Original Article

Evaluation of the Dental Plaque pH Recovery Effect of a Xylitol Lozenge on Patients with Fixed Orthodontic Appliances

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Abstract: The purpose of this study was to evaluate the influence of a xylitol lozenge on the dental plaque pH profile of fixed orthodontic patients. Twelve volunteers participated in this study. Before the measurement of plaque pH, subjects were asked to refrain from brushing their teeth for 48 hours and from eating and drinking for two hours. The subjects' baseline dental plaque pH was recorded using the touch technique. It was followed by a one-minute rinse with 15 ml of a 10% solution of sucrose, and subsequent plaque pH measurements were carried out during the next one hour. Xylitol lozenges were taken five times a day during a 14-day period. The variables of resting-plaque pH, minimum-plaque pH (MP pH), time required to reach MP pH (TMP), last-plaque (LP) pH at the end of one hour, cH area (CH), and pH at each test time were calculated for each pH test of the subjects. The paired sample *t*-test was used for statistical comparison. The mean MP pH values increased from 4.81 to 5.09 in the experimental measurement ($P < .05$). The mean TMP was not affected by the use of xylitol ($P > .05$). Although the LP pH showed an increase during the experimental period, the difference between control and experimental periods was not statistically significant ($P > .05$). The CH of the experimental period was significantly less than that of the control period ($P < .05$). As a result, the use of a xylitol lozenge after a sucrose challenge can be an advisable practice for fixed orthodontic patients to prevent future dental caries. (*Angle Orthod* 2004;74:240–244.)

Key Words: Dental plaque pH; Xylitol lozenge; Fixed orthodontic therapy; Dental caries risk

INTRODUCTION

Orthodontic treatment can provide functional and esthetic improvement in patients, but orthodontic appliances like brackets or ligatures often cause plaque accumulation. Plaque removal is a problem in individuals carrying orthodontic brackets and ligatures. Many orthodontic patients have difficulty in mechanically removing plaque because of the ligatures or brackets. In some instances, enamel demineralization or carious lesion may be seen. Insufficient oral hygiene is a common finding in orthodontic patients.[1–4]

The enamel demineralization associated with fixed orthodontic therapy is an extremely rapid process caused by a high and continuous cariogenic challenge in the plaque developed around brackets and underneath ill-fitting bands.[1] Orthodontically treated subjects have more teeth with white spot lesions than untreated subjects. Some studies showed that orthodontic treatment with multibanded appliances contributes to the development of new areas of enamel demineralization and to an increase in the severity of enamel opacities as measured by the opacity index. White spot lesions after orthodontic treatment with fixed appliances may present an esthetic problem, even after more than five years of treatment.[5–7]

Decalcification of the labial (buccal) surfaces of teeth during orthodontic therapy is a problem that is of clinical importance, as shown by the finding that 3.6% of the in-control teeth had white spots and 10% had them after orthodontic treatment and that 50% of the patients experienced an increase in white spots.[8]

The consumption of sucrose is considered to be one of the principal dietary factors in promoting dental caries. Mutans streptococci, particularly *Streptococcus mutans*, and

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other so-called low-pH non–mutans streptococci are considered virulent members of the dental plaque microflora, and its characteristic cariogenicity depends on the availability of sucrose. One of the most effective methods of dental caries prevention, therefore, is to substitute other sweetening substances for sucrose. However, lack of patient compliance with these sweeteners may cause failure of this method of preventing caries.[9–11]

A variety of sugar alcohols have been used as sugar substitutes in foods. The replacement of fermentable sugars with non- or low-fermentable sweeteners in confectionery is considered to be a practical way to prevent dental caries. Takahashi-Abbe et al[11] showed that sorbitol inhibits acid production in the deep layers of dental plaque, in which acid production is directly involved in the initiation of dental caries. This sorbitol inhibition in vivo is considered to occur in a manner similar to that of S. mutans in vitro in this study. In addition, there may be other plaque bacteria for which sugar metabolisms are inhibited by sorbitol, and the oxygen level in dental plaque may significantly affect the sorbitol inhibition in vivo. Xylitol, a five-carbon natural sugar alcohol, has been shown in many studies to be a successful dental caries–preventive natural carbohydrate sweetener after a total or partial substitution of dietary sucrose by this pentitol.[12]

Various mechanisms have been put forward as explanations for this caries-preventive effect. Not only is xylitol not fermented by most dental plaque bacteria but it also interferes with the in vitro growth of mutans streptococci. The beneficial effects of xylitol on dental caries have been attributed partly to this nonfermentability. However, there are also claims of specific effects on microbial growth and metabolism and on de- and remineralization processes. Reduced plaque formation has been reported, and decrease in the number of salivary mutans streptococci and less gingivitis also have been observed.[13]

The purpose of this study was to evaluate the influence of a xylitol lozenge on the dental plaque pH profile of patients wearing fixed orthodontic appliances.

