Adhesive Plastic Coating 23

II. Microscratches Apparent on Adhesive Plastic Coated Teeth 26

III. Light Microscope Photographs of Apparent Subsurface Decalcification. 28

INTRODUCTION

Cement-failure and subsequent decalcification under orthodontic bands is a real problem, not only to the orthodontist, but to the patient and family dentist as well. Many methods of prevention have been suggested in an effort to make teeth more resistant to the side-effects of cement-failure. Chief among these has been the topical application of inorganic and, more recently, organic fluorides. Although these measures have met with some success, an entirely satisfactory solution is not yet available. With the advent of the adhesive plastics, mechanical, rather than chemical, protection has been suggested. It is the purpose of this investigation to characterize the effectiveness of the plastics in comparison with that of acidulated phosphate-fluorides in resisting enamel decalcification.

REVIEW OF THE LITERATURE

Decalcification and Decay

Although orthodontic therapy is generally beneficial, it is not totally without risks, the most immediately apparent of which is enamel decalcification. This decalcification, fostered by cement-failure under orthodontic bands or by inadequate oral hygiene adjacent to orthodontic bands, differs in location--but not in pathological or histological characteristics--from decalcification elsewhere. Muhler (1970) noted that, in children with orthodontic appliances, one finds the greatest increase in decalcification on the buccal and lingual surfaces of the teeth. The most common areas of cement-failure are the molars and, unfortunately, the upper incisors.

An obvious way to avoid this problem is to have no loose bands. This, however, is impossible. It seems only logical, therefore, that one should rely on methods which have been proven useful in preventing the decay process. Obvious choices would be chemical and mechanical agents which produce surface changes or provide mechanical protective barriers, either of which might be sufficient to protect the tooth until cement-failure is discovered and remedied.

Chemical Agents

Inorganic Fluorides

The most widely advocated form of chemical protection is the

application of an inorganic stannous or sodium fluoride.

Volker (1939) first noted that enamel takes up fluoride and other minerals, thereby resulting in a reduction of solubility. The basis of fluoride uptake has been studied extensively since then. Brudevold (1959), for example, studied the enamel surface and found it to be composed of calcium phosphate crystals in the form of hydroxyapatite. When these crystals are exposed to a strong sodium fluoride solution, they dissolve and form calcium fluoride, sodium phosphate, and sodium hydroxide. These products wash away leaving a small amount of calcium fluoride precipitate on the surface which, in turn, slowly dissolves into a weak fluoride solution and enters into another reaction. It is this second surface reaction at a low fluoride concentration that causes the relatively insoluble, and therefore more resistant, fluorapatite to form. Whatever the mechanism, fluoride has achieved widespread acceptance.

However, many conflicting reports concerning the effectiveness of stannous and sodium fluorides have appeared. For example, Muhler (1958) noted a reduction in caries (16%) in adults treated with a single dose of stannous fluoride, while Wellock, Maitland and Brudevold (1965) measured no reduction in caries in children after a single application of 8% stannous fluoride. Torell and Ericsson (1965), and Horowitz and Lucye (1966) report similar results (no reduction in caries).

Prior to these negative reports, Seniff (1962) reported that the application of 8% stannous fluoride preceding orthodontic banding reduced the incidence of decalcification significantly. Ingervall (1962)

has suggested similar pretreatment applications to resist decalcification under orthodontic bands. However, in view of the conflicting reports it would seem unwise for one to rely solely on stannous fluoride to delay the onset of decalcification or decay.

Acidulated Phosphate-Fluorides

Brudevold et al. (1963) observed appreciable penetration of enamel with an acidic sodium phosphate solution containing sodium fluoride at a pH of 3. An increase in uptake of fluoride by enamel occurred with an increase in concentration and a decrease in pH. The acidulated phosphate-fluoride (APF) was felt to be superior to stannous fluoride because there was a reduction of seventy percent new DMF surfaces compared to controls, there were no heavy metals in the composition to stain the teeth, the solution was stable when kept in plastic containers, and the taste proved acceptable. Moreover, there was no incidence of gingival irritation or blanching as was seen with stannous fluoride (Muhler, 1957).

Mellberg et al. (1966), however, found the fluorapatite crystal formed by APF to be slightly soluble. When washed for one day, two-thirds of the fluoride dissolved away in a simulated saliva solution of calcium phosphate. After this initial loss, there was no subsequent secondary dissolution of fluoride from the surface even after one week. Therefore, it may be assumed that the fluorapatite crystals that remain are bound firmly and afford the optimal chemical protection to the enamel surface.

Horowitz (1969), in a two-year study of acidulated phosphate-fluorides, found them effective in reducing the DMF rate thirty-three percent ($p < 0.05$), and suggested their application as a preventive treatment.

Aasenden et al. (1972) examined the effects of daily rinsing and ingestion of APF and sodium fluoride and showed the APF solution to be superior in decreasing the DMF rate. Moreover, he stressed the desirability of post-eruptive applications. Frankl et al. (1972) observed similar decreases in DMF with daily rinses of .02% sodium fluoride in an acidulated phosphate solution. With this solution, a depression in salivary pH to 4.25 - 5.25 for 10 to 30 seconds was effected and this depression presumably enhanced the deposition of fluoride on the enamel surface.

Finally, Hirschfield (1972), comparing stannous fluoride, an organic amine fluoride not available in this country ("Elmex Fluid," Gaba, Ltd., Basel, Switzerland); and an acidulated phosphate-fluoride (Thera-Flur, Davies Rose Hoyt, Needham, Massachusetts), reports that of these agents only "Elmex" and Thera-Flur (APF) are capable of reducing, but not eliminating, decalcification under loose orthodontic bands. Evidence exists, therefore, that fluorides are not totally effective in preventing decalcification and may perhaps only delay its onset.

Mechanical Barriers

Varnishes

Perhaps the solution for the problem of decalcification lies

with coating the tooth with a tough mechanical barrier prior to appliance placement. As early as 1940 the prophylactic use of colloidal varnishes was suggested in the literature as a mechanism to prevent decalcification (Lefkowitz, 1940). Meyers (1952), for example, recommended the use of copal varnish to protect the teeth under orthodontic bands. He found an increase of 5.9 areas of decalcification in treated cases verses 27.4 areas in untreated cases. Although not universally used (due to the solubility of the varnish) this type of mechanical pretreatment is mentioned occasionally in the literature today. A less soluble agent, however, might prove more effective. Towards this end, workers have recently turned to the plastic systems.

Adhesive Plastics

Since the chemical barrier effected by the fluorides and the highly soluble mechanical barrier of the varnishes are not totally effective in preventing decalcification or decay, perhaps the adhesive plastics, with their stronger mechanical retention will prove to be more beneficial.

Cueto and Buonocore (1967) reported the results of treating 269 subjects with an adhesive plastic pit and fissure sealant, composed of methyl-2-cyanoacrylate with powdered fillers, and showed an 86.3 percent reduction in decay. Buonocore (1970) revealed the results of his "longer-lasting" sealant (Nuva-Seal) which employs an ultra-violet light activating system and again showed an impressive reduction in DMF. H. Lee and Swartz (1971) evaluated a polyurethane adhesive resin in an *in vitro*

study. Penetration could be observed into the depths of the pits and fissures and it was felt this seal would be effective in decreasing DMF and, accordingly, an in vivo study was suggested. However, to date no data have been published. For a review of adhesive plastics sealants to date and a discussion of the positive effects, mainly the decrease in DMF, of pretreatment, Rippa (1973) should be consulted.

