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ABSTRACT

Previous studies demonstrated that the chewing of a 2.5% (mass fraction) α -tricalcium-phosphate-fortified (α -TCP) experimental chewing gum released sufficient calcium and phosphate to eliminate any fall in the tooth mineral saturation of plaque fluid after a sucrose rinse (Vogel *et al.*, 1998). In contrast, the chewing of a conventional sugar-free gum did not eliminate this decrease in saturation. The purpose of this study was to examine if the release of ions from plaque calcium-phosphate pools induced by this gum could provide protection during subsequent exposure to cariogenic conditions. Fourteen subjects accumulated plaque for 48 hrs, fasted overnight, chewed a control or experimental gum for 15 min, and subsequently rinsed 1 min with a mass fraction 10% sucrose solution. Before gum chewing, and at 7 min and 15 min afterward, whole plaque, plaque fluid, and salivary samples were obtained and analyzed by micro-analytical techniques. Additional samples were collected and analyzed at 25 min (7 min after the sucrose rinse). Although the results confirmed the deposition of large amounts of calcium and phosphates in plaque seen in the previous study, only a small increase was seen in plaque-fluid-free calcium and phosphate before sucrose administration. This suggests that few of the mineral ions were mobilized under non-cariogenic conditions. However, 7 min after the sucrose rinsing, an increase in these concentrations was seen which, based on hydroxyapatite ion activity product calculations, indicated a decrease in the driving force for demineralization compared with that seen with the control gum. These results suggest that the chewing of the experimental gum deposits a labile mineral reservoir in plaque that can resist a subsequent cariogenic challenge.

KEY WORDS: gums, caries, plaque, saliva, enamel saturation.

Composition of Plaque and Saliva Following use of an α -Tricalcium-phosphate-containing Chewing Gum and a Subsequent Sucrose Challenge

INTRODUCTION

Chewing gums are considered to be potential anticaries agents (Leach *et al.*, 1989), because, as a consequence of their effect on salivary flow, they can induce increases in plaque and salivary pH (Jensen and Wefel, 1989; Park *et al.*, 1990; Manning and Edgar, 1993). This higher pH can increase tooth mineral saturation during a challenge and thus decrease demineralization. Increased calcium and phosphate concentrations in the oral environment can also increase tooth mineral saturation in oral fluids (Ashley and Wilson, 1977; Vogel *et al.*, 1990; Margolis and Moreno, 1992). Therefore, an increased anticaries effect might be anticipated from the release of these ions during chewing of gums fortified with appropriate calcium phosphate minerals. Unfortunately, studies of candies or gums fortified with dicalcium phosphate dihydrate have not demonstrated their clinical efficacy (Richardson *et al.*, 1972; Ashley and Wilson, 1977; Rankine *et al.*, 1989). This failure has been ascribed to the low solubility of this mineral at neutral pH and the correlated difficulty of inducing a calcium phosphate plaque reservoir from an insoluble source (Vogel *et al.*, 1998). Recently, it was demonstrated (Vogel *et al.*, 1998) that, when an acidic gum was used to increase the solubility of a calcium phosphate additive (α -tricalcium phosphate), a substantial increase in plaque fluid and saliva calcium and phosphate could be attained in subjects who chewed the gum following a sucrose rinse. These increases raised tooth mineral saturation in plaque fluid high enough to cancel entirely any decrease in saturation induced by the sucrose rinse. However, with the use of a control gum following a sucrose rinse, a substantial decrease in saturation still occurred. Thus, the experimental gum appears to be more effective than a conventional gum in ameliorating a cariogenic challenge that occurred prior to gum chewing. Large increases were also seen in this study in the total calcium and phosphate content of whole plaque. The purpose of the current study was to investigate the degree to which these ions are mobilized by a challenge that occurs after gum chewing has ceased. Specifically, it was hypothesized that the experimental gum deposits a mineral reservoir in plaque that releases mineral ions into plaque fluid during a subsequent acidogenic challenge. The experimental gum therefore could potentially provide a protective effect during a future episode of cariogenic attack.

MATERIALS & METHODS

Experimental and Control Gums

The control gum was sugarless (mass fraction 50% sorbitol) grape-flavored Bubble Yum Bubble Gum (LifeSavers, East Hanover, NJ, USA) containing a mass fraction of 0.8% organic acids as flavoring agents. The experimental gum was identical to the control gum except that it also contained a mass fraction of 2.5% α -tricalcium phosphate (α -TCP) prepared as previously described (Vogel *et al.*, 1998).

