

# A Randomized Clinical Trial of the Anti-Caries Efficacy of 5,000 compared to 1,450 ppm Fluoridated Toothpaste on Root Caries Lesions in Elderly Disabled Nursing Home Residents

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## Dear Author

Reference [Sigel and Castellean, 1988] is mentioned in the text but is not in the reference list. Please add to the list or delete the reference from the text. Thank you.

## Key Words

Fluoride toothpaste · Randomized clinical trial · Root caries

## Abstract

Root caries is prevalent in elderly disabled nursing home residents in Denmark. This study aimed to compare the effectiveness of tooth brushing with 5,000 versus 1,450 ppm of fluoridated toothpaste (F-toothpaste) for controlling root caries in nursing home residents. The duration of the study was 8 months. Elderly disabled residents ( $n = 176$ ) in 6 nursing homes in the Copenhagen area consented to take part in the study. They were randomly assigned to use one of the two toothpastes. Both groups had their teeth brushed twice a day by the nursing staff. A total of 125 residents completed the study. Baseline and follow-up clinical examinations were performed by one calibrated examiner. Texture, contour, location and colour of root caries lesions were used to evaluate lesion activity. No differences ( $p$  values  $>0.16$ ) were noted in the baseline examination with regards to age, mouth dryness, wearing of partial or full dentures in one of the jaws, occurrence of plaque and active (2.61 vs. 2.67; SD, 1.7 vs. 1.8) or arrested lesions (0.62 vs. 0.63; SD, 1.7 vs. 1.7) between the 5,000 and the 1,450 ppm fluoride groups, respectively. Mean numbers of active root caries lesions at the follow-up examination were 1.05 (2.76) versus 2.55 (1.91) and mean numbers of arrested caries lesions were 2.13 (1.68) versus

0.61 (1.76) in the 5,000 and the 1,450 ppm fluoride groups, respectively ( $p < 0.001$ ). To conclude, 5,000 ppm F-toothpaste is significantly more effective for controlling root caries lesion progression and promoting remineralization compared to 1,450 ppm F-toothpaste.

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Studies from Denmark indicate that: (1) the proportion of elderly people in the total population will increase dramatically during the next decades; (2) elderly people maintain more of their teeth than previously; (3) the dentition in those who still have their own teeth are heavily restored; (4) gingival recession is frequent in elderly people, and (5) many fragile elderly people use medicine and the standard of home-based oral hygiene is far from optimal [Ekstrand et al., 1998; Petersen et al., 2004; Holm-Pedersen et al., 2005; Petersen and Yamamoto, 2005; Ekstrand et al., 2008]. Consequently, coronal caries, caries next to restorations and root caries may be an increasing health problem for fragile elderly people and an increasing burden logistically and economically for the Danish society in general [Petersen et al., 2004; Ekstrand et al., 2008]. Similar oral health problems have been described in other industrial countries [Chalmers et al., 2002; Österberg et al., 2006].

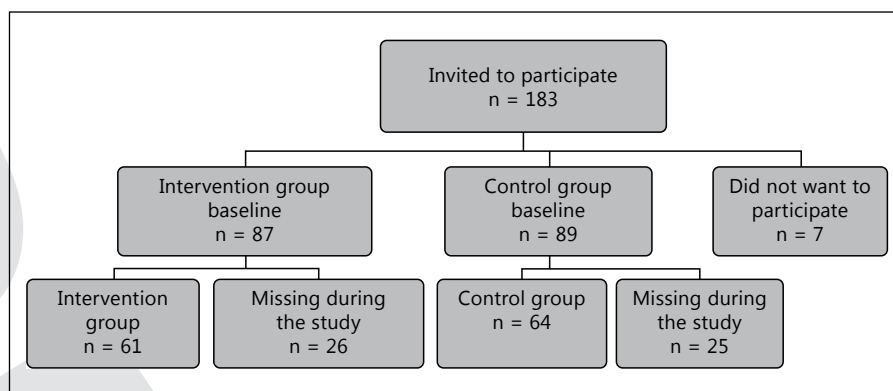
Caries is a biofilm-mediated disease in the dental hard tissues [Selwitz et al., 2007]. Fluoride reduces progression

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**Fig. 1.** Graphic illustration of the selection and sampling of the study population. Missing during the study: intervention group: deceased (14), moved away (2), other reasons (10); control group: deceased (9), moved away (1), other reasons (15). Other reasons: inadequate sampling of data in 1 case in each group; did not want to participate any longer; did not fulfil the inclusion criteria any longer (bedridden, deterioration of mental state, etc.).



of lesions and aids net remineralization by reducing dissolution of the crystals during a pH drop and remineralizing partly dissolved crystals during pH cycling [Fejerskov, 2004]. Regular tooth brushing with fluoridated toothpaste (F-toothpaste) is important in caries prevention as it combines mechanical disruption of tooth bio-film and fluoride delivery.