If these adhesive plastics are effective in decreasing the incidence of caries they might similarly be effective in preventing decalcification adjacent to and under orthodontic bands. H. Lee et al. (1973) introduced commercially an adhesive polymeric coating system (Protecto, Lee Pharmaceuticals, Inc., South El Monte, California) to be painted on enamel and used as a prophylactic or restorative coating. To date, there are no published data as to the effectiveness of this agent.

Pretreatment of the Enamel Surface

Prior to the placement of a protective plastic coating, the enamel surface must be pumiced, acid etched, and dried. It is sufficient to state that acid etchants, at optimal concentrations, are recommended by all adhesive plastic manufacturers as well as many researchers (Buonocore, 1955; Gwinnett, 1971; B. Lee et al., 1971; Retief, 1973), and that these etching agents improve the retention of the plastic coatings.

However, a controversy exists concerning the long-range effects of acid-etch on enamel. The surface changes on the enamel

are clinically similar to incipient decalcification. Is it consistent with prevention to introduce a precursor to that which you are trying to avoid? In an in vitro study, Newman and Facq (1971) claim that pumicing an etched surface restores the normal appearance immediately. A parallel in vivo celloiden-replication series by the same researchers (1971) produced the same results. From these data one can assume that the clinical appearance of decalcification caused by acid-etch can be reversed. A more basic question, however, is whether the calcium-phosphate ratio remains the same. Lenz and Muhleman (1963a and b) state that rather than frank chemical remineralization, a salivary pellicle is formed on the enamel surface. They describe this pellicle as "a finely ground amorphous precipitate of unknown but probably inorganic in nature," and conclude that a chemical re-balance is not achieved.

Wei (1970), using an electron probe on etched enamel, showed a decrease in the calcium to phosphate ratio which returned to near-normal levels after a brief exposure to a remineralizing solution similar to saliva. Albert and Grenoble (1971) report that after a one-hour exposure to saliva, the etched surface appears to have begun to remineralize and that within ninety-six hours the etched enamel surface has returned to normal appearance. The data in support of these theories are not conclusive and the subject of remineralization requires more extensive research. However, there is evidence to suggest that the decalcification which is inflicted as part of pretreatment is visibly gone within four days. This

would indicate, therefore, that pretreatment etchants would not be a significant factor when an evaluation of decalcification is done by clinical visual inspection.

Conclusions

There are both chemical and mechanical barriers which may serve to delay the onset of decalcification under orthodontic bands. There is some evidence that acidulated phosphate-fluorides and amine-fluorides may be successful. There are some *a priori* reasons to assume that the plastics are also effective but to date no clinical tests substantiate this. It is only logical, therefore, that the adhesive plastics be compared with the acidulated phosphate-fluoride agents as to their effectiveness in resisting decalcification under orthodontic bands.

MATERIALS AND METHODS

Sample

Twenty-four patients, fifteen males and nine females, who required therapeutic removal of four first bicuspids were selected from among those patients beginning orthodontic treatment at Case Western Reserve University Department of Orthodontics. The nature of the study and its significance were explained in detail, both to the subject and to his or her parents. A signed and witnessed consent form was obtained for each participant (Appendix V).

The only criteria, other than consent, used in the selection of subjects, were:

1. the necessity of first bicuspid extractions as determined by standard diagnostic procedures,
2. the absence of restorations or caries on the buccal surfaces of the first bicuspid teeth, and
3. the ability to deliver these teeth atraumatically.

Experimental Design

A table of random numbers was used to assign various treatment-combinations to each patient. The 24 sets of treatments were designed so that each agent appeared in all four quadrants with the same frequency (Table I).

TABLE I

TREATMENT PROTOCOL

Patient	Quadrant			
	Right		Left	
	Upper	Lower	Upper	Lower
1	Luride	Thera-Flur	Protecto	Nuva-Seal
2	Nuva-Seal	Protecto	Luride	Thera-Flur
3	Thera-Flur	Luride	Nuva-Seal	Protecto
4	Protecto	Nuva-Seal	Thera-Flur	Luride
5	Luride	Protecto	Thera-Flur	Nuva-Seal
6	Nuva-Seal	Thera-Flur	Luride	Protecto
7	Protecto	Luride	Nuva-Seal	Thera-Flur
8	Thera-Flur	Nuva-Seal	Protecto	Luride
9	Luride	Protecto	Nuva-Seal	Thera-Flur
10	Thera-Flur	Nuva-Seal	Luride	Protecto
11	Protecto	Luride	Thera-Flur	Nuva-Seal
12	Nuva-Seal	Thera-Flur	Protecto	Luride
13	Nuva-Seal	Thera-Flur	Protecto	Luride
14	Protecto	Luride	Thera-Flur	Nuva-Seal
15	Thera-Flur	Nuva-Seal	Luride	Protecto
16	Luride	Protecto	Nuva-Seal	Thera-Flur
17	Thera-Flur	Nuva-Seal	Protecto	Luride
18	Protecto	Luride	Nuva-Seal	Thera-Flur
19	Nuva-Seal	Thera-Flur	Luride	Protecto
20	Luride	Protecto	Thera-Flur	Nuva-Seal
21	Protecto	Nuva-Seal	Thera-Flur	Luride
22	Thera-Flur	Luride	Nuva-Seal	Protecto
23	Nuva-Seal	Protecto	Luride	Thera-Flur
24	Luride	Thera-Flur	Protecto	Nuva-Seal

Clinical Procedure

Only the buccal surfaces of the four first bicuspids were treated with the protective agents. The agents were:

1. Luride (Davies Rose Hoyt, Needham, Massachusetts), an acidulated phosphate fluoride containing 1.23% fluoride ion from sodium fluoride.

2. Thera-Flur (Davies Rose Hoyt, Needham, Massachusetts), an acidulated phosphate fluoride containing 0.5% fluoride ion from sodium fluoride.

3. Nuva-Seal (L. D. Caulk, Co., Division of Dentsply, Milford, Delaware), a hybrid epoxy enamel coating with a chemical monomer composition of bis-phenol A-glycidyl methacrylate.

4. Protecto (Lee Pharmaceuticals, Inc., South El Monte, California), a composite epoxy enamel coating with a chemical monomer composition of bis-phenol A-glycidyl methacrylate and refractory grade fibers.

Both Nuva-Seal and Protecto consist, when polymerized, of dimethylmethacrylate and a hybrid epoxy molecule.

A thorough pumicing and air drying preceded treatment for both the Luride and Thera-Flur and one four-minute application, according to manufacturer's instructions, preceded orthodontic banding by 30 minutes. Application was carried out under a rubber dam to prevent cross-contamination, and the surfaces were washed after each application.

The Protecto and Nuva-Seal were also applied under a rubber dam and according to manufacturer's instructions which specified:

1. pumicing

2. application of an etchant (50% phosphoric acid) for 120 seconds

3. initiating the epoxy systems with benzoin methyl ether for Nuva-Seal or benzoyl peroxide for Protecto

4. application of a thin coat of epoxy

5. activating the epoxy with ultra-violet light for Nuva-Seal or with tertiary amines for Protecto

6. contouring and polishing

Following the above procedures, bicuspid bands (Unitek Corp., Monrovia, California) were cemented on each of the first bicuspids using carboxylate cement (Durelon, Premier Corp., Philadelphia, Pennsylvania). The inner buccal surface of each band was thinly coated with vaseline and cement placed only on the lingual and interproximal surfaces. After the cement had hardened, a warm water spray was used to flush the buccal area clean. The intent was to create an environment conducive to decalcification on the buccal surface, much as would be seen associated with cement-failure. This procedure was suggested by the "gold plate technique" of von der Fehr (1961) and was similar to that used by Hirschfield (1972).

