The effects of soft drinks on etched and sealed enamel

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Decalcification of enamel around bonded orthodontic brackets and under orthodontic bands has long been a concern of orthodontists. In some instances, the orthodontist may be held responsible for the presence of posttreatment decalcification, not only by the public, but also by the dental profession in general. Machen,[1] an orthodontist and Juris Doctor, has stated that from a legal standpoint, the responsibility for preventing decalcification lies with the practitioner. That statement alone could have far-reaching implications for the orthodontic specialty.

The similarity between decalcification and the early stages of carious lesions has been explored over the last four decades.[2-6] Investigators agree that decalcification is the first step in the breakdown of enamel, and that degrees of decalcification probably exist, depending on the progression of the lesion. Decalcification is defined as loss of calcified tooth substance; it occurs when the pH of the oral environment favors diffusion of calcium and phosphate ions out of the enamel.[7] If severe loss of ions occurs, frank cavitation can result. Quoting from Mitchell,[7] "The inter-dependence of bacteria, sugar, enamel, and time in the etiology of caries is well accepted, but other factors may predispose to an increased risk of decalcification during treatment. Among them are: ORAL HYGIENE. Streptococcus mutans and lactobacilli are associated with the initiation and development of caries. Plaque on the surface of the tooth acts as a physical barrier limiting the diffusion of acid away from the surface of the tooth, and preventing remineralization from calcium and phosphate ions. DIET. The role of fermentable carbohydrates in caries has been well documented. Frequent consumption of sugary foods or drinks has been shown to be most damaging, as the pH of plaque drops below the critical 5.5 for about 20 minutes. In addition, fixed appliances restrict the ability

Abstract

Decalcification around appliances is often a problem for orthodontic patients. This study was undertaken to determine the effects of cola soft drinks on enamel. Twenty-seven extracted teeth were soaked in nine test solutions (different cola drinks) for 72 hours. The scanning electron microscope revealed destruction of enamel in all specimens. Light-cured sealants offered little protection for enamel surfaces. Dark cola drinks containing phosphoric acid should be seen as a true hazard for patients with fixed appliances.

Key Words

Decalcification • Phosphoric acid • SEM

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Figure 1
Waxed out crown with exposed labial surface after 72 hour exposure to test solution.

Figure 2
Following removal of the wax, the area of enamel dissolution is visible.

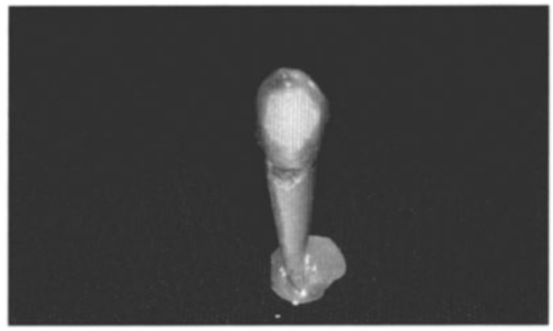

Figure 1

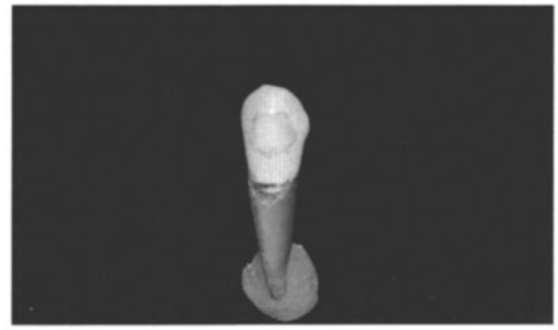

Figure 2

of the tongue and saliva to remove food particles from the mouth, with the result that breakdown of more complex carbohydrates gives rise to a prolonged acid challenge to the tooth surface. BOND TECHNIQUE. The presence of adhesive flash around bonded orthodontic attachments can predispose to plaque accumulation."

Some investigators[7,8] have found white spots at the labiogingival aspect of the teeth, frequently the maxillary and mandibular incisors. Surprisingly, they did not find lesions on the lingual surfaces of canines and incisors, even after prolonged 3 x 3 retainer wear.