Data from substantial clinical trials have suggested that for every 500-ppm increase in the toothpaste fluoride concentration a reduction of 6–8% in caries prevalence can be expected [Stephen et al., 1988; O'Mullane et al., 1997; Wong et al., 2011]. This is said to occur in particular within the range in concentration from 1,000 to 2,500 ppm fluoride [Pessan et al., 2011]. Even though 5,000 ppm F-toothpaste has been in use for several years, there is limited evidence of the effectiveness of using 5,000 ppm F-toothpaste compared to a standard (1,000–1,450 ppm fluoride) toothpaste [Baysan et al., 2001; Lynch and Baysan, 2001; Ekstrand et al., 2008, Nordström and Birkhed, 2010].

The aim of this 8-month study was to evaluate the effectiveness of tooth brushing done twice daily by nurses with 5,000 ppm F-toothpaste in controlling root caries lesions in elderly disabled people living in nursing homes. A control group was included in which 1,450 ppm F-toothpaste was used. The 8-month study period was chosen based on the experience obtained in a previous study [Ekstrand et al., 2008].

## Materials and Methods

### Clinical Trial

According to Danish legislation [Danish Health Act, 2010], elderly citizens who cannot utilize the general dental care system due to physical or mental limitations are offered a special

oral health programme under the auspices of the local municipality. Hence, nursing homes in Copenhagen city are visited by a dental hygienist on a regular basis. By e-mail, the 45 nursing homes in Copenhagen city were invited to participate in the study and 6 nursing homes responded positively to the invitation.

### Sample Size Estimation

Sample size estimation was based on the following considerations: power = 80%, significance level  $\alpha = 5\%$ , standard deviation = 4.0 [Fure and Zickert, 1990; Fejerskov and Nyvad, 1996; Ekstrand et al., 1998], smallest difference in means (changing from active to arrested, which is clinically important) was set to 2. Using Lehr's formula [Lehr, 1992]:  $16/(\text{standardized difference})^2$  where the standardized difference in this study is  $2/4 = 0.5$  gives 64 residents in each of the two groups. To achieve that number at the end of the study we estimated that at least 180 residents were required to participate initially.

### The Study Population

The study population consisted of consecutively recruited residents at the 6 nursing homes. Inclusion criteria were: residents who were not able to brush their teeth themselves; residents who would allow the nursing staff to brush their teeth; residents who had 5 or more natural teeth; residents with  $\geq 1$  root caries lesion, and residents who were not bedridden (permanently bedridden persons in nursing homes in Denmark are in most cases terminal ill).

The study population was recruited in the following manner: residents already living at the nursing homes were asked to participate. Whenever the hygienist (principle investigator, examiner 2) made his regular visits to the nursing home, the nursing staff informed him if a new resident had moved in. If the inclusion criteria were fulfilled and informed consent was obtained from the resident, the resident was allocated either to the control or the intervention group by simple random sampling. Each participant drew a number; if it was even they were allocated to the intervention group and if it was uneven to the control group. The selection and the sampling of the study population are shown in figure 1.

Participants in the intervention group (group 1) had their teeth brushed by nursing staff twice a day with the 5,000 ppm F-tooth-

**Table 1.** The 4 variable criteria and scores used to judge activity of root caries lesions

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Texture of the lesion when gently probed
Hard (0), leathery (2), soft (3)
Contour of the surface
No cavitation or the surroundings of the cavity smooth to probing (1)
Cavitation with irregular border (2)
Distance from the lesion to the gingival margin
≥1 mm from the gingival margin (1)
<1 mm from the gingival margin (2)
Colour of the lesion
Dark brown/black (1)
Light brown/yellowish (2)

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paste (Duraphat 5,000; Colgate Palmolive, Guildford, UK). Participants in the control group (group 2) had their teeth brushed by nurses twice a day with the 1,450 ppm F-toothpaste (Colgate Ultra Cavity Protection; Colgate Palmolive).