MATERIALS AND METHODS

Twelve volunteers, five males and seven females, participated in this study. They were in fixed orthodontic treatment and had at least 26 teeth. The patients were examined dentally and periodontally. Those subjects requiring restorations were treated, or the fissures were sealed. Initial periodontal treatment included supragingival scaling and polishing. The participants had no active dental caries or serious periodontal problems. The brackets were bonded using a fluoride-free orthodontic resin (Transbond XT, 3M Unitek, Monrovia, Calif), and archwires and ligatures were applied.

Baseline plaque pH (T0) measurements were taken one month after the placement of orthodontic attachments. The subjects followed regular oral hygiene procedures during the first month before baseline measurement. After T0 measurements, subjects were instructed to use xylitol lozenges. The subjects took xylitol lozenges five times a day during a 14-day period. The time when each lozenge was taken was recorded in a diary. The schedule required one lozenge to be taken immediately after food or drink consumption. A second measurement (T1) was performed at this stage, after 14 days of use of xylitol lozenges. All measurements were carried out by the same examiner at the same time of day before and after using the xylitol lozenges.

Two measurement locations from each participant were used for intraoral dental plaque pH measurements. In all plaque, pH measurements were carried out at 24 interdental locations. Before the measurement of plaque pH, subjects were asked to refrain from brushing their teeth for 48 hours and from eating and drinking for two hours. The subjects' baseline dental plaque pH was recorded using a touch technique.[14] It was followed by a one-minute rinse with 15 ml of a 10% solution of sucrose. Then, further plaque pH measurements (totally 24 for each period) were carried out at intervals of two minutes for the first 30 minutes and at four-mm intervals for the second half-time in one hour.

All plaque pH measurements were made using a miniature pH electrode (Dental Beetrode NMPH 1, WPI, UK) and pH meter (Model SA-210, Orion Research, Tampa, Florida, USA) calibrated with pH 4.01 and pH 7.00 buffers as supplied by the manufacturer (WTW, Weilheim, Germany). A reference electrode (DRIREF-5 5 mm, WPI, USA) was placed in a glass filled with 3 M KCl solution. Subjects were instructed to keep their finger in the same glass during pH measurements. The electrode was then carefully slipped approximately two mm into the dental plaque along the labiomesial aspect of the surface of the upper first premolars on both the left and the right sides immediately apical to the contact area. It was held in place so that a stable reading could be taken. Care was taken to avoid any electrode contact with the gingival and oral mucosa. Immediately after a plaque pH reading was taken at the proposed interproximal site, the antimony electrode was cleaned with distilled water and calibrated again. Plaque pH of the second interproximal site was measured as described above.

Statistical analysis

The means and standard deviations of the plaque pH values were computed for each testing time. From each plaque pH test for each subject, the variables of resting-plaque (RP) pH, minimum-plaque (MP) pH, time required to reach MP pH (TMP), last-plaque (LP) pH at the end of one hour, cH area (CH) under RP-pH value (CH-RP), CH under critical pH value (pH = 5.5) (CH-5.5), and pH at each test time were calculated. The CH under the curve is a value that combines how low the pH falls and for how long. The

TABLE 1. The Means, SDs, Minimum, and Maximum of Plaque pH Values[a]

	Baseline			Experimental	
	Min–Max	Mean ± SD	*P*	Min–Max	Mean ± SD
RP pH	4.56–7.13	6.34 ± 0.61	0.519	5.12–6.95	6.24 ± 0.55
MP pH	4.05–5.47	4.81 ± 0.38	0.008	4.36–6.28	5.09 ± 0.54
TMP	1.00–12.00	5.79 ± 3.61	0.212	1.00–12.00	4.29 ± 3.21
LP pH	4.60–7.33	5.96 ± 0.62	0.102	4.61–6.94	6.12 ± 0.66
CH-RP	13.29–70.2	39.03 ± 16.49	0.012	8.97–54.45	28.15 ± 13.33
CH-5.5	0.00–28.90	12.80 ± 10.18	0.020	0.00–34.24	7.33 ± 8.96

[a] SD indicates standard deviation; Min–Max, Minimum–Maximum; RP, resting plaque; MP, minimum plaque; TMP, time required to reach for MP pH; LP, last plaque; CH, cH area; and CH-RP, CH under RP-pH value.