Twelve weeks later, the bands were removed, photographs taken and the plastic-coated teeth stripped of their protective agents by means of an anterior band remover and a scaler. The teeth were allowed to remain in the mouth to remineralize for an additional 96 hours. Following this period the teeth were extracted using careful forceps placement so as not to disturb the buccal surfaces. The teeth were wiped clean with a damp cloth, numbered on each root, and stored in a humidor.

Evaluation of Decalcification

Upon completion of all extractions, the teeth were mounted

on 5 X 8 inch index cards. Four sets of bicuspids were mounted per card and each was assigned an experimental number. The extent of buccal decalcification was ranked blindly and independently by four observers: Drs. Joel Wisotzky (oral biologist), Lysle Johnston (orthodontist), Sanford Neuger (orthodontist), and Edward Rossi (oral pathologist).

For each patient, the four bicuspids were ordered from 1, the best (i.e., least amount of decalcification), to 4, the worst (i.e., the greatest amount of decalcification). Any forceps marks or cracks were outlined by the experimentor prior to rating and the observers were instructed to ignore these in evaluating the surface.

Friedman's blocked analysis of variance for ordinal data was used to determine if there was a significant difference among the various pretreatment agents. The test statistic, χ_r^2, may be defined:

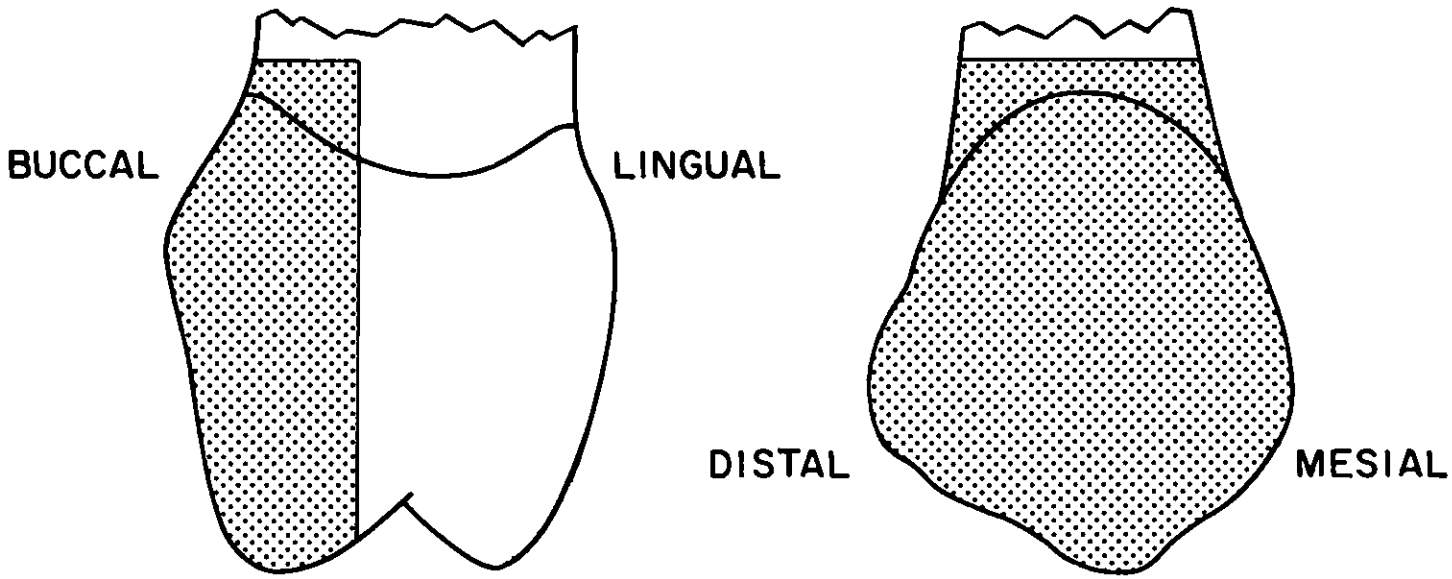
$$\chi_r^2 = \frac{12}{NK(K+1)} \sum_{j=1}^{K} (Rj)^2 - 3N(K+1), \text{ where}$$

N = number of patients, K = number of treatments, and Rj = sum of the rankings for the jth treatment. The statistic has an approximate χ^2 distribution, with K-1 degrees of freedom (Siegel, 1956).

Scanning Electron Observations

In order to examine more closely the basis for this visual ranking, five sets of first bicuspids were selected; three because they were reliably ranked by all observers and two because of inconsistent rankings. They were sectioned from the lingual to below

Figure 1. Sectioning Technique for Scanning Electron Microscope Observations.


BUCCAL
LINGUAL
DISTAL
MESIAL

the cervical area leaving the entire buccal surface intact (Figure 1). These sections were cleansed lightly to remove debris and each secured to aluminum stubs with "Duco" cement (E. I. du Pont de Nemours Co., Inc., Wilmington, Delaware). The teeth were sealed along their margins with silver conducting paint (G.C. Electronics, Rockford, Illinois), and placed in a vacuum evacuator (Varian, model VE10, Varian Co., Palo Alto, California) and coated with a gold paladium alloy (T. Pella Co., Tustin, California) to a thickness of approximately 200Å to insure proper conduction of the electrons away from the tooth surface for optimal resolution.

Photomicrographs were taken of the buccal surfaces in the scanning electron microscope (model S4-10, Cambridge Scientific Instrument Corp., Morton Grove, Illinois) in such a way as to show both normal and decalcified enamel surfaces. The photographs were later returned to the observers to be ranked again.

More highly magnified photographs of the decalcified surfaces were also taken in an attempt to determine the nature of the decalcification process and the relationship of the adhesive plastics to enamel.

RESULTS

The combined ranks obtained by tabulating the scores of the four observers are shown in Table II.

The overall differences were highly significant ($\chi^2 = 27.79$, $p<.01$). From a glance at the table it can be seen that the adhesive plastics, as a group, performed better than the fluorides in resisting decalcification. Individually, Protecto was considerably more effective than either Luride or Thera-Flur and somewhat more effective than Nuva-Seal.

TABLE II

COMBINED DECALCIFICATION RANKS AS SCORED BY FOUR OBSERVERS

Patient	Treatments			
	Luride	Thera-flur	Nuva-seal	Protecto
1	16 (4)[a]	7 (2)	6 (1)	11 (3)
2	9 (3)	16 (4)	8 (2)	7 (1)
3	16 (4)	9 (2)	10 (3)	5 (1)
4	16 (4)	9 (2)	10 (3)	5 (1)
5	15 (4)	12 (3)	9 (2)	4 (1)
6	15 (4)	9 (2)	11 (3)	5 (1)
7	16 (4)	12 (3)	7 (2)	5 (1)
8	12 (3)	16 (4)	7 (2)	5 (1)
9	12 (3)	16 (4)	6 (1.5)	6 (1.5)
10	15 (4)	11 (3)	8 (2)	6 (1)
11	10 (2.5)	16 (4)	4 (1)	10 (2.5)
12	12 (4)	10 (2.5)	8 (1)	10 (2.5)
13	14 (4)	6 (1)	12 (3)	8 (2)
14	12 (3.5)	7 (1)	12 (3.5)	9 (2)
15	16 (4)	6 (1)	11 (3)	7 (2)
16	16 (4)	8 (2)	5 (1)	11 (3)
17	8 (2)	13 (3.5)	13 (3.5)	6 (1)
18	12 (3.5)	12 (3.5)	8 (1.5)	8 (1.5)
19	15 (4)	13 (3)	7 (2)	5 (1)
20	11 (3.5)	11 (3.5)	8 (1)	10 (2)
21	11 (3)	16 (4)	5 (1)	8 (2)
22	11 (2.5)	14 (4)	11 (2.5)	4 (1)
23	7 (2)	13 (3)	5 (1)	15 (4)
24	13 (3)	15 (4)	6 (1.5)	6 (1.5)
T+j	310	277	197	176
$\bar{X}j$	12.92	11.54	8.2	7.33
Rank Total	82.5	69	48	40.5
Median Rank	3.75	3.05	1.92	1.42

[a]Numbers in parentheses are within-patient ranks.