Subjects, Administration, and Sampling

Experiments were performed in a random order based on a two-degree cross-over design with subjects waiting at least one week between experiments. All procedures

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were done with the informed consent of the subjects following protocols reviewed and approved by the appropriate institutional review boards of the American Dental Association and the National Institute of Standards and Technology. Twelve male and two female subjects, ages 25 to 53, with no dentures or unfilled cavities, participated in these studies. Each subject was supplied with an electric toothbrush (Braun Oral B, Redwood, CA, USA) and was given instructions designed to maximize his/her oral hygiene. Two days prior to sampling, subjects were instructed to brush and floss their teeth thoroughly and to refrain from further brushing or flossing for the next 48 hrs. They were also asked not to eat or drink (except water) overnight before the experiments, which were performed at about 8:30 a.m. Plaque and saliva samples were collected before the gum was chewed (baseline), after which gum chewing commenced immediately (time zero = start of gum chewing). Additional plaque and saliva samples were then obtained at 7 min and 15 min. After the 15-minute saliva and plaque collection, 2 g of sucrose dissolved in 18 g of water was administered as a one-minute rinse, and additional plaque and saliva samples were collected 7 min later. Since plaque collection takes about 1 min, saliva collection takes 1 min, and sucrose rinsing was done for 1 min, this last sample was taken about 25 min from the time start of gum chewing and is so noted in the data tables.

Collection and Analysis of Samples

The general method of plaque and saliva handling and analysis used here has been extensively described (Vogel *et al.*, 1990, 1997), and the methodological details are identical to those described in a recent publication (Vogel *et al.*, 1998). Therefore, the procedure is only briefly summarized here. Important features of these techniques with respect to plaque are: collection of plaque with thin plastic strips, weighing and handling of samples under mineral oil to prevent evaporation, centrifugation of plaque to separate plaque fluid and the whole plaque solids, recovery of plaque fluid with mineral-oil-filled micropipettes, and extraction of the whole plaque residue with 0.1 mol/L HClO_4 . Important features with respect to salivary samples include: collection by expectoration without prior swallowing, splitting of the saliva into two aliquots, extraction of one aliquot with 0.1 mol/L HClO_4 , and centrifugation of the second aliquot to obtain the clarified fluid. Since collection of the seven-, 15-, and 25-minute plaque samples required about 1 min, the actual times of the saliva samplings were at the (8 to 9) min, (16 to 17) min, and (26 to 27) min time intervals, which, for simplicity, are also referred to as seven-, 15-, and 25-minute samples. The composition of the acid extracts of plaque and saliva, or of the plaque fluid and clarified saliva, was then measured by means of micro-electrodes (plaque-fluid-free calcium, plaque fluid, and salivary pH) and microspectrophotometry (total calcium and total phosphate). The ion activity product with respect to hydroxyapatite (IAP_{HAp}) is commonly used as a measure of the saturation of fluid phases with respect to tooth mineral (Brown, 1974; Vogel *et al.*, 1990). Although the solubility product for tooth enamel calculated in this manner has been found to be variable (Patel and Brown, 1975), the single value of $-\log (\text{IAP})_{\text{HAp}} = 54.3$ (Moreno and Zahradnik, 1974) has been frequently cited (Margolis *et al.*, 1988, 1993; Margolis and Moreno, 1992). The $-\log (\text{IAP})_{\text{HAp}}$ values were calculated from the clarified saliva or plaque fluid pH, free calcium, and phosphate concentrations as previously described (Vogel *et al.*, 1998). Because of problems previously observed in the use of calcium micro-electrodes in saliva, salivary-free calcium was estimated as a fixed 0.53 fraction of the centrifuged total calcium (Chow *et al.*, 1994; Vogel *et al.*, 1998). It should be noted that recent modifications to

the microcalcium electrode have improved its performance in saliva (unpublished data).

Statistical Methods

Comparisons of the experimental and control gums were performed by analyses of covariance (ANCOVA), in which the dependent variables were the changes from baseline (time = 0), and the baseline scores were used as covariables. Because each subject provided data on both study treatments, "subject" was used as a blocking factor. Post-ANCOVA comparisons were then performed by two-sided *t* tests, in which the variability estimate was obtained from the mean square error in the ANCOVA. A level of significance of $\alpha = 0.05$ was used in all statistical tests of hypotheses. The term "significant" in the text (*e.g.*, significantly less) refers to this level. In the Tables, " $\pm$ " is used to denote the standard deviation.