Gedalia et al.[9] found softening of enamel surfaces following 1 hour of exposure to Coca-Cola and noted that chewing hard cheese resulted in rehardening, probably due to redeposition of calcium and phosphate ions, but that stimulating saliva by chewing paraffin did not have the same rehardening effect. Grenby,[10] in his in vitro experiment on the effect of soft drinks on dental enamel, evaluated eight different soft drinks, including several citrus fruit drinks, and found that the demineralizing action on hydroxylapatite of the acids already in the drinks eclipsed the effects of the acid generated by oral micro-organisms from the sugars in the drinks.

O'Reilly and Featherstone,[11] in their study on demineralization and remineralization around orthodontic appliances, reported that a measurable and significant amount of demineralization, as quantified by microhardness testing, occurs immediately adjacent to orthodontic appliances after only 1 month, even with the use of a proven fluoride dentifrice. And further, the demineralization was the result of plaque activity in vivo and not the initial acid etching before bonding.

Numerous modalities have been tested to eliminate decalcified white spots on teeth, all with varying success. Among them are fluoride rinses and gels that are brushed on the teeth,[12-15] thus hardening the enamel; adhesive sealers that are painted over the etched enamel; fluoride releasing adhesives for attaching bonded brackets; and fluoride releasing peripherals, such as power chains and elastomerics.[16-20] Glass ionomer cements are now being developed that may hold promise for preventing white marks.

Clearly, the subject of decalcification is complex and of great importance to the orthodontic specialty. Not only must we deal with the public's perception of our procedures and the legal ramifications to which they are attached, but also the final cosmetic results, which are entrusted to our hands. Because so may of our patients routinely drink cola-type soft drinks, the following study was devised to test two hypotheses: First, that cola soft drinks have a deleterious effect on enamel regardless of etching the teeth for the purpose of bonding brackets, and second, that etched enamel, with or without light-cured sealant, leaves enamel more susceptible to erosion in cola solutions. Because acid etching to attach bonded brackets removes the fluoride-rich outer layer of enamel,[21] it is reasonable to hypothesize that the procedure for attaching brackets to teeth leaves the teeth more susceptible to decalcification.

Methods and materials

Twenty-seven extracted maxillary and mandibular teeth—four premolars, five canines, and 18 incisors—were retrieved from various local dental practices. The teeth all had virgin enamel, free from restorations or decay. All teeth used in the experimental design were handled in the same manner, and they were randomly assigned to the different test solutions. Differences in enamel thickness and texture were discounted as not clinically relevant. The teeth were soaked for 3 days in undiluted bleach for debridement of remaining soft tissues. At the end of that time they were removed from the bleach, washed, and dried. The crowns of the teeth were waxed out using a hard inlay wax, except for a 4 mm by 4 mm buccal or labial window.

The teeth were divided into three groups (one control and two experimental groups) with nine teeth in each group. Nine different cola drinks

