Plaque-inhibiting effect of dentifrices containing stannous fluoride

BJARNE SVATUN

Department of Pedodontics, Dental Faculty, University of Oslo, Oslo, Norway

Svatun, B. Plaque-inhibiting effect of dentifrices containing stannous fluoride. *Acta Odontol. Scand.* 36, 205–210

The present study showed that the plaque inhibiting effect of aqueous solutions of stannous fluoride can be maintained in toothpastes. A commercial toothpaste containing 0.14 per cent of water soluble tin was effective whereas one containing 0.03 per cent showed no effect. The plaque inhibiting effect was shown in one study where the toothpastes were applied in cap splints and the plaque was scored after four days by the Plaque Index of Löe, and in another where the effect of locally applied pastes was monitored 24 hours later by the Gingival margin Plaque Index of Harrap. The present investigation supports the view that the stannous ion is essential in the plaque inhibition caused by stannous fluoride preparation. The excact mechanism is unknown but it is speculated that a change in the surface potential of oral bacteria through interaction with the stannous ion may be important.

Keywords: Preventive dentistry; plaque formation; surface potential

Bjarne Svatun, Department of Pedodontics, Dental Faculty, Geitmyrsveien 71, Oslo 4, Norway

Recent research has shown that stannous fluoride applied as mouthrinses is effective in preventing plaque formation. In one study (24) this effect was evaluated by electron microscopy of pieces of enamel which had been carried in a device in the mouth. Another study, where microbiologic and electron microscopic techniques were used, demonstrated a marked reduction of bacterial accumulation following stannous fluoride mouthrinsing (9). Traditional clinical trials have confirmed that solutions of stannous fluoride (0.2 per cent and 0.3 per cent) prevented plaque formation when applied as mouthrinses twice a day (21, 22). However, when aqueous solutions were used, side effects such as a strong metallic taste and a yellowish-brown discoloration of the tongue and the teeth were reported. The 0.3 per cent solution also induced a desquamative lesion of the oral mucosa in one of the test persons (22). Another disadvantage was that the solutions had to be prepared immediately before the use to avoid hydrolysis and oxidation (12, 14).

Commercial dentifrices containing stannous fluoride have been used in some countries for several years. It is well established that a reduction in the caries increment can be obtained by regular use of this type of toothpaste (4). Except for occasionally reported dental pigmentation (5, 17) no untoward side effects have been observed. It seemed, therefore, of interest to test the

Received for publication, June 30, 1978

plaque-inhibiting effect of stannous fluoride in toothpastes. As the plaque-inhibiting effect of stannous fluoride may be caused by stannous ions, the content of water soluble tin in the dentifrices was measured.

MATERIAL AND METHODS

Clinical test

Experiment 1. Four dentifrices were tested:

1. Toothpaste "A", a commercial dentifrice containing 0.4 per cent stannous fluoride.
2. Toothpaste "B" was identical with "A" but without stannous fluoride.
3. Toothpaste "C", a commercial dentifrice containing 0.4 per cent stannous fluoride and 1 per cent stannous pyrophosphate.
4. Toothpaste "D" contained 0.8 per cent chlorhexidine digluconate.

The test panel consisted of 12 female dental hygienist students. Nine of them had previously participated in a clinical test concerning the plaque-inhibiting effect of stannous fluoride mouthrinses. Cap splints were used for studying the plaque-inhibiting effect of dentifrices *in vivo* as described by Strålfors (23) and Gjermo & Rölla (6). The test was performed according to a double blind design and the different dentifrices were randomly distributed among the test panel in each of four experimental series. The test periods lasted for four days and the students received a thorough prophylaxis with total removal of plaque and calculus at the start of each period. The students rinsed with 10 ml of a 15 per cent (w/v) sucrose solution for one minute every second hour to enhance plaque formation. The cap splints were made of 2 mm thick polyvinyl plates and adjusted to cover the teeth only. They were kept *in situ* every morning an every evening for two minutes, each containing approximately 1 1/2 g of the dentifrice to be tested. No mechanical oral hygiene was permitted during the test period, but the students had three days of habitual oral hygiene between each experiment. Each series was concluded with recording of the Plaque Index (Pl.I) as described by Löe (15). Student's t-test was used to evaluate statistical significance.