DISCUSSION

For a variety of reasons it may be assumed that the experimental design employed here had considerable power to resolve among-treatment differences; accordingly it is not surprising that significant differences were detected.

The analysis employed takes patient differences into consideration and, though non-parametric, is quite efficient (around 90%, Siegel, (1956). Moreover, it may be assumed that rankings used in this investigation were highly reliable and, though intra-observer data are not available for this study, inter-observer differences were slight (Appendix I). While a person might have great difficulty in assessing the absolute amount of decalcification present on any one tooth ("recognition") he should have much less trouble ordering them, essentially a problem of "discrimination" (Werner, 1968). For example, a young listener can recognize with reasonable certainty no more than 5 to 7 different pitches, while it can be shown that he can distinguish 350,000 tones when presented in pairs for "discrimination" (Stevens, and Galanter, 1957). It is assumed therefore, that the rankings used here are somewhat more reliable than the absolute judgement approach of Hirschfield (1972).

Moreover, visual scoring may be the most appropriate level at which to attack the problem--it deals directly with the clinical conditions as seen by the patient, parents, as well as the orthodontist,

after band removal. Chemical analysis (enamel biopsy) was not employed because it posed the problem of controlled sampling from a precise portion of the tooth and knowing what readout to expect from incipient decalcification. Scanning electron microscopic observations were tried as a means of ranking, as will be seen, but proved inappropriate due to the apparent subsurface characteristic of incipient decalcification.

It was assumed that surface changes would accompany the decalcification process and that these changes would become more apparent when observed under the SEM. The results of the SEM rankings along with a comparison to the original visual data appear in Table III. These rankings, which are also highly reproducible, show a consistent discrimination between fluorides and the adhesive plastics. Unfortunately, when one compares the visual rankings with the SEM data they seem almost diametrically opposed. In every instance where a tooth treated with an adhesive plastic was judged clinically as having the least (1 or 2) decalcification, the SEM photomicrograph showed it to have the most irregular topography. Conversely, when an APF treated tooth was judged clinically as having the most extensive decalcification (3 or 4), the SEM photomicrograph showed it as having a highly regular topography. Perikymata, which produce the undulating appearance to the topography, were either absent or discontinuous under the adhesive plastics, while being very pronounced and continuous on the APF treated teeth (See Plate I).

Several explanations may be offered. Incipient decalcification probably begins initially as a subsurface phenomenon. This could explain the smooth, intact, perikymata observed under SEM even on clinically

TABLE III

COMPARISON OF RANKINGS--VISUAL AND SEM FOR FIVE SUBJECTS

Patient	Luride	Thera-Flur	Nuva-Seal	Protecto
	Combined SEM Rankings			
1	6 (1)[a]	7 (2)	13 (3)	15 (4)
7	7 (2)	5 (1)	13 (3)	15 (4)
14	8 (2)	4 (1)	16 (4)	12 (3)
19	7 (2)	5 (1)	14 (3.5)	14 (3.5)
24	6 (1.5)	6 (1.5)	13 (3)	15 (4)
Median Rank	1.75	1.33	3.35	3.75
	Combined Visual Rankings			
1	16 (4)	7 (2)	6 (1)	11 (3)
7	16 (4)	12 (3)	7 (2)	5 (1)
14	12 (3.5)	7 (1)	12 (3.5)	9 (2)
19	15 (4)	13 (3)	7 (2)	5 (1)
24	13 (3)	15 (4)	6 (1.5)	6 (1.5)
Median Rank	3.75	3.05	1.92	1.42

[a]Numbers in parentheses are within-patient ranks.

PLATE I

COMPARISON OF PERIKYMATA

A. Perikymata as seen under SEM on the surface of a tooth pre-treated with acidulated phosphate-fluoride (Luride, #243) X20.

B. Perikymata as seen under SEM on the surface of a tooth pre-treated with an adhesive plastic coating (Nuva-Seal, #113) X20.





decalcified teeth (Swedlow, 1974). Conversely, during the removal of the adhesive plastics, microscratches can be incorporated onto the enamel surface from either the band removing pliers or the scalers. These scratches are not visible clinically but when observed on an SEM photomicrograph they give a somewhat variegated appearance of decalcification (See Plate II). Because of these problems the SEM may, therefore, be considered an inappropriate tool to evaluate the clinical appearance of early incipient decalcification.

Once a specimen showing decalcification is coated for observation under the SEM only the surface area can be viewed and if no change is apparent on the surface there must, therefore, be a change below the surface. In an effort to provide a unified interpretation (and gain peace of mind), one micron, longitudinal sections of clinically decalcified teeth were mounted on glass slides for a brief pilot study. Under transmitting light microscopy the decalcified areas could be observed and photographed (Ultraphot II, Carl Zeiss, Oberkochen/Wuertt, West Germany). Employing high magnification, the outer layer of enamel was observed to be intact and the perikymata were evident (See Plate III). These findings are consistent with those of Silverstone (1973), who reports on the subsurface characteristics of "approximal white lesions." Therefore, it may be suggested that incipient decalcification is initially a subsurface phenomenon, and the clinical appearance is due largely to optical changes caused by mineral loss in this subsurface area.