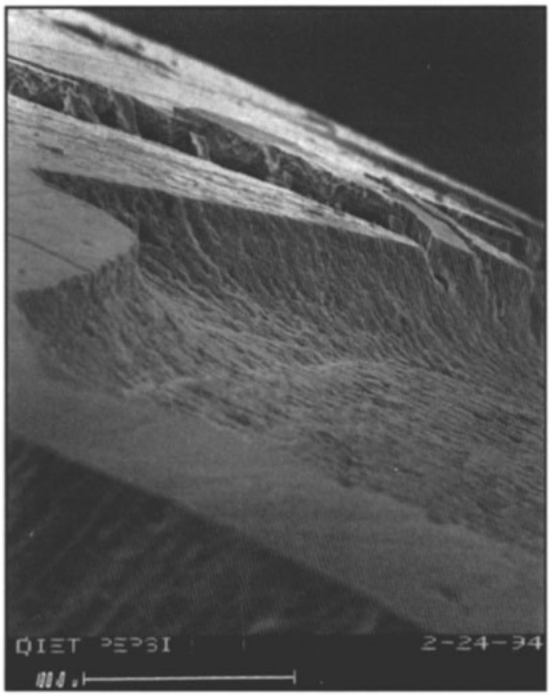

Figure 3A

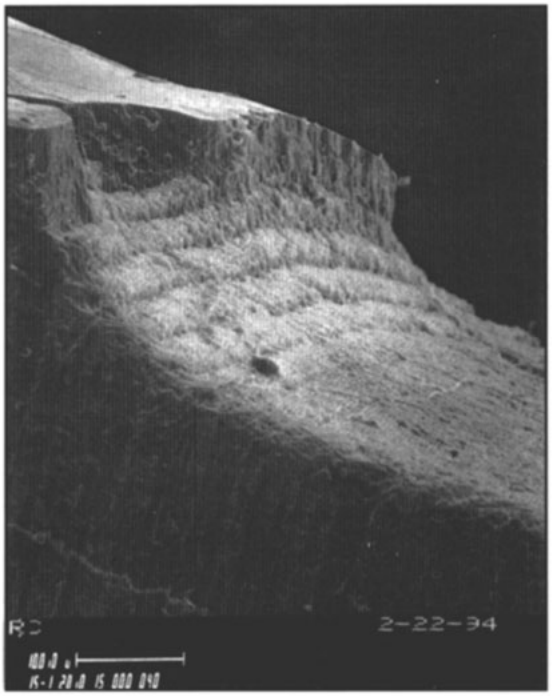

Figure 3B

Figure 3A-B
A: Diet Pepsi, no etchant or sealant. 300x magnification.
B: RC, no etchant or sealant, 300x magnification.

were tested: Coca-Cola, Pepsi, RC, Dr. Pepper, Crystal Pepsi, Diet Coke, Diet Pepsi, Diet Rite (also called Diet RC), and Diet Dr. Pepper. Teeth in the control group were neither etched nor sealed according to experimental protocol. Teeth in the first experimental group were etched with 37% phosphoric acid for 10 seconds, washed for 5 seconds, then dried. Likewise, teeth in the second experimental group were etched with 37% phosphoric acid for 10 seconds, washed for 5 seconds and dried, then sealed with Transbond Light Cured Adhesive (Unitek), and hardened for 20 seconds with a visible light-curing unit.

Early bonding research by Buonocore showed that remineralization of etched enamel occurs by itself when teeth are left in the presence of saliva in vivo (a finding corroborated by Gedalia and Grenby), so it seemed reasonable to test the solubility of etched enamel. And since sealants seem to wear off over time, the experimental protocol included teeth that had been etched and sealed, to see if the colas affect the sealant.

The teeth were labeled with a waterproof marking pen, then soaked in a test solution (one of the cola drinks) for 72 hours. The solutions were changed at 24-hour intervals to insure that they were fresh. At the end of the experimental period, the teeth were removed from the solution, washed under tap water, dried with compressed dry air for 5 seconds, and placed in labeled pill bottles to prevent mishandling.

The crowns of the teeth were taken to the University of Oklahoma School of Dentistry, Department of Pathology, where they were sectioned down the long axis of the crown from incisal to gingival, making certain the cut passed through the area exposed to the test solutions. A second thin cut of approximately 1 to 2 mm was made down the crown long axis, again through the test site. It was this thin sliver of tooth that was used in the experimental design. The sections were taped to mounting pods, labeled, and coated with a layer of gold-platinum in a sputter-coater for viewing. The specimens were examined and photographed under low resolution of the electron microscope (magnification 10x and 300x) at the Samuel R. Noble Electron Microscope Laboratory at the University of Oklahoma by research scientists skilled in the use of this instrument (Figures 3 to 5).

Results

The primary hypothesis, that cola soft drinks have a deleterious effect on enamel, was tested. The results showed, beyond doubt and as seen in the electron photomicrographs, that exposure to cola drinks results in damage to tooth enamel. The results of testing the secondary hypothesis, that etching the teeth prior to bonding makes the teeth more susceptible to the effects of the phosphoric acid, were less clear; enamel destruction was nearly equal in the etched and the control groups. Micrographs of the test sites showed destruction of the enamel that looked like large craters on a moonscape. In fact, all of the experimental solutions likely would have com-

Figure 4A-C
A: Crystal Pepsi, etched, 10x magnification.
B: Crystal Pepsi, etched, 300x magnification.
C: Regular Coke, etched. 300x magnification.