Regular meetings were held at the nursing homes during which the nursing staff were instructed by examiner 2 on how to brush the teeth of residents after breakfast and before sleeping time in the evening. The staff were asked to remove partial dentures, apply the toothpaste perpendicular to the head and brush (corresponding to about 0.5 cm) for around 2 min. Following this, residents were asked to spit out the toothpaste without rinsing. Examiner 1 provided the nursing homes with toothpaste, where the tubes were covered by paper so the nurses and the participants were in principle unaware of who received the 5,000 or 1,450 ppm F-toothpaste.

The study was approved in February 2008 by the Ethical Board of Frederiksberg and Copenhagen.

#### *The Root Caries Scoring System*

In a previous study [Ekstrand et al., 2008], a root caries scoring system was developed and tested (table 1). The individual scores were summed to give a total score (a score of 3–5 characterized lesions as arrested and 6–9 as active).

#### *The Reproducibility of the Devised Score System*

First author (K.E., examiner 1) trained the principle investigator (J.P., examiner 2) in the scoring system. Initially, the training involved 6 elderly patients with 20 root caries lesions in a nursing home in Copenhagen. A reproducibility study was established using freshly extracted teeth (15 teeth with 23 individual root caries lesions) for assessing the 4 parameters presented in table 1. A line was drawn with a permanent marker to indicate the level of the gingival margin. All assessments were performed twice by both examiners with a period of 1 week between the first and second assessments.

#### *Clinical Examination*

##### *Baseline*

Examiner 2 began by recording the status of the dentition in terms of number of teeth and occurrence of dentures. The dental

status of the teeth was classified according to the following system: (1) tooth present, (2) radix (root) present and (3) bridge extension. A mirror test where the mirror is placed in the oral sulcus in one side of the mouth was then performed. If the mirror stuck to the oral mucosa it was, in this study, an indication of mouth dryness. Occurrence of buccal plaque was scored on 4 selected teeth using the following score system: (0) no visible plaque; (1) plaque covering not more than the gingival 1/3 part of the surface; (2) plaque covering 1/3–2/3 of the surface, and finally (3) plaque covering >2/3 of the surface. The 4 selected teeth were 16, 22, 36 and 42. If these teeth were absent the nearest tooth was selected. Examiner 2 then brushed the teeth on the participant.

Status of the root caries lesions on teeth present was classified according to table 1.

#### *Follow-Up Examination*

Clinical assessments were conducted according to the methods described at baseline. The follow-up examination took place approximately 8 months after the baseline examination. Examiner 2, who conducted the clinical investigation also at the follow-up examination, was blinded to which group the participants belonged to.

#### *Statistical Considerations*

##### *Inter- and Intra-Examiner Reproducibility*

Inter- and intra-examiner reproducibility was assessed using unweighted kappa and percentage agreement. For the inter-examiner reproducibility the first assessments made by the two examiners were used.

##### *Baseline Examination*

Caries on root surfaces was dichotomized as arrested (3–5 points) or active (6–9 points). For subjects completing the study baseline, characteristics of the study groups were compared (t test) for age, number of teeth present, number of active root caries lesions and number of arrested lesions. Occurrence of plaque on an individual level was expressed as median score for the 4 teeth and the two groups were compared using a median test (Mann-Whitney U test). Group differences in number of residents with partial or full dentures and with oral dryness were compared using a  $\chi^2$  test.

##### *Follow-up Examination and Difference from the Baseline Examination*

The following outcomes were possible concerning changes from baseline to the follow-up examination of the individual lesions: (1) active at baseline, still active at the follow-up examination; (2) active at baseline, arrested at the follow-up examination; (3) arrested at baseline, arrested at the follow-up examination, and (4) arrested at baseline, active at the follow-up examination. For this part of the calculations only lesions recorded at baseline as well as at the follow-up examination were used. Wilcoxon and Mann-Whitney tests [Sigel and Castellean, 1988] were used to see if there were any significant changes in the number of active and arrested lesions over the study period in the intervention versus the control group.

Descriptive statistics were used to describe the predictive value of texture in the decision as to whether the lesion was active or arrested.