Given, then, that visual scoring proved highly reliable and

PLATE II

MICROSCRATCHES APPARENT ON ADHESIVE PLASTIC COATED TEETH

A. Microscratches as seen under the SEM on a tooth pretreated with an adhesive plastic coating (Protecto, #112) X20.

B. Microscratches as seen under the SEM on a tooth pretreated with an adhesive plastic coating (Nuva-Seal, #241) X90.



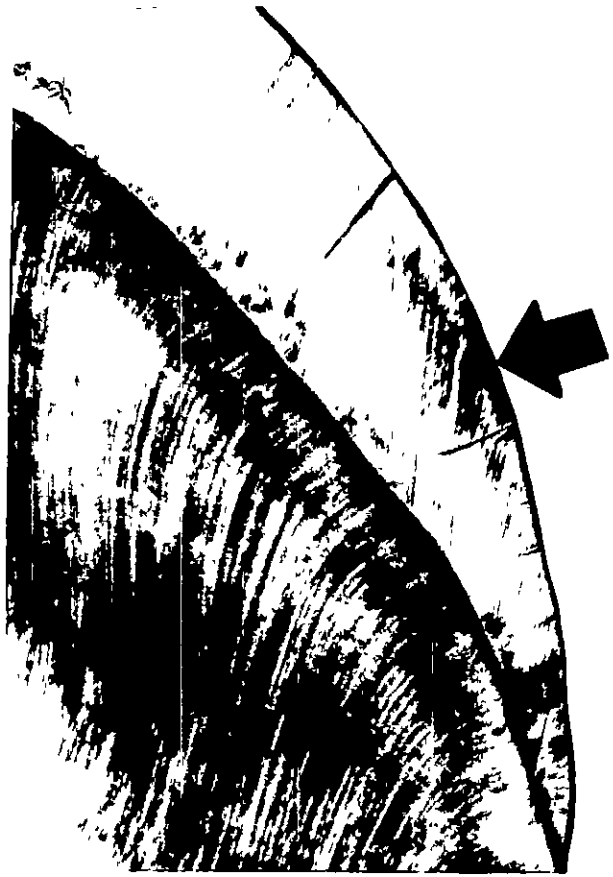


PLATE III

LIGHT MICROSCOPE PHOTOGRAPHS OF APPARENT SUBSURFACE DECALCIFICATION

A. Decalcification as seen on a ground section (Thera-Flur, #244) X20.

B. Higher magnification of the same area of decalcification (Thera-Flur, #244) X70.



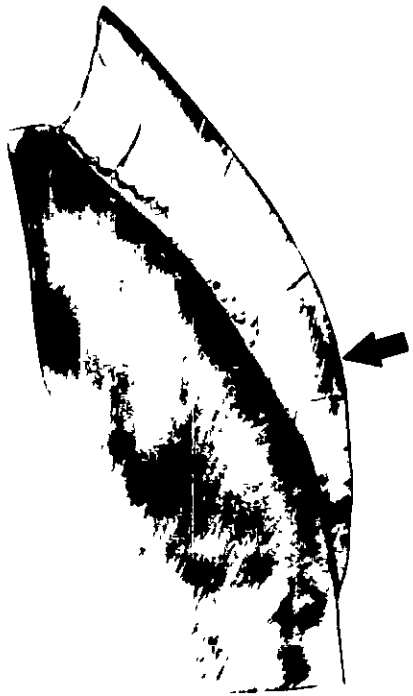
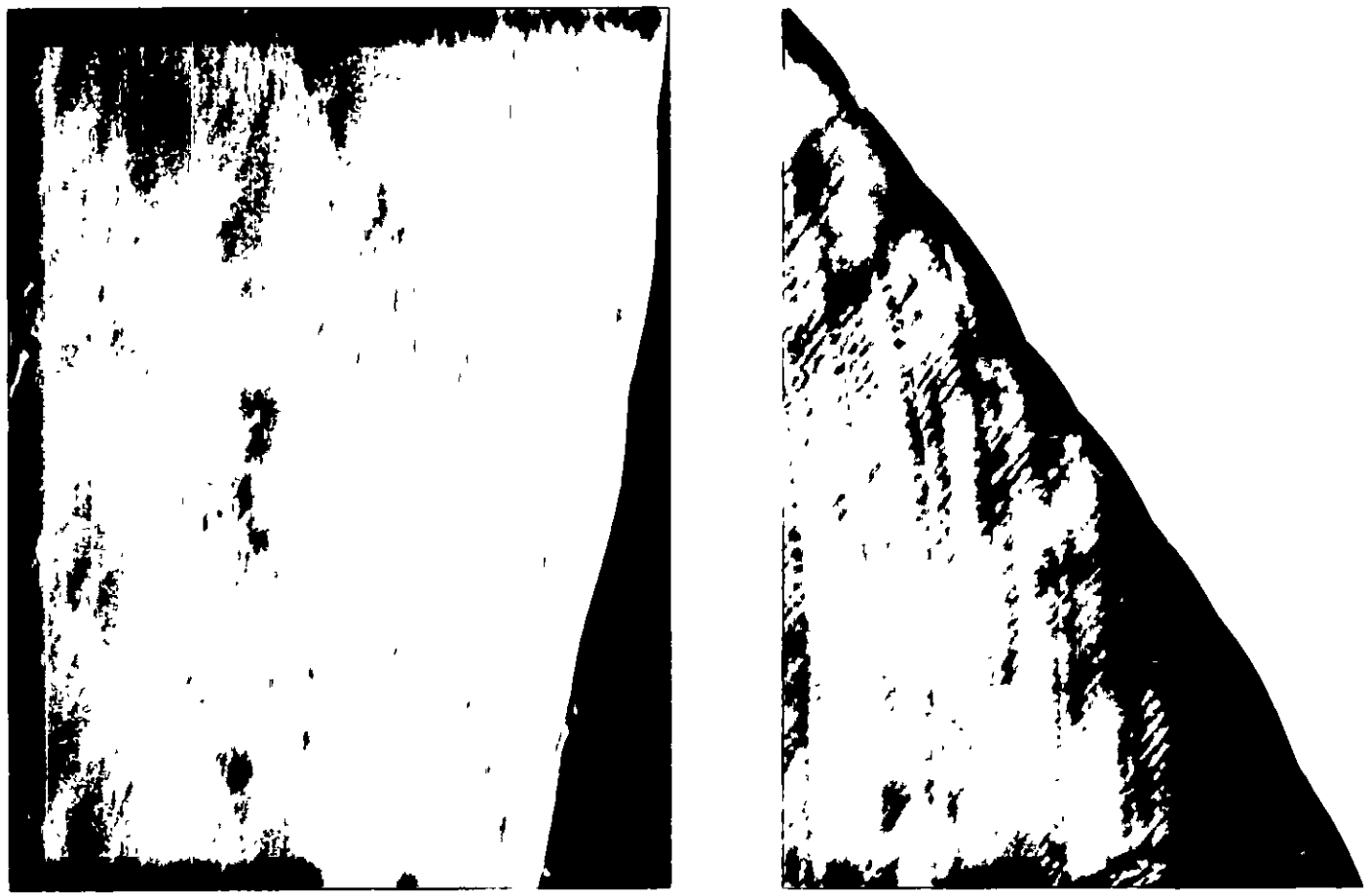


PLATE III (continued)

C. High magnification of the same area of decalcification showing intact perikymata and a continuous enamel layer (Thera-Flur, #244) X150.