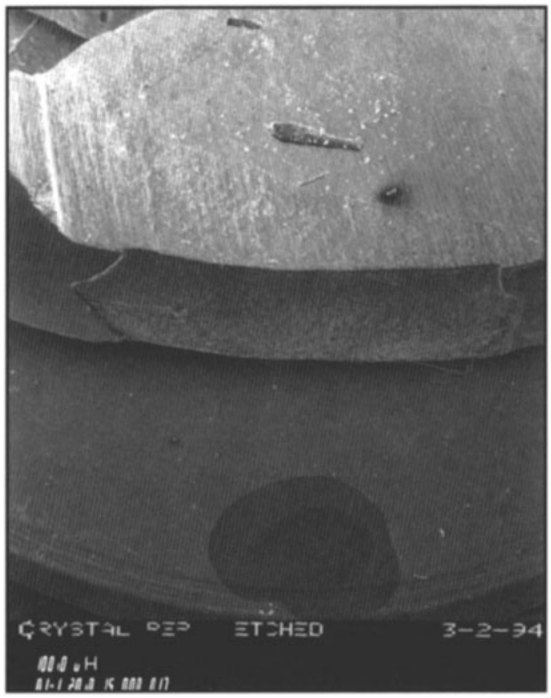

Figure 4A

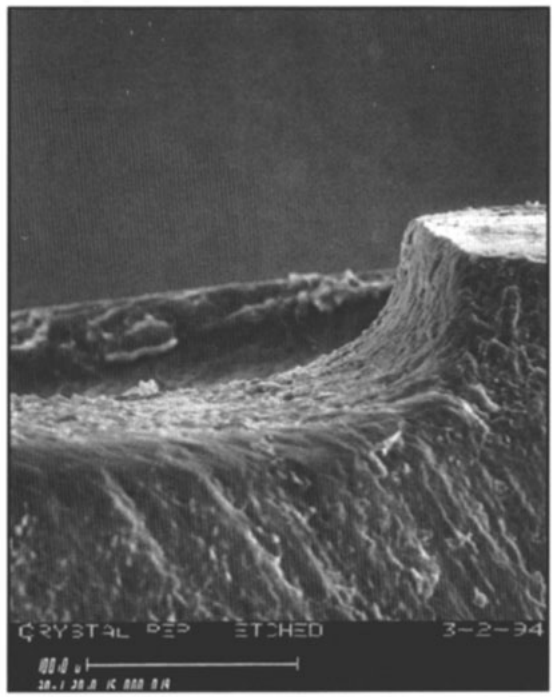

Figure 4B

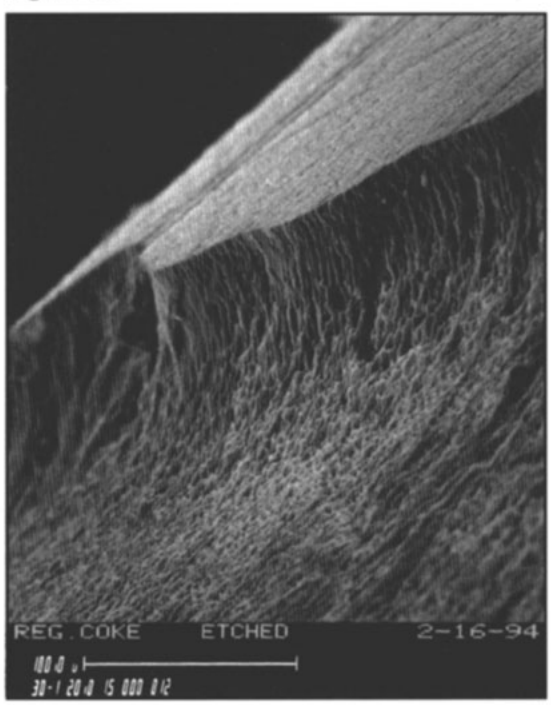

Figure 4C

pletely dissolved the enamel, given enough time. Enamel rods were clearly opened, much like when the tooth was originally etched for bonding, except that the chemicals appeared to be significantly more invasive. The edges of the lesions were deep enough to be visible with the naked eye, and under SEM were quite dramatic. What can be said without reservation is that the chemicals in cola soft drinks absolutely affect the integrity of the enamel surface. There were, however, indications that teeth in certain of the control groups, that is, those that had not been etched, were slightly less affected by the colas. Erosion appeared to be shallower and more gently rounded at the edges of the lesions in the Diet Coke, Diet Dr. Pepper, Diet RC (Diet Rite), Dr. Pepper, and Diet Pepsi groups.

It is interesting to view the specimens that were etched and sealed with a light cured sealant. Most showed small islands of sealant that withstood the acid attack. However the vast majority of the sealant was removed by chemical attack in the experimental process, possibly by undermining resorption.