RESULTS

Tables 1 and 2 show the results for the salivary and plaque analyses, respectively. The increase in salivary flow with gum chewing was similar for both gums (Table 1). The flow rate did not decrease after the chewing period during the 7 min following the sucrose administration. With the gum-mediated increases in salivary flow, salivary pH values significantly increased in a similar manner, for both the control and experimental gums. Following gum chewing and sucrose rinsing, a return to baseline salivary pH values was observed for both gums. Chewing the control gum and the subsequent sucrose rinse produced only small changes in the total calcium, and thus the calculated free calcium concentration, in centrifuged and in whole saliva. It should be noted that a small systematic error is apparent in the control gum data, because the total centrifuged saliva calcium concentration was greater than the whole saliva calcium concentration. However, the difference between these average values was very small (only slightly greater than the error of the microcalcium determination). With use of the experimental gum, a statistically significant increase in whole or centrifuged saliva total calcium concentration (or equivalently the estimated free calcium) was seen relative to the control gum values. This increase was especially large with respect to the whole saliva total calcium. Both gums produced an overall decrease in whole and centrifuged salivary phosphate concentration following gum chewing, which appeared to be increasing back to baseline levels with the cessation of chewing (25 min). As with total calcium, increases in the whole and centrifuged salivary phosphate concentrations were seen, relative to the control gum, with the α -TCP gum, but the difference was statistically significant only in the whole saliva seven-minute and 15-minute values.

Plaque fluid pHs were similar at baseline, 7 min, and 15 min with both gums. Sucrose rinsing produced a decrease in pH with both gums that was only 0.13 unit higher with the experimental gum. Increases were seen in plaque-fluid-free calcium concentration after subjects chewed the control gum at the seven- and 15-minute time periods, but no consistent increase was seen in the plaque fluid total calcium concentration. Although further increases were seen in these quantities with the experimental gums at these times, the difference was not statistically significant. Corresponding to the decrease in salivary phosphate, plaque fluid phosphate concentration fell in a similar fashion with both gums at 7 min and 15 min. After the

Table 1. Weight, Composition, and Hydroxyapatite Ion Activity Products $[-\log (IAP)_{\text{HAP}}]^a$ of Centrifuged Saliva and/or Whole Saliva Samples Collected for 1 min Before (baseline) and at 7 min and 15 min after the Chewing of Experimental (Exp.) or Control (Cont.) Gums, and at 7 min after a Subsequent Sucrose Rinse (25 min)^b

Sample	pH	CENTRIFUGED SALIVA			$-\log (IAP)_{\text{HAP}}$	WHOLE SALIVA		
		Free Calcium mmol/L	Total Calcium mmol/L	Total Phosphate mmol/L		Total Calcium mmol/L	Total Phosphate mmol/L	Weight (g)
Cont. baseline	6.87 ± 0.20	0.74 ± 0.13 ^a	1.39 ± 0.24	5.4 ± 1.2	50.51 ± 0.92	1.78 ± 0.36	5.8 ± 1.7	1.57 ± 0.59
Exp. baseline	6.89 ± 0.20	0.75 ± 0.13	1.41 ± 0.25	5.0 ± 1.2	50.42 ± 1.02	1.98 ± 0.50	5.7 ± 1.5	1.49 ± 0.62
Cont. 7	7.32 ± 0.14	0.92 ± 0.16	1.73 ± 0.31	2.99 ± 0.42	48.50 ± 0.83	1.68 ± 0.29	3.11 ± 0.34	1.89 ± 0.56
Exp. 7	7.27 ± 0.12	1.17 ± 0.22 ^e	2.22 ± 0.42 ^e	3.21 ± 0.37	48.06 ± 0.72	4.6 ± 1.5 ^f	4.9 ± 1.4 ^e	1.85 ± 0.55
Cont. 15	7.23 ± 0.14	0.85 ± 0.15	1.61 ± 0.29	3.44 ± 0.48	48.91 ± 0.95	1.50 ± 0.29	3.43 ± 0.44	1.86 ± 0.55
Exp. 15	7.23 ± 0.14	0.99 ± 0.21 ^d	1.86 ± 0.39 ^d	3.48 ± 0.51	48.55 ± 0.93	3.07 ± 0.89 ^f	4.26 ± 0.76 ^f	1.90 ± 0.59
Cont. 25	6.85 ± 0.22	0.84 ± 0.13	1.59 ± 0.25	4.32 ± 0.81	50.62 ± 1.19	1.49 ± 0.29	4.45 ± 0.88	2.36 ± 0.98
Exp. 25	6.81 ± 0.26	0.89 ± 0.27	1.69 ± 0.51	4.15 ± 0.77	50.80 ± 1.36	2.20 ± 0.59 ^f	4.66 ± 0.87	2.07 ± 0.68