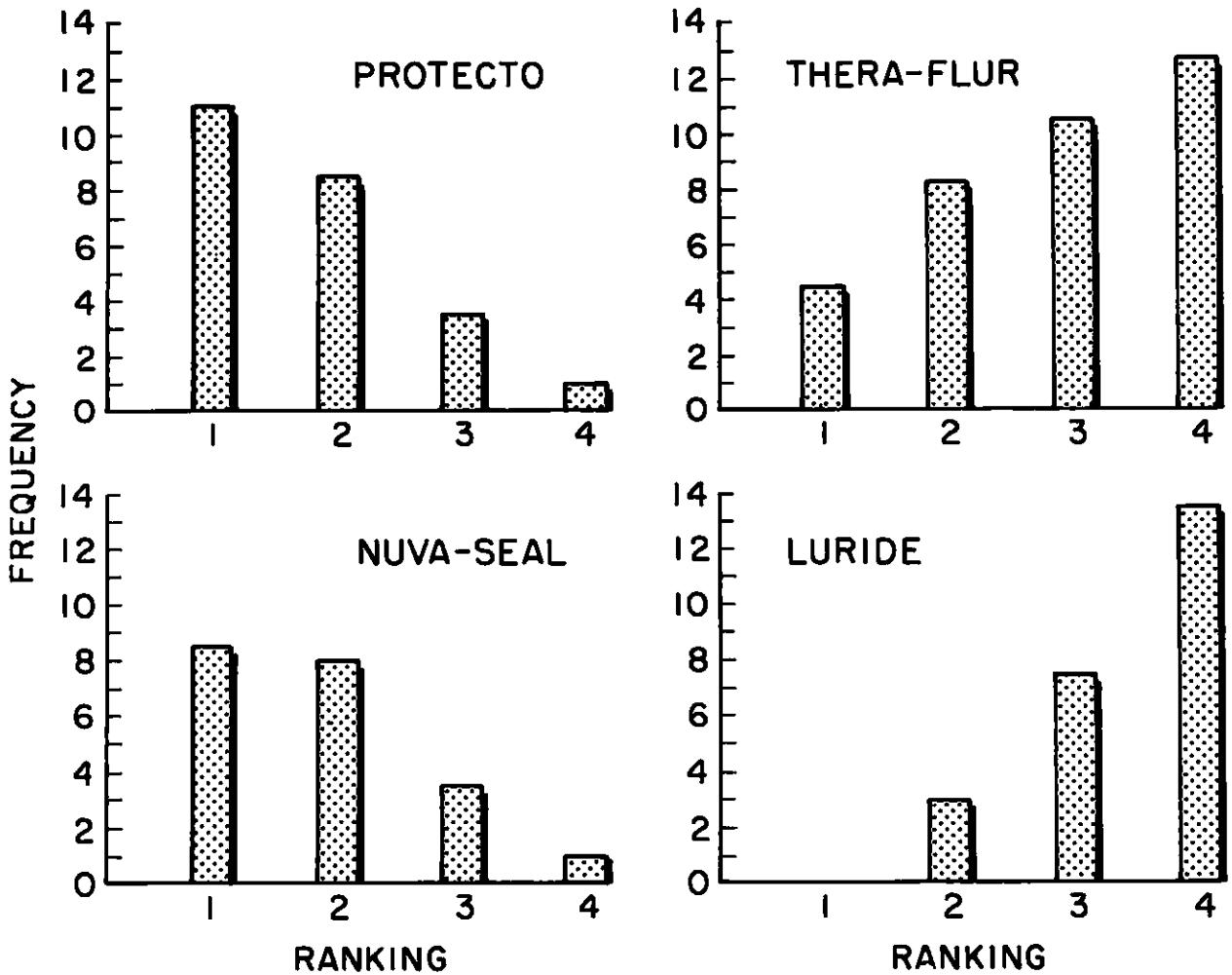
D. Same area of decalcification as seen under the SEM (Thera-Flur, #244) X180.



is presumably a valid way to investigate incipient decalcification, the highly significant among-treatment differences warrant discussion. The adhesive plastics were, consistently, better than the APF's, which according to Hirschfield (1972), are much better than no treatment at all. Protecto appears to have conferred the greatest resistance to decalcification. Were the plastic coatings to undergo adhesive failure, one could argue that this could well create a surface even more conducive to decalcification than a loose orthodontic band. This hypothetical failure of a plastic coating could suggest that one might see catostrophic decalcification or frank decay. This was not the case, however, as shown on the bar graphs (Figure 2). Moreover, when one views all four graphs the dichotomy between the plastics and the fluorides becomes quite obvious.

In respect to ease of application, it should be mentioned that the adhesive plastics require several additional steps as compared with the APF's and are therefore more time consuming. Care must be taken to keep the tooth surface free of moisture, to minimize the extent of gingival irritation by over-extended material and to prevent flow of the material into the interproximal region thus causing difficulties in banding. During band placement, fracturing of the material must be avoided. The cost of the adhesive plastic is considerable. Contouring the band properly around the buccal surface also presents its problems. Preformed bands are not manufactured with the thickness of an adhesive plastic in mind. Careful burnishing is mandatory and again time consuming. The inability to place the plastics interproximally is also a questionable feature. Moreover, even if one could do this,

Figure 2. Bar Graph Comparison of the Pretreatment Agents.


PROTECTO
THERA-FLUR
NUVA-SEAL
LURIDE
FREQUENCY
RANKING
RANKING
0
2
4
6
8
10
12
14
1
2
3
4

would it be wise to increase the mesial-distal diameter of a tooth, especially where maximum anchorage is a concern?

Perhaps the solution is a graded response to a graded potential problem. The clearly superior adhesive plastic could be used in selected instances, prior to the onset of orthodontic treatment, where there is evidence of continuous poor oral hygiene, a high caries index, or evidence of early decalcification. For these situations the orthodontist would be well advised to take the extra time and assure himself and his patient of the best possible result.

For the remaining majority of one's patients, application of APF along with good oral hygiene, excellent band placement with periodic checking, and a regimented six month recall program with the family dentist should prove sufficient.

SUMMARY AND CONCLUSIONS

A clinical study was conducted to investigate and compare the effects of two acidulated phosphate-fluorides and two adhesive plastic coatings in delaying the onset of decalcification on the teeth of twenty-four randomly selected patients who presented themselves for orthodontic treatment and were diagnosed as requiring the therapeutic removal of first bicuspids.

The teeth were randomly assigned treatment combinations of acidulated phosphate-fluorides (Luride and Thera-Flur), and hybrid epoxy enamel coatings (Nuva-Seal and Protecto). The agents were applied to the buccal surfaces of the teeth and well adapted bands were seated with cement on all but the buccal surfaces. With this environment being conducive to decalcification, the teeth remained in the mouth for 12 weeks prior to extraction.

The data consisted of the visual ranking of decalcification performed blindly and independently by four observers.

A Friedman blocked, non-parametric analysis of variance was performed to determine if there were significant differences among treatments. The visual rankings indicate that the adhesive plastics provide the greatest resistance to decalcification; specifically, Protecto was associated with the least decalcification.

Data obtained from SEM observations indicated that decalcification is visually and initially a subsurface phenomenon, and that

microscratches are created on the enamel surface when the adhesive plastics are removed. Thus, SEM pictures are misleading and constitute a relatively inappropriate tool to investigate the clinical appearance of incipient decalcification.

It is concluded that the effective but costlier and more time-consuming adhesive plastics should be employed prior to orthodontic treatment on those patients who show an increased risk of decalcification. For the remaining majority of one's patients, prophylactic pretreatment with APF and a conscientious, well-coordinated regime of band inspection should prove sufficient.

APPENDIX I

INDIVIDUAL RANKINGS BY OBSERVERS

Subject	Observer[a]	Luride	Thera-flur	Nuva-seal	Protecto
1[b]	A	4	1	2	3
	B	4	1	2	3
	C	4	3	1	2
	D	4	2	1	3
Totals		16	7	6	11
Overall Rank		4	2	1	3
2[c]	A	3	4	1	2
	B	3	4	2	1
	C	1	4	2	3
	D	2	4	3	1
Totals		9	16	8	7
Overall Rank		3	4	2	1
3[c]	A	4	1	3	2
	B	4	3	2	1
	C	4	2	3	1
	D	4	3	2	1
Totals		16	9	10	5
Overall Rank		4	2	3	1

Subject	Observer	Luride	Thera-flur	Nuva-seal	Protecto
4	A	4	3	1	2
	B	4	2	3	1
	C	4	2	3	1
	D	4	2	3	1
Totals		16	9	10	5
Overall Rank		4	2	3	1
5	A	4	3	2	1
	B	3	4	2	1
	C	4	3	2	1
	D	4	2	3	1
Totals		15	12	9	4
Overall Rank		4	3	2	1
6	A	3	2	4	1
	B	4	3	1	2
	C	4	2	3	1
	D	4	2	3	1
Totals		15	9	11	5
Overall Rank		4	2	3	1