Discussion

It is clear from the evaluation of the electron photomicrographs that cola soft drinks have a devastating effect on the integrity of the enamel surface in vitro. While it may be argued that in children who drink colas the enamel is not exposed to these solutions continuously for 72 hours, it is difficult to say just how long the acid and sugar from these drinks remain in contact with the teeth. A child who drinks three or four colas per day throughout the course of treatment could very well end up with 72 total contact hours. Certainly, the process in humans is more complex than simply soaking extracted teeth in various test solutions. Other factors must be taken into account, including plaque formation and retention, bacterial activity and sugar fermentation, salivary flow rates, additional dietary

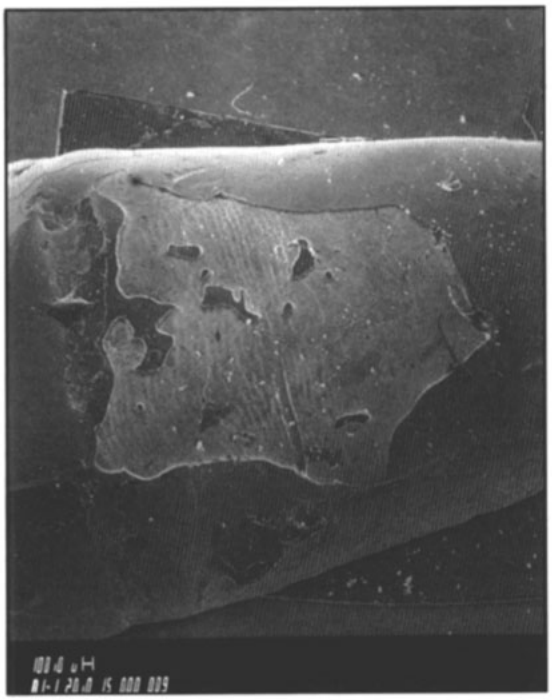

Figure 5A

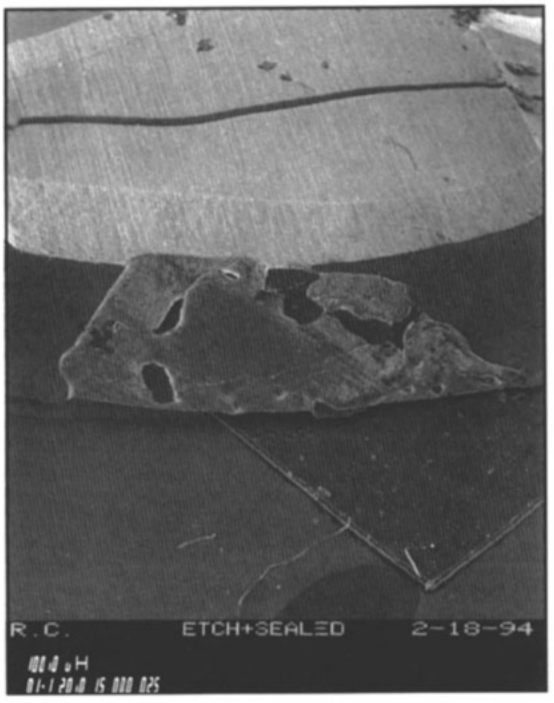

Figure 5B

Figure 5A-D
A: Diet Pepsi, etched and sealed. Islands of sealant remain. 10x magnification.
B: RC, etched and sealed. Islands of sealant remain. 10x magnification.
C: RC, etched and sealed. 300x magnification.
D: Regular Coke, etched and sealed. 300x magnification.