**Table 2.** Levels of intra- and inter-examiner reproducibility expressed as percentage agreement and weighted kappa for the gold standard (examiner 1) and the principal clinical examiner (examiner 2)

	Intra-agreement examiner 1	Intra-agreement examiner 2	Inter-agreement	Kappa intra-examiner 1	Kappa intra-examiner 2	Kappa
Texture	87	87	91	0.80	0.80	0.87
Contour	91	87	83	0.75	0.68	0.65
Distance	91	87	87	0.83	0.83	0.74
Colour	87	91	87	0.74	0.81	0.74

## Results

No reports of side effects due to the toothpaste or the brushing were noted during the study.

### *Intra- and Inter-Examiner Reproducibility*

Table 2 shows levels of intra- and inter-examiner reproducibility. The lowest level was seen concerning the parameter contour where the kappa value for examiner 2 was 0.65, but when the reproducibility for contour was expressed by perfect percentage agreement the value was 83%.

### *Baseline Data*

A total of 176 out of 183 residents consented to take part in the study. Figure 1 shows the details of the residents allocated to the two groups and the exclusions, the majority of which were related to deaths or moving to other nursing homes during the 8-month study period.

A total of 127 residents completed the study, but data were only available from 125 (71% of the total sample), of whom 82 were female and 43 male. For these 125 residents the mean age was 81.7 years (1 SD = 11.6) and the mean number of teeth was 16.5 (7.5). Fifty-three participants (42%) had partial dentures in one or both jaws or full dentures in one of the jaws. Twice as many wore dentures in the upper jaw compared to the lower jaw. Fifty-one (41%) were scored as having dry mouth according to the mirror test. Based on examination, 3% of the residents had no plaque; 76% were classified as having plaque covering 1/3 of the tooth surfaces next to the marginal gingiva; 21% had plaque covering up to 2/3 of the tooth's surface, and only 1 (0.8%) participant had plaque covering more than 2/3 of the tooth's surfaces. A total of 412 root caries lesions were identified ranging from 1 to 23 lesions in the participants. A total of 75 lesions were diagnosed as arrested (18%) and 337 (82%) as active.

Table 3 reveals that no statistical significant differences were seen at baseline concerning the parameters: age, number of teeth, and plaque status. Concerning the mean number of active (2.61 vs. 2.67) as well as arrested lesions (0.62 vs. 0.63), there was no significant difference between the two groups. Finally, there were no inter-group differences in the number of participants with oral dryness ( $p = 0.872$ ) or wearing partial or full dentures ( $p = 0.310$ ).

### *Follow-up Data for Those Who Completed the Study*

There were no significant differences between the groups regarding oral dryness ( $\chi^2$  test = 2.1023;  $p = 0.147$ ) or plaque status (Mann-Whitney U test,  $z = -0.697$ ;  $p = 0.486$ ) at the follow-up examination.

Compared to the baseline examination, 16 teeth with root caries lesions were missing (2 teeth from 2 residents in the intervention group, and 14 teeth from 2 residents in the control group). A total of 396 root caries lesions were recorded both at baseline and at the follow-up examination.

Table 4 presents the changes happening from baseline to the follow-up examination. Significantly more active baseline lesions arrested during the study period in the intervention group (mean 1.72) compared to the control group (mean 0.28;  $p < 0.00001$ ). Correspondingly, significantly more lesions were maintained to be active at the follow-up examination in the control group (mean 2.34) versus the intervention group (0.87;  $p < 0.00001$ ).

With respect to those lesions which were recorded as arrested at baseline, no significant differences were seen between the intervention group versus the control group in terms of the lesions scored as arrested ( $p = 0.96$ ) or active ( $p = 0.19$ ) at the follow-up examination.

In summary, the mean number of active and arrested lesions in the intervention group at the follow-up was 1.05 (2.76) and 2.13 (1.68), respectively, versus 2.55 (1.91) and 0.61 (1.76) in the control group ( $p$  values  $< 0.00001$ ).