TABLE 2. Pearson's Correlation Analysis Among RP pH, MP pH, LP pH, TMP, and cH values[a]

		MP pH	TMP	LP pH	CH-RP	CH-5.5
RP pH	*r*	0.638a*	0.502*	0.711**	0.066	0.282
	P	0.001	0.012	0.000	0.758	0.182
MP pH	*r*		0.036	0.806**	−0.072	0.403
	P		0.867	0.000	0.838	0.051
TMP	*r*			−0.020	−0.008	0.175
	P			0.927	0.971	0.412
LP pH	*r*				0.118	0.438*
	P				0.583	0.032
CH-RP	*r*					0.595**
	P					0.002

[a] RP indicates resting plaque; MP, minimum plaque; LP, last plaque; TMP, time required to reach for MP pH; CH, cH area; and CH-RP, cH area under RP-pH value.

* Correlation is significant at the 0.01 level (two tailed).

** Correlation is significant at the 0.05 level (two tailed).

area enclosed by the resting pH value or critical pH value and the pH curve is a term that estimates cumulative insult to the tooth by a given cariogenic challenge. The paired samples *t*-test was used to compare the control and the experimental data. The relationships between the test parameters were assessed by Pearson's correlation analysis.

RESULTS

The mean RP pH values of participants did not change when using xylitol lozenge during the two-week period ($P > .05$). However, the mean MP pH values increased from 4.81 to 5.09 in experimental measurement ($P < .05$). The mean TMP was not affected by the use of xylitol ($P > .05$). Although the LP pH showed an increase during the experimental period, the difference between control and experimental periods was not statistically significant ($P > .05$). The mean CH-RP and CH-5.5 of the experimental period were significantly less than those of the control period ($P < .05$) (Table 1).

Pearson's correlation analysis showed that the RP pH was related to the MP pH and the LP pH ($P < .05$). The RP pH also was correlated with the TMP ($P < .05$). There was no correlation between the TMP and the MP pH and the LP pH ($P > .05$) (Table 2).

The levels indicating mean pH values from each time point are shown in Figure 1. The pH values of the exper-

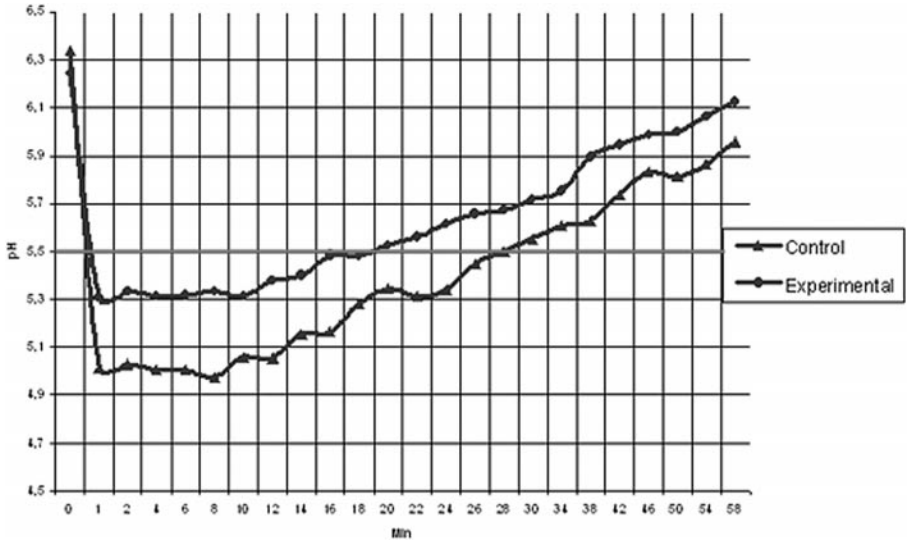

FIGURE 1. The levels indicating mean pH values from each time point for the control and experimental periods.

imental period were higher than that of the control. Similarly, for the experimental period, the area under the line of critical pH value also was less than that of the control. As shown in Figure 1, the last pH value at the end of the pH measurements was higher than that of the control.

DISCUSSION

One of the problems encountered during orthodontic treatment is the maintenance of adequate oral hygiene by the patient. The placement of orthodontic bands and brackets increases the risk of plaque accumulation. This study allowed comparisons of the ability of plaque to metabolize sucrose for fixed orthodontic patients, after ingestion of xylitol lozenges for 14 days.

Three independent methods of measuring plaque pH have been established. They are the plaque-sampling method,[10] the touch electrode system,[14] and the indwelling electrode system, which allows the dental plaque to accumulate in situ so that its pH can be measured directly and continuously.[15] One part of the touch electrode system, the antimony electrode method, has the merits of simplicity, cheapness, and flexibility.[16,17] Because the touch electrode system can be used for in vivo dental plaque pH measurement at multiple sites in the mouth for a large number of subjects, we chose to use it in this study.