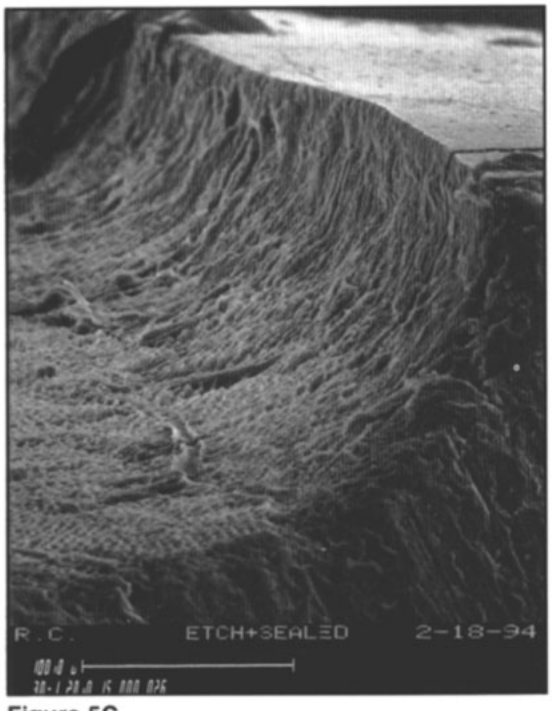

Figure 5C

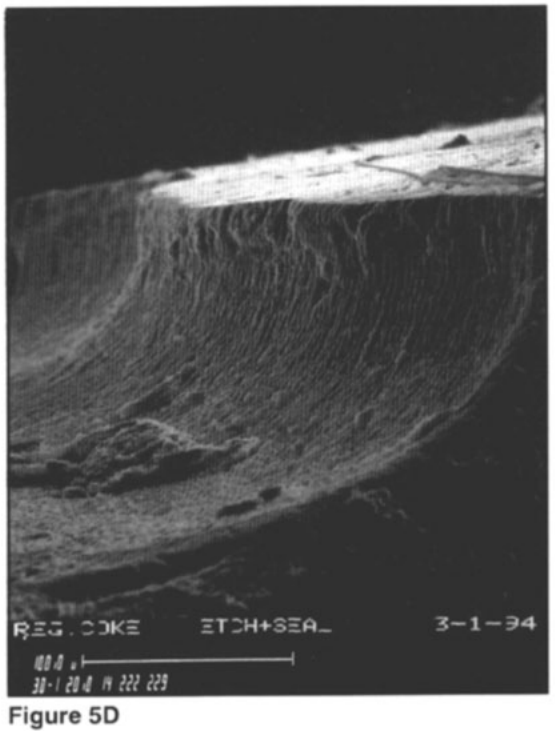

Figure 5D

insults, oral hygiene habits, hormonal influence, unexplored chemicals in cola drinks, depth of enamel etch in the bonding process, quality of sealants, and amount of fluoride use, all of which likely have an influence on the condition of the enamel at the end of treatment.

Anecdotally, children without braces drink as much cola as those with braces. Yet seldom is decalcification seen clinically in children who do not have braces. If that is true, could it be that etching the teeth makes them more susceptible to the effects of the acid and sugar found in these drinks? Or do braces simply promote plaque retention, thus increasing the likelihood of damage? It is interesting to note that most decalcification is found from canine to canine, both maxillary and mandibular.[7,8] Why is it, then, that decalcification is seldom seen on premolars or molars (personal observation)? A possible explanation could be that, as soft drinks are in-

gested, the solution washes over the fronts of the teeth on its way to the esophagus, and generally bypasses the teeth in the posterior quadrants. Of additional interest is the fact that seldom is decalcification seen on the lingual surfaces of the teeth. The same colas likely come in contact with all exposed tooth surfaces. But most decalcification is seen labially. The only differences are the etching of the labial surfaces, the braces, and the fact that the tongue and saliva are in almost constant contact with the lingual surfaces of the teeth, thus making them more self-cleansing.