^a Free calcium values estimated from total calcium (see text). This estimated value of the free calcium, along with the measured phosphate and pH, was used to calculate the ion activity products of hydroxyapatite $[-\log (IAP)_{\text{HAP}}]$. An increase in hydroxyapatite saturation of plaque fluid or saliva is shown by the negative values increasing toward zero.

^b Statistical comparisons were performed with the use of analyses of covariance, with "subject" used as a blocking factor ($n = 14$).

^c The $\pm$ refers to the standard deviation.

^d Experimental gum significantly greater than control gum, $p < 0.05$.

^e Experimental gum significantly greater than control gum, $p < 0.01$.

^f Experimental gum significantly greater than control gum, $p < 0.001$.

Table 2. Weight, Composition, and Hydroxyapatite Ion Activity Products $[-\log (IAP)_{\text{HAP}}]^a$ of Plaque and/or Plaque Fluid 1 min Before (baseline), and at 7 min and 15 min after the Chewing of Experimental (Exp.) or Control (Cont.) Gums, and at 7 min after a Subsequent Sucrose Rinse (25 min)^b

Sample	pH	PLAQUE FLUID			$-\log (IAP)_{\text{HAP}}$	WHOLE PLAQUE		
		Free Calcium mmol/L	Total Calcium mmol/L	Total Phosphate mmol/L		Total Calcium $\mu\text{g}/\text{mg}$	Total Phosphate $\mu\text{g}/\text{mg}$	Weight mg
Cont. baseline	7.12 ± 0.40	0.86 ± 0.40 ^a	2.33 ± 0.73	12.8 ± 3.0	48.6 ± 1.6	1.5 ± 1.1	3.9 ± 2.2	1.27 ± 0.41
Exp. baseline	6.98 ± 0.36	0.83 ± 0.37	2.34 ± 0.78	13.9 ± 4.6	49.4 ± 1.4	1.5 ± 1.4	4.2 ± 3.0	1.09 ± 0.39
Cont. 7	6.84 ± 0.41	1.14 ± 0.35	3.0 ± 1.3	10.6 ± 2.3	49.6 ± 2.3	1.3 ± 1.1	3.9 ± 2.4	1.44 ± 0.53
Exp. 7	6.83 ± 0.34	2.2 ± 1.4	3.4 ± 1.7	9.4 ± 2.3	48.6 ± 1.1	2.7 ± 1.6 ^e	5.7 ± 4.1	1.55 ± 0.80
Cont. 15	7.00 ± 0.32	1.27 ± 0.41	2.31 ± 0.62	9.9 ± 1.4	48.6 ± 1.9	1.29 ± 0.95	3.5 ± 2.1	1.37 ± 0.48
Exp. 15	6.98 ± 0.34	1.32 ± 0.49	2.6 ± 1.0	10.0 ± 2.5	48.4 ± 1.3	2.6 ± 1.9 ^e	5.4 ± 4.0	1.47 ± 0.72
Cont. 25	5.37 ± 0.31	3.07 ± 1.72	5.4 ± 2.4	10.7 ± 3.1	56.8 ± 2.1	1.24 ± 0.66	2.6 ± 1.3	1.55 ± 0.51
Exp. 25	5.50 ± 0.36	5.05 ± 1.90 ^e	8.9 ± 2.7 ^f	16.3 ± 4.7 ^e	54.2 ± 2.2 ^e	2.0 ± 1.4	3.6 ± 2.5	1.50 ± 0.59

^a Free calcium values directly measured with micro-electrode (see text). This measured value of the free calcium, along with the measured phosphate and pH, was used to calculate the ion activity products of hydroxyapatite $[-\log (IAP)_{\text{HAP}}]$. An increase in hydroxyapatite saturation of plaque fluid or saliva is shown by the negative values increasing toward zero.