Because self-cleansing is difficult in regions such as the bracket-carrying teeth or under the ligatures, disturbance of plaque cannot be achieved by oral hygiene measures. The resting pH in plaque results from a delicate balance between alkali and acid generation, which, in turn, is dependent both on the bacterial composition of the plaque and on the store of substrates and buffers from, and metabolite clearance into, the flowing oral fluid. The in vivo resting pH will vary with site-specific changing saliva flows. Urea supplied continuously at concentrations normal for saliva and gingival crevicular fluid can raise the resting pH of the dental plaque by an amount that would probably be significant in reducing in vivo dental caries.[18]

The age of plaque is an important factor for plaque pH measurement. The pH and buffering capacity of saliva might contribute to this phenomenon.[19] In this study, the subjects were instructed not to brush their teeth for 48 hours before the pH measurements were taken. This was done to ensure the presence of representative oral bacterial flora on the accessible tooth surfaces. All measurements were made at the same time of day because of the circadian rhythm of salivation.

Xylitol has attracted much attention as an alternative sweetener. Essentially, all clinical studies concerning the effects of xylitol on caries development agree on its noncariogenicity and on the beneficial effect of substituting sucrose with xylitol in chewing gums and sweets.[20] In this study, we showed that the xylitol lozenge can reduce acidogenicity of dental plaque. After a sucrose challenge, plaque pH returned quickly to the resting value because of the use of xylitol lozenges.

Xylitol is a natural, sweet carbohydrate, which is systematically classified in organic chemistry as a polyol (polyhydric alcohol or sugar alcohol). This means that the xylitol molecule has no reducing groups; all five-carbon atoms of the molecule bind a hydroxyl group (OH). Owing to this structure, xylitol and other five-carbon polyols can be called pentitols. Their general chemical formula is $(CH_2O)_5H_2$. Related polyols are sorbitol (D-glucitol) and D-mannitol. The latter polyols consist of a six-carbon skeleton and are thus called hexitols. Their general structural formula is $(CH_2O)_6H_2$. Thus, xylitol may be able to inhibit the growth of *Streptococcus sobrinus*, *Actinomyces* species, and lactobacilli.[21]

A xylitol-based caries prevention program has the benefits of at least the following features: (1) no expensive equipment or gadgets are needed, (2) no high-salaried health care personnel are needed, (3) no procedures are involved, (4) there is individual control over intake, and (5) the use of xylitol-based saliva stimulants may be regarded in most cases as a pleasurable experience.[21] Most of these benefits also were experienced in our study.

Chewing gum containing antimicrobial agents (xylitol or chlorhexidine acetate and xylitol) significantly improved periodontal health in elderly occupants of residential homes. The acceptance of both chewing gums was high, but more participants in the chlorhexidine acetate xylitol (ACHX) group felt that the gum kept their mouth healthy.[22] However, to use chewing gum during fixed orthodontic therapy may present some problems to the patients. Therefore, we preferred lozenges instead of chewing gum. Also, the participants did not experience any side effects because of xylitol lozenges.

Xylitol has been shown not to reduce salivary or plaque pH, and in some studies it has been shown to provide a measure of resistance to drops in salivary or plaque pH after a carbohydrate challenge. The nonfermentability of xylitol by many oral bacteria and its interference with bacterial metabolism are probably responsible for these results. However, the characteristic that xylitol does not lower the pH of dental plaque below 5.7 in vivo is shared by most other polyols. Mutans streptococci can metabolize sorbitol and mannitol but not xylitol. One study of 14 days' duration also found that sorbitol produced a plaque pH response to sucrose challenge that was similar to that of xylitol.[14]

CONCLUSIONS

One of the problems encountered during orthodontic treatment is the maintenance of adequate oral hygiene by the patient. The placement of orthodontic bands and brackets increases the risk of plaque accumulation, caries, decalcification, etc. Consequently, orthodontic patients must practice strict plaque control to prevent the development of

dental pathosis. This study allowed comparisons of the ability of plaque to metabolize sucrose for fixed orthodontic patients after ingestion of xylitol lozenges for 14 days. In this study, two-week xylitol lozenge usage caused higher MP pH values, which meant a less acidic challenge to dental hard tissue during orthodontic treatment. Moreover, one the best effects of xylitol lozenge usage in fixed orthodontic patients was that a significantly smaller CH was obtained. Therefore, when the xylitol lozenge was sucked after a sucrose challenge, the plaque pH returned quickly to the resting value. As a result, the use of a xylitol lozenge after sucrose challenge can be an advisable routine for fixed orthodontic patients.

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