Electron photomicrographs clearly show ledges formed where the acid insult has eroded enamel next to the waxed-out surfaces. While all teeth in all three groups were affected by the erosive action of the phosphoric acid, it did appear that Dr. Pepper drinks showed the least invasive properties, although that observation is purely subjective. There were, as previously stated, certain variables that were difficult to quantify in this study. Among them were the relative degree of acidity in each of the drinks, other chemical factors present in the solutions that could not be accounted for, and, perhaps most important, susceptibility of enamel to insult. Susceptibility may be affected by enamel density, resistance to acid attack, and previous uptake of fluoride in the experimental teeth. Additionally, it was difficult to quantify depth of erosion into the enamel. However, none of the teeth remained undamaged, and all micrographs showed dramatic destruction of tooth substance.

A subject that is of particular interest to orthodontists is the use of sealants. While the second experimental group was both etched and sealed with a light-cured sealant, it was obvious that much of the sealant was removed along with the enamel. And while the low resolution pictures clearly show islands of sealant remaining, much of the material was gone, with underlying enamel in the same condition as enamel from the other two groups. Perhaps sealants must be laid down in a thicker layer in order to be effective in protecting the teeth. The sealant seen on low resolution micrographs may simply represent islands of plastic that were thick enough to withstand the chemical attack.

Since so many orthodontic patients drink cola-type soft drinks, one of the most important things to be considered by our profession is how to prevent dissolution of the enamel by acid attack. Numerous studies have shown the effectiveness of preventing demineralization by the daily use of a fluoride dentifrice and daily application of a fluoride mouth rinse.[12-15] This is particularly important since it is difficult to keep patients from drinking these beverages.

The current study was able to substantiate, subjectively, the hypothesis that etching the teeth with phosphoric acid prior to bonding brackets made them more susceptible to acid attack from cola soft drinks. The action of the chemicals was of sufficient degree that enamel was destroyed in the test site regardless of what was or was not done, but there appeared to be shallower erosion in those teeth that had virgin enamel. Future studies in this area should consider a reduction of contact hours with the soft drinks, which might give a clearer picture of the effects on the

teeth following etching procedures. Three days of soaking in the test solutions caused such damage to the enamel that it made quantification of the damage somewhat difficult.

Conclusions

It is clear from the results of the study that cola soft drinks affect the integrity of the enamel surface. This study is important because it points to a dietary insult that is wholly preventable. The following conclusions can be drawn or inferred:

1. Cola soft drinks caused a dissolution of the enamel surface in all of the control and experimental teeth used in the study.
2. There was some subjective evidence that etching the enamel surface caused deeper erosion of the enamel in all of the test solutions, and that five of the teeth that were not etched showed a lesser degree of erosion.
3. The light-cured sealant had little protective effect on the enamel surface.
4. Because of the degree of enamel destruction, future studies might consider decreasing the length of exposure to the test solutions in evaluating the same hypothesis. Clinical impressions would lead one to believe that the degree of demineralization is related to the frequency and volume of consumption.

This study raises several questions that may have relevance for clinical orthodontics. First, if the sealants were of no benefit in protecting the enamel surface, why are they used? Though anecdotal, they apparently provide little holding power for the bracket. This has been demonstrated over and over again in the author's practice. Second, we may be deluding ourselves by thinking that the tooth is protected when the sealant is placed, when in fact, the tooth may actually be more vulnerable to chemical insult. When sealant runs into opened enamel rods and hardens, it may prevent the enamel from being healed by the calcium, phosphate, or fluoride ions present in the saliva. Perhaps we should focus on etching only the smallest portion of the tooth that will accept a bracket, not using sealant, and completing the bonding process with a thorough fluoride treatment, while the enamel rods are still open. Further, this and other evidence indicates that daily use of fluorides, even in patients who are apparently good brushers, is of prime importance in protecting the enamel.