^b Statistical comparisons were performed by analyses of covariance, with "subject" used as a blocking factor ($n = 14$).

^c The $\pm$ refers to the standard deviation.

^d Experimental gum significantly greater than control gum, $p < 0.05$.

^e Experimental gum significantly greater than control gum, $p < 0.01$.

^f Experimental gum significantly greater than control gum, $p < 0.001$.

sucrose-mediated pH decrease, large increases were found in plaque-fluid-free or total calcium concentration with the control gum (*i.e.*, at 25 min), but the plaque fluid phosphate concentration remained depressed from baseline level. However, at this same time point, a statistically significant increase occurred in all these quantities after subjects chewed the experimental gum.

In whole plaque, almost no change was seen from baseline calcium and phosphate content with the control gum, except for a small decrease after sucrose administration (25-minute sample).

However, with the experimental gum, increases in the concentrations of these ions from baseline values were found at 7 min and 15 min, and a large decrease (nearly to baseline) occurred after sucrose. These changes were significant, with respect to the control, for only the pre-sucrose calcium values, falling just short of significance for the remaining calcium and phosphate values ($p \approx 0.06$, all values).

The saturation with respect to tooth mineral behaves in a similar fashion for both gums. Specifically, in saliva, a primarily pH-mediated increase in saturation at 7 min and 15 min (Table

1), followed by a return to baseline levels as the salivary pH decreases at 25 min. In plaque fluid after the chewing of either gum, small, compensatory changes in composition (free calcium concentration increased, while the phosphate concentration decreased) were not enough to produce any significant changes in plaque fluid tooth mineral saturation. However, 7 min following the control gum-sucrose rinse regimen, plaque fluid saturation decreased about 8 orders of magnitude. With the experimental gum, this plaque fluid saturation decrease, which was moderated by increases in plaque fluid calcium and phosphate concentrations, was considerably less, about 5.8 orders of magnitude.

DISCUSSION

For both the control and experimental gums, baseline values for all the parameters shown in Tables 1 and 2 were similar to values previously obtained in similar experiments (Vogel *et al.*, 1998) and those reported in the literature (summarized in Nikiforuk, 1985; and by Margolis and Moreno, 1994). As in the previous study (Vogel *et al.*, 1998), the salivary flow rates were higher than the unstimulated salivary flow reported by Dawes and Macpherson (1992). This was probably due to the lack of expectoration before the one-minute saliva collection period, and the salivary stimulation induced in the subjects by the collection of plaque samples immediately before the saliva samples were obtained. Flow rate did not decline at the seven-minute post-sucrose collection, indicating a slow return to the baseline flow rates, perhaps influenced by the flow-stimulating effects of residual oral sugar. More importantly, the flow rates did not significantly differ between the experimental and control gums at any period. In accordance with previous observations (Nikiforuk, 1985; Dawes and Macpherson, 1992), the increase in saliva flow resulted in an increase in salivary pH that was similar for both gums. This increase in flow appears to be responsible for the decrease in salivary phosphate concentration seen with the control, since salivary phosphate concentration is known to vary inversely with flow rate (Lagerlöf, 1983; Chow *et al.*, 1994). The small difference between the whole saliva and centrifuged saliva total calcium and phosphate concentrations at baseline and the still smaller differences following control gum chewing suggest that salivary stores of these ions were small, especially in the latter samples. With respect to the experimental gum, an increase in whole saliva phosphate concentration and a still larger increase in whole saliva calcium concentration were seen relative to the control gum (Table 1). Previously, large increases in the amounts of these ions in the fluid phase of saliva were found in samples collected immediately after subjects chewed gums containing other soluble calcium phosphate compounds (Chow *et al.*, 1994), and recent studies have indicated a similar increase with the α -TCP additive used here (unpublished data). These results suggest that the increased whole saliva calcium and phosphate following the use of the experimental gum are primarily due to the formation of new salivary reservoirs rather than to the release of undissolved particles of α -TCP, as was suggested with DCPD-containing gums (Pickel and Bilotti, 1965). The release from these reservoirs, and perhaps from α -TCP particles remaining in the gum, was responsible for the increase in centrifuged saliva calcium. However, this increase, which is primarily in the seven-minute samples, was not

enough to increase the hydroxyapatite saturation of saliva significantly. Given the high salivary free calcium observed in the first minutes after subjects chewed the fortified gum noted above, this result may be due to the relatively late collection of salivary samples in the current study (8 to 9 min after chewing started).