Subject	Observer	Luride	Thera-flur	Nuva-seal	Protecto
7[b]	A	4	3	2	1
	B	4	3	2	1
	C	4	3	1	2
	D	4	3	2	1
Totals		16	12	7	5
Overall Rank		4	3	2	1
8	A	3	4	1	2
	B	3	4	2	1
	C	3	4	2	1
	D	3	4	2	1
Totals		12	16	7	5
Overall Rank		3	4	2	1
9	A	3	4	1	2
	B	3	4	2	1
	C	3	4	2	1
	D	3	4	1	2
Totals		12	16	6	6
Overall Rank		3	4	1.5	1.5

Subject	Observer	Luride	Thera-flur	Nuva-seal	Protecto
10	A	3	2	4	1
	B	4	3	2	1
	C	4	3	1	2
	D	4	3	1	2
Totals		15	11	8	6
Overall Rank		4	3	2	1
11	A	3	4	1	2
	B	2	4	1	3
	C	3	4	1	2
	D	2	4	1	3
Totals		10	16	4	10
Overall Rank		2.5	4	1	2.5
12	A	4	3	2	1
	B	3	4	2	1
	C	2	1	3	4
	D	3	2	1	4
Totals		12	10	8	10
Overall Rank		4	2.5	1	2.5

Subject	Observer	Luride	Thera-flur	Nuva-seal	Protecto
13	A	3	1	4	2
	B	4	1	3	2
	C	3	2	4	1
	D	4	2	1	3
Totals		14	6	12	8
Overall Rank		4	1	3	2
14[b]	A	2	1	4	3
	B	4	3	2	1
	C	3	2	4	1
	D	3	1	2	4
Totals		12	7	12	9
Overall Rank		3.5	1	3.5	2
15	A	4	1	3	2
	B	4	3	2	1
	C	4	1	3	2
	D	4	1	3	2
Totals		16	6	11	7
Overall Rank		4	1	3	2

Subject	Observer	Luride	Thera-flur	Nuva-seal	Protecto
16	A	4	1	1	2
	B	4	2	1	3
	C	4	2	1	3
	D	4	3	2	3
Totals		16	8	5	11
Overall Rank		4	2	1	3
17	A	4	3	2	1
	B	2	3	4	1
	C	1	3	4	2
	D	1	4	3	2
Totals		8	13	13	6
Overall Rank		2	3.5	3.5	1
18	A	4	3	2	1
	B	3	4	1	2
	C	2	3	1	4
	D	3	2	4	1
Totals		12	12	8	8
Overall Rank		3.5	3.5	1.5	1.5

Subject	Observer	Luride	Thera-flur	Nuva-seal	Protecto
19[b]	A	4	3	2	1
	B	4	3	1	2
	C	4	3	2	1
	D	3	4	2	2
Totals		15	13	7	5
Overall Rank		4	3	2	1
20	A	2	3	1	4
	B	4	3	2	1
	C	4	2	3	1
	D	1	3	2	4
Totals		11	11	8	10
Overall Rank		3.5	3.5	1	2
21[c]	A	3	4	1	2
	B	2	4	1	3
	C	3	4	2	1
	D	3	4	1	2
Totals		11	16	5	8
Overall Rank		3	4	1	2

Subject	Observer	Luride	Thera-flur	Nuva-seal	Protecto
22	A	2	4	3	1
	B	3	4	2	1
	C	2	3	4	1
	D	4	3	2	1
Totals		11	14	11	4
Overall Rank		2.5	4	2.5	1
23	A	2	3	1	4
	B	2	4	1	3
	C	1	3	2	4
	D	2	3	1	4
Totals		7	13	5	15
Overall Rank		2	3	1	4
24[b]	A	3	4	1	2
	B	3	4	2	1
	C	4	3	2	1
	D	3	4	1	2
Totals		13	15	6	6
Overall Rank		3	4	1.5	1.5

[a] The observers were Dr. Johnston (A), Dr. Wisotzky (B), Dr. Neuger (C), and Dr. Rossi (D).

[b] Teeth selected for SEM observations

[c] Teeth graded clinically in the mouth and not available for extraction.

APPENDIX II

SEM PHOTOMICROGRAPHS OF SUBJECT 24

A. Bicuspid #243 treated with Luride and ranked 1 by observers, X20.

B. Bicuspid #244 treated with Thera-Flur and ranked 2 by observers, X20.





APPENDIX II (continued)

C. Bicuspid #241 treated with Nuva-Seal and ranked 3 by observers, X20.

D. Bicuspid #242 treated with Protecto and ranked 4 by observers, X20.





APPENDIX III

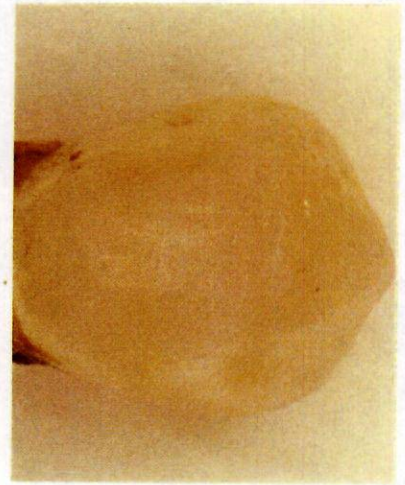
COLOR PHOTOGRAPHS OF SUBJECTS 24 and 7

A. Bicuspid #241 treated with Nuva-Seal ranked 1.5 by observers clinically.

B. Bicuspid #242 treated with Protecto ranked 1.5 by observers clinically.

C. Bicuspid #243 treated with Luride ranked 3 by observers clinically.

D. Bicuspid #244 treated with Thera-Flur ranked 4 by observers clinically.









APPENDIX III (continued)

E. Bicuspid #71[a] treated with Protecto ranked 1 by observers clinically.

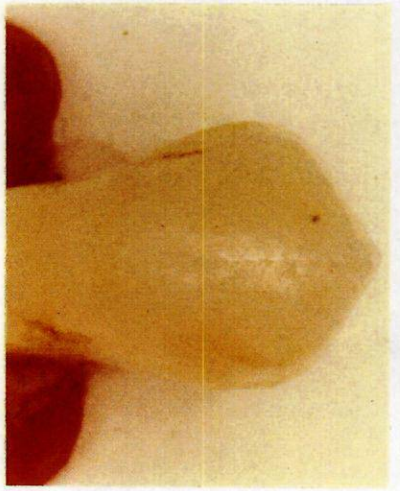
F. Bicuspid #72[a] treated with Nuva-Seal ranked 2 by observers clinically.

G. Bicuspid #73 treated with Thera-Flur ranked 3 by observers clinically.

H. Bicuspid #74 treated with Luride ranked 4 by observers clinically.

[a] Note the outlined forceps-marks.









APPENDIX IV

INDUCED MICROSCRATCHES AND ENAMEL ADHESIVE INTERFACE

A. Microscratches induced on the left side during adhesive plastic coating removal. Right side untreated. X16. A pilot study to show that during removal of the adhesive plastics surface changes do occur.

B. Interface between adhesive plastic coating and acid etched enamel, X520.





APPENDIX V

CASE WESTERN RESERVE, SCHOOL OF DENTISTRY
PATIENT CONSENT FOR STUDIES

TITLE OF PROJECT: An Evaluation of the Effects of Various Pretreatment Agents Prior to Orthodontic Banding In Increasing the Resistance of Human Enamel to Decalcification.

The following information is given to you regarding a clinical study of which you may become a part of if you so elect. Please read the following items carefully, and if you feel that you would like to become part of the study, sign at the bottom of the page.

1. The purpose of this study is to evaluate the effects of different treatments in reducing decalcification, or "white spots" on teeth after orthodontic appliances have been removed.