**Table 3.** Data characterizing the two groups at baseline, tests used and p levels

Samples	5,000 ppm (n = 61)	1,450 ppm (n = 64)	Test	p
Baseline: age				
Mean 81.7 (11.6)	mean 82.1 (11.7)	mean 81.4 (11.6)	independent sample t test	0.720
Range 45–103	range 45–103	range 49–99	t = 0.339	
Baseline: teeth				
Mean 16.5 (7.5)	mean 16.9 (7.9)	mean 16.1 (7.1)	independent sample t test	0.340
Range 3–32	range 3–32	range 4–32	t = 0.590	
Baseline: plaque				
	mean rank = 62.97 (n = 57)	mean rank = 56.25 (n = 61)	Mann-Whitney U test	0.160
			z = -1.405	
Baseline: root caries lesions				
Mean 3.27 (3.0)	mean 3.26 (3.2)	mean 3.28 (2.8)	independent sample t test	0.623
Range 1–23	range 1–25	range 1–16	t = 0.350	
Baseline: active lesions				
Mean 2.64 (1.8)	mean 2.61 (1.7)	mean 2.67 (1.8)	independent sample t test	0.526
Range 1–14	range 1–14	range 1–9	t = -0.207	
Baseline: arrested lesions				
Mean 0.62 (1.8)	mean 0.62 (1.7)	mean 0.63 (1.7)	independent sample t test	0.809
Range 1–11	range 1–11	range 1–9	t = -0.07	

Figures in parentheses indicate 1 SD.

**Table 4.** Changes between baseline and follow-up examination in the two groups

	Number of participants	Number of lesions	Mean number of lesions	SD
Active at baseline and arrested at follow-up (p < 0.00001)				
Intervention group	61	105	1.72	1.17
Control group	64	18	0.28	0.65
Active at baseline and active at follow-up (p < 0.00001)				
Intervention group	61	53	0.87	1.83
Control group	64	150	2.34	1.72
Arrested at baseline and arrested at follow-up (p = 0.96)				
Intervention group	61	23	0.38	1.13
Control group	64	22	0.34	1.25
Arrested at baseline and active at follow-up (p = 0.96)				
Intervention group	61	9	0.15	1.43
Control group	64	14	0.22	0.49

Table 5 shows texture scores (0, 2, 3) related to whether the lesions at baseline and follow-up were scored as active or arrested in the intervention and in the control groups. When the lesions were recorded as active, independently of whether it was in the intervention or in the control group, very few lesions texture-wise were classi-

fied as hard (baseline examination: 3% of the cases in the study group and 2% in the control group; follow-up examination: 16% in the intervention group and 2% in the control group). In contrast, when the lesions were recorded as arrested, in >90% of the cases the lesions were classified as hard.

**Table 5.** Texture scores related to activity assessment of the lesion in the intervention and control groups at baseline and follow-up examination

Score	Arrested lesions n	Active lesions n
Intervention group at baseline		
0	31	5
2	3	89
3	0	66
Total	34	160
Control group at baseline		
0	32	3
2	3	99
3	0	65
Total	35	167
Intervention group at follow-up		
0	127	10
2	4	23
3	0	30
Total	131	63
Control group at follow-up		
0	41	5
2	0	57
3	0	99
Total	41	161

## Discussion

It is well known that caries and particularly root caries is difficult to control in the fragile part of the Danish population [Holm-Pedersen et al., 2005]. Data indicate that similar trends are seen in other countries [Chalmers et al., 2002; Holm-Pedersen, 2005; Österberg et al., 2006]. Primary or secondary caries preventive methods are therefore required. The use of 5,000 ppm F-toothpaste is suggested to be one method to gain better control with root caries in frail elderly people [Lynch et al., 2000; Baysan et al., 2001]. In a previous study [Ekstrand et al., 2008], including frail people older than 75 years living in their own homes, it was found that self-performed tooth brushing with 5,000 ppm F-toothpaste twice a day was as effective as brushing with 1,450 ppm F-toothpaste supplemented with monthly professional tooth cleaning for controlling root caries progression.

In this study, conducted on disabled elderly people with a mean age of >80 years and living in nursing homes, 5,000 ppm F-toothpaste was significantly more

effective for controlling root caries progression than 1,450 ppm F-toothpaste, when teeth were brushed by nurses (table 4).

Consecutively enrolled participants and random assignment to one of the two groups reduced the chance of selection bias. A total of 29% of subjects failed to complete the study. Approximately half of these were related to the death of the resident or residents moving to other nursing homes. As the number of residents who did not fulfil the study were equally distributed between the intervention group (n = 25) and the control group (n = 25; fig. 1), it is not likely that the exclusions influenced the results.

The sample size calculation estimated that about 64 residents in each group should complete the study for the data to be statistically sound. This was in general achieved (intervention group, n = 61; control group, n = 64). However, it is important to mention that the sample size is influenced by the standard deviation of root caries lesions in the population to be investigated, in this case disabled elderly people. Current data are not available, but based on previous literature [Fure and Zickert, 1990; Fejerskov and Nyvad, 1996; Ekstrand et al., 1998] the value of 4.0 was finally chosen.