In plaque fluid during the gum-chewing period, when the plaque was not sucrose-challenged, the pH values were similar with both gums. Furthermore, no increase in pH was seen, indicating that the buffer capacity of plaque was sufficient to overcome the 0.4 elevation in salivary pH during this period. The overall decrease in plaque fluid phosphate concentration during the chewing of both gums may be a reflection of the decrease in salivary phosphate concentration and the increase in salivary flow (Vogel *et al.*, 1998). Although a very large increase in whole plaque calcium and phosphate deposits was induced by the α -TCP gum at 7 min and 15 min, only small and inconsistent effects were seen in plaque fluid, and, consequently, no effect was observed in the ion activity product with respect to hydroxyapatite.

After sucrose (25 min), the plaque fluid pH of the control gum group decreased by about ≈ 1.5 unit (Table 2). A substantial increase in plaque-fluid-free and total calcium concentration was seen in these samples and can be attributed to the pH-mediated release of this ion from whole plaque stores and a decrease in plaque fluid calcium binding (Rose *et al.*, 1993; Margolis and Moreno, 1994; Vogel *et al.*, 1998). Unlike calcium, plaque fluid phosphate concentration was not affected by sucrose in the control gum samples and remained depressed from baseline levels, an effect that has been attributed to phosphate utilization by the bacterial cells (Margolis and Moreno, 1992). The decrease in whole plaque phosphate (Table 2) is in agreement with this model, as are recent studies where a release of phosphate was observed during *in vitro* acidification of plaque with HCl (Vogel *et al.*, 1999).

Although the plaque pH decrease was slightly less with the experimental gum, the difference was not significant. However, in contrast to the similarity of plaque fluid mineral ion concentration values at 7 min and 15 min, the experimental gum free and total calcium and total phosphate concentrations exhibited a statistically significant increase after the sucrose rinse (25 min). The source of this calcium and phosphate appears to be the whole plaque calcium and phosphate: The 25-minute control gum whole plaque calcium and phosphate decreased, on average, 0.05 $\mu\text{g}/\text{mg}$ and 0.84 $\mu\text{g}/\text{mg}$, respectively, from the pre-sucrose 15-minute sample, while, for the experimental gum, the decreases were 0.57 $\mu\text{g}/\text{mg}$ and 1.66 $\mu\text{g}/\text{mg}$. These increases in plaque fluid calcium and phosphate relative to the control gum were primarily responsible for the 2.6 order of magnitude higher tooth mineral saturation following sucrose. Specifically, the 0.13-unit difference in pH between these gums after sucrose, which was also observed in previous experiments (Vogel *et al.*, 1998), accounts for only 1 unit of the observed change in $-\log(\text{IAP})_{\text{HAP}}$. More importantly, with regard to the nominal solubility of tooth enamel discussed above [$-\log(\text{IAP})_{\text{HAP}} = 54.3$], undersaturation conditions were found in the control gum plaque fluid after sucrose, while the plaque recovered after the experimental gum remained saturated. It can thus be concluded, as hypothesized, that the α -tricalcium-phosphate-fortified experimental gum produces substantial calcium phosphate deposits, and that these deposits release mineral ions into plaque

fluid during a subsequent challenge. This release counteracts the decrease seen with a control gum and suggests that the experimental gum may have anticaries potential.

Previous studies have shown a powerful effect on the saturation of plaque fluid with respect to enamel when the type of gum used in this study was chewed after an acidogenic challenge. Although the persistence of the effects observed here remains to be investigated, the results of this study suggest that the major value of the α -TCP-fortified acidic gum, in the absence of a challenge, may be the deposition of acid-labile calcium and phosphate plaque deposits rather than the direct production of significant remineralization conditions. However, it should be noted that recent studies (unpublished data) suggest that a higher concentration of α -TCP, or the use of separate calcium and phosphate compounds, may be more efficacious in this regard than the mass fraction 2.5 % α -TCP additive tested here. Finally, although the possibility of calculus formation from topical calcium and phosphate treatments appears to be minimal (Vogel et al., 1998), the effect of their continued use is not known.

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