2. Only cases which have been diagnosed for extraction of four first bicuspids as part of orthodontic treatment will be selected. These teeth would have to be therapeutically removed whether or not the child participates in this study. Selection will be related to orthodontic treatment only. It is the opinion of the Orthodontic Department that this study will in no way hinder or delay treatment, nor will it have any permanent effects on the patient.

3. Four clinical agents will be painted on the teeth to be extracted and orthodontic bands will be placed for approximately three months, until the time that the teeth are to be extracted as a routine and necessary part of the individual patient's orthodontic treatment. Each of the four agents is presently used clinically in the United States and is approved by the American Dental Association.

4. If you elect to participate in this study, all care and precaution will be taken for your welfare. Your name and personal information will be kept confidential. Patient identification will be done by code number.

5. You may withdraw from this study at any time.

I, the undersigned, understand that my child has been asked to be a cooperating participant in this project to be conducted in the School of Dentistry at Case Western Reserve University. The studies described above, the procedure contemplated, and benefits involved have been explained to me by the Project Investigator, Dr. Henry F. Neumann, and I agree to participate my child therein as a volunteer patient.

SIGNATURE OF PARENT_____

CHILD'S NAME_____ AGE_____

WITNESSED BY_____ DATE_____
(Signature of Project Investigator)

LITERATURE CITED

Aasenden, R., DePaola, P. F. and Brudevold, F. 1972. Effects of daily rinsing and ingestion of fluoride solutions upon dental caries and enamel fluoride. Arch. Oral Biol., 17: 1705-1714.

Albert, M. and Grenoble, D. E. 1971. An in vivo study of enamel remineralization after acid etching. J. So. Cal. Dent. Ass., 39: 747-751.

Brudevold, F. 1959. Action of topically applied fluorides. J. Dent. Child., 26: 186-190.

Brudevold, F., Savary, A., Gardner, D. E., Spinelli, M. J. and Speirs, R. 1963. A study of acidulated fluoride solutions. I. In vitro effects on enamel. Arch. Oral Biol., 8: 167-177.

Buonocore, M. G. 1955. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J. Dent. Res., 34: 849-853.

Buonocore, M. G. 1970. Adhesive sealing of pits and fissures for caries prevention, with use of ultraviolet light. J. Amer. Dent. Ass., 80: 324-328.

Cueto, E. I. and Buonocore, M. G. 1967. Sealing of pits and fissures with an adhesive resin: its use in caries prevention. J. Amer. Dent. Ass., 75: 121-128.

Fehr, F. von der. 1961. The effect of fluorides on the caries resistance of enamel. Acta Odont. Scand., 19: 431-442.

Frankl, S. N., Fleisch, S. and Diodati, R. R. 1972. The topical anticariogenic effect of daily rinsing with an acidulated fluoride solution. J. Amer. Dent. Ass., 85: 882-891.

Gwinnett, A. J. 1971. Histologic changes in human enamel following treatment with acidic adhesive conditioning agents. Arch. Oral Biol., 16: 731-738.

Hirschfield, R. E. 1972. An evaluation of various fluoride pretreatment procedures prior to orthodontic banding in increasing the resistance of human enamel to decalcification. Unpublished M.S. thesis, Case Western Reserve University, Cleveland, Ohio. ii + 70p.

Horowitz, H. S. 1969. Effect on dental caries of topically applied acidulated phosphate-fluoride: results after two years. J. Amer. Dent. Ass., 78: 568-572.

Horowitz, H. S. and Lucye, H.S. 1966. A clinical study of stannous fluoride in a prophylaxis paste and as a solution. J. Oral Ther., 3: 17-25.

Ingervall, B. 1962. The influence of orthodontic appliances on caries frequency. Odont. Revy, 13: 175-190.

Lee, B. D., Phillips, R. W. and Swartz, M. L. 1971. The influence of phosphoric acid etching on retention of acrylic resin to bovine enamel. J. Amer. Dent. Ass., 82: 1381-1386.

Lee, H. L. and Swartz, M. L. 1971. Sealing of developmental pits and fissures: I. In vitro study. J. Dent. Res., 50: 133-140.

Lee, H. L., Orlowski, J. A. and Kobashigawa, A. T. 1973. A protective coating for combating decalcification in orthodontic practice. J. Clin. Orthod., 7: 249-256.

Lefkowitz, W. 1940. Histological evidence of the harmful effect of cement under orthodontic bands. J. Dent. Res., 19: 47-55.

Lenz, H. and Muhlemann, H. R. 1963a. In vivo and in vitro effects of saliva on etched or mechanically marked enamel after certain periods of time. Helv. Odont. Acta, 7: 30-33.

Lenz, H. and Muhlemann, H. R. 1963b. Repair of etched enamel exposed to the oral environment. Helv. Odont. Acta, 7: 47-49.

Mellberg, J. R., Laakso, P. V. and Nicholson, C. R. 1966. The acquisition and loss of fluoride by topically fluoridated human tooth enamel. Arch. Oral Biol., 11: 1213-1220.

Meyers, M. J. 1952. Protection of enamel under orthodontic bands. Amer. J. Orthod., 38: 866-874.

Muhler, J. C. 1957. Effect on gingiva and occurrence of pigmentation on teeth following the topical application of stannous fluoride or stannous chlorofluoride. J. Periodont., 28: 281-286.

Muhler, J. C. 1958. The effect of a single topical application of stannous fluoride on the incidence of dental caries in adults. J. Dent. Res., 37: 415-416.

Muhler, J. C. 1970. Dental caries--orthodontic appliances--SnF_2. J. Dent. Child., 37: 218-221.

Newman, G. V. and Facq, J. M. 1971. The effects of adhesive systems on tooth surfaces. Am. J. Orthod., 59: 67-75.

Retief, D. H. 1973. Effect of conditioning the enamel surface with phosphoric acid. J. Dent. Res., 52: 333-339.

Rippa, A. 1973. Occlusal sealing; rationale of the technique and historical review. J. Amer. Soc. Prev. Dent., 3: 32-39.

Seniff, R. W. 1962. Enamel surface changes caused by oxyphosphate cement. Amer. J. Orthod., 48: 219-220.

Siegel, S. 1956. Nonparametric Statistics for the Behavioral Sciences. New York, McGraw-Hill Book Company, Inc., pp. 166-173.

Silverstone, L. M. 1973. Structure of carious enamel, including the early lesion. Oral Sci. Rev., 3: 100-160.

Stevens, S. S. and Galanter, E. H. 1957. Ratio scales and category scales for a dozen perceptual continua. J. Exper. Psychol., 54: 377.

Swedlow, D. March, 1974. Personal communication.

Torell, P. and Ericsson, Y. 1965. Two year clinical tests with different methods of local caries-preventive fluorine application in Swedish school-children. Acta Odont. Scand., 23: 287-322.

Volker, J. F. 1939. Effect of fluorine on solubility of enamel and dentine. Proc. Soc. Exper. Biol. and Med., 42: 725-727.

Wei, S. H. Y. 1970. Electron microprobe analyses of the remineralization of enamel. J. Dent. Res., 49: 621-625.

Wellock, W. D., Maitland, A. and Brudevold, F. 1965. Caries increments, tooth discoloration, the state of oral hygiene in children given a single annual application of acid phosphate-fluoride and stannous fluoride. Arch. Oral Biol., 10: 453-457.

Werner, G. 1968. Medical Physiology, Volume II, edited by V. B. Mountcastle, chapter 70. St. Louis, The C. V. Mosby Company, pp. 1643-1671.