The level of kappa values is influenced by the number of categories in the parameter used in the scoring system and by the prevalence of observations within the parameter. As 3 of the 4 parameters in the root caries classification system used in the present study operate with only two categories, and it could be expected that one of the categories was much more prevalent than the other, it was decided also to show the reproducibility by means of percentage agreement. Whether expressed by percentage agreement or by unweighted kappa, the reproducibility between examiner 1 and examiner 2 was substantial to excellent, as were the levels of intra-examiner reproducibility (table 2). The advantage of the root caries scoring system used is that it is not the examiner but a computer that eventually decides whether the lesion is active or arrested. This method limited the chance for that information bias to influence the results.

The development of the root caries scoring system was based on suggestions from Nyvad and Fejerskov [1986], Fejerskov and Nyvad [1996] and Lynch and Baysan [2001]. The validity of the root caries scoring system used in this study to differentiate between active and arrested lesions at a single examination has been evaluated in a previous study and found acceptable [Ekstrand et al., 2008]. As seen from table 1, texture is graduated into three levels: hard, leathery and soft (soft is allocated 3 points). Thus, as a cumulative score of >5 points indi-

cates that the lesion is active, all soft lesions are classified as active as the other 3 parameters each scored at least 1 point.

Internal analyses showed that 79% of the soft lesions at baseline that became leathery during the study were lesions from residents in the intervention group. Furthermore, 75% of the soft lesions at baseline which became hard during the study period were lesions from the residents in the intervention group. The literature supports the suggestion that dentine, from being soft, can reharden due to remineralization [ten Cate et al., 1998; Petersson et al., 2011]. As there was no difference in plaque conditions between the two groups at the final examination, the only parameter which can promote rehardening of the dentine observed is the fluoride, and the best rehardening was achieved with the high fluoride concentration (5,000 ppm) compared to the 1,450 ppm concentration.

Actually, based on the data presented in table 5 it is arguable that texture should be the only parameter to be used for assessing the activity status of the root caries lesions in this study. Thus, even though the texture of the lesion is part of assessing lesion activity in this study, it is interesting to learn that in >90 of the cases where the lesions were characterized as arrested the lesions were hard to probing, and in >80% of the cases where the lesions were active, the lesions were leathery or soft to probing. In this study it seems to have been sufficient to use only texture as the single parameter for judging the activity status of the lesion. Whether this strong predictive value of texture is reflected by the effect of fluoride, the ingredient investigated in this study, or whether the same results would appear if the active ingredient to be investigated focused on chemical plaque control, for example, cannot be clarified. It was interesting to note that there was no increase in the level of oral hygiene during the study period, indicating poor compliance from the nursing staff. However, many lesions arrested during the study period, in particular in the intervention group. Preliminary studies indicate that during the time when brushing takes place a mean saliva concentration of 650 ( $\pm 270$ ) ppm fluoride can be measured when tooth brushing is performed using 5,000 ppm F-toothpaste [Ekstrand, 2006]. The corresponding figure when brushing with 1,450 ppm F-toothpaste was 110 ( $\pm 45$ ) ppm fluoride. Further, at least for a couple of hours twice a day the fluoride concentration is 5 times higher in the saliva of those who use 5,000 versus those using 1,450 ppm F-toothpaste [Ekstrand, 2006]. It is furthermore well accepted that the formation of calcium fluoride ( $\text{CaF}_2$ ) is concentration dependent and requires a concentration of >100 ppm fluoride to be

formed [Gerould, 1945; Buzalaf et al., 2011]. The 5,000 ppm F-toothpaste provides a significant advantage over 1,450 F-toothpaste in this sense. Finally, it is reasonable to indicate that concentrations of fluoride around 650 ppm for several minutes, as during tooth brushing, might decrease the metabolic activities in the plaque [Koo, 2008; Nordström et al., 2009; Buzalaf et al., 2011].

## Conclusion

This study suggests that 5,000 ppm F-toothpaste is significantly more effective for controlling root caries lesion progression and promoting remineralization compared to 1,450 ppm F-toothpaste in a population who received help with brushing twice daily in a long-term care setting.

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## Disclosure Statement

Roger Ellwood is an employee of the Colgate Palmolive company. The other authors declare no conflicts of interest.

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