As an afterthought, perhaps we should take the advice of McGuinness,[22] who said that, to his knowledge, "none of the manufacturers of cola drinks containing phosphoric acid have printed warnings on their products about the consumption of such beverages during fixed orthodontic treatment, and that perhaps it is time our specialty made an approach to such manufacturers to place health warnings on their products. Certainly, a solution of sucrose with an pH of 2.3 is not the ideal drink for patients with fixed appliances in place."

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References

1. Machen DE. Oral hygiene assessment: Plaque accumulation, gingival inflammation, decalcification, and caries: Legal aspects of orthodontic practice: Risk management concepts. Am J Orthod Dentofac Orthop 1991;100:93-94.
2. Lefkowitz W. Histological evidence of the harmful effect of cement under orthodontic bands. J Dent Res 1940;19:47-55.
3. Sved A. Prevention of decalcification of enamel, Am J Orthod 1946;32:373-383.
4. Myers MJ. Protection of enamel underneath orthodontic bands. Am J Orthod 1952;38:866-874.
5. Bach EN. Incidence of caries during orthodontic treatment. Am J Orthod 1953;39:756-778.
6. Adams R J. The effects of fixed orthodontic appliances on cariogenicity, quantity and microscopic morphology of oral lactobacilli. J Oral Med 1967; 22:88-89.
7. Mitchell L. Decalcification during orthodontic treatment with fixed appliances - an overview. Brit J Orthod 1992;19:199-205.
8. Gorelick L, Geiger A, Gwinnett J. Incidence of white spot formation after bonding and banding. Am J Orthod 1982;81:93-98.
9. Gedalia I., et al. Tooth enamel softening with a cola type drink and re-hardening with hard cheese or stimulated saliva in situ. J Oral Rehabil 1991;18: 501-506.
10. Grenby TH. In vitro experiments on effect of soft drinks on dental enamel. Oralprophylaxe 1990; 12:103-113.
11. O'Reilly M, Featherstone J. Demineralization and remineralization around orthodontic appliances: An in vivo study. Am J Orthod Dentofac Orthop 1987; 92: 33-40.
12. Corbett J, Shannon I. Prevention of decalcification in orthodontic patients: A preliminary clinical trial with a mixture of fluorides. Col Dent Assoc J 1980; 18:16-17.
13. Boyd R. Comparison of three self-applied topical fluoride preparations for control of decalcification. Angle Orthod 1993; 63(1): 25-30.
14. Saloum F, Sondhi A. Preventing enamel decalcification after orthodontic treatment. J Am Dent Assoc 1987;115:257-261.
15. Hughes D, Hembree J, Weber F. Preparations to prevent enamel decalcification during orthodontic treatment compared. Am J Orthod 1979; 75(4): 416-419.
16. Mitchell L. An investigation into the effect of a fluoride releasing adhesive on the prevalence of enamel surface changes associated with directly bonded orthodontic attachments. Brit J Orthod 1992;19:207-214.
17. Fox N. Fluoride release from orthodontic bonding materials. An in vitro study. Brit J Orthod 1990; 17:293-298.
18. Bishara S, Swift E, Chan D. Evaluation of fluoride release from an orthodontic bonding system. Am J Orthod Dentofac Orthop 1991;100(2):106-109.
19. Klockowski R, et al. Bond strength and durability of glass ionomer cements as bonding agents in the placement of orthodontic brackets. Am J Orthod Dentofac Orthop 1989;96(1):60-64.
20. Sonis A, Snell W. An evaluation of a fluoride-releasing, visible light-activated bonding system for orthodontic bracket placement. Am J Orthod Dentofac Orthop 1988;95(4):306-311.
21. Arbuckle G, Willis G. Enamel management during orthodontic treatment. J Ind Dent Assoc 1992; July-Aug:12-15.
22. McGuinness N. Letters to the editor. Brit J Orthod 1992;19(2):166.