Experiment 2. A study on the influence of stannous fluoride on plaque growth in a 24 hours period was conducted in a group of mentally subnormal persons consisting of eight day home patients. They had all participated in a controlled oral hygiene program for one year with a thorough professional prophylaxis every second week. This program was concluded just prior to the experiment and their gingival conditions were good. Their teeth were pumiced and then polished with either a commercial abrasive paste containing 3 per cent monofluorophosphate or with the stannous fluoride/stannous pyrophosphate dentifrice "C". Both pastes were used in all persons. Mechanical oral hygiene was suspended for 24 hours and plaque was scored using the Gingival margin Plaque Index (GmPII) described by Harrap (11): Plaque was disclosed by the use of Diaplaque® after spraying the teeth with water. Excess disclosing agent was removed by further water spraying. The examiner then estimated the percentage of the length of the buccal gingival margin in contact with plaque on the surface of each tooth after the teeth had been dried with air and cotton rolls. The buccal gingival margin was defined to extend into the interproximal region as far as visible when a complete dentition was present. When the next tooth was missing the measurements were made to the midpoint of the proximal surface of the tooth. All teeth except the second and third molars in each quadrant were scored. The scores of the individual teeth were averaged to give a plaque score

for the whole mouth. Student's t-test was used to evaluate statistical significance.

In addition, a pilot study was performed in mentally subnormal persons with poor oral hygiene and established periodontal disease, using toothpaste "C" in cap splints.

Determination of tin

Water soluble tin was determined by means of atomic absorption spectroscopy (AAS). Suspensions of toothpaste in deionized water (1g/10 ml) was stirred for one hour, centrifuged and filtered and the water phase analyzed for tin. For analyses of solutions containing more than 1 μg Sn ml^{-1} conventional AAS was used, aspirating the sample directly into the air/acetylene flame. When the content of tin was lower than 1 μg ml^{-1} a modified technique, the hydride generating method, was used. The acidified sample was added to a sodiumborohydride solution in a hydride generator and the evolved hydride was swept by a carrier gas into an argon/hydrogen flame. In this way tin is separated from its matrix, which can often be complex, and a lower detection limit is obtained, in this case 1 ng tin.

Two different atomic absorption spectrophotometers (Perkin Elmer models 303 and 503) equipped with recorders were used for the measurements. An electrodeless discharge lamp was used as a light source and all determinations were made with a deuterium background corrector. The most sensitive wavelength for tin (225 nm) was chosen. The samples and standards contained the same amount of hydrochloric acid which is important especially for the hydride generation technique. The hydrochloric acid was of suprapure quality (A.G. Merck, Darmstadt), while all the other chemicals were reagent grade. Distilled water was used for all preparation and dilution purposes of solutions. The analyses were performed in cooperation with The Institute of Industrial Research (SIF), Oslo.

RESULTS

The individual and mean Pl. I. values of the participants through all the series are shown in Table 1. The highest Pl. I. values were observed in the placebo dentifrice "B" group, but the mean Pl. I. after employment of toothpaste "A" was only slightly lower than for "B". All participants showed their lowest scores when the chlorhexidine-containing toothpaste was used, but toothpaste "C" also gave markedly lower mean Pl. I. values than did pastes "A" and "B". The differences were statistically significant ($P < 0.001$). The range of the observations was relatively large in group "C" (Fig. 1). However, this was mainly due to a high Pl. I. value of two individuals (A.E.A. and A.C.L.). The study of the Pl. I. values of the different tooth surfaces separately revealed that the interproximal surfaces scored highest and the lingual surfaces lowest in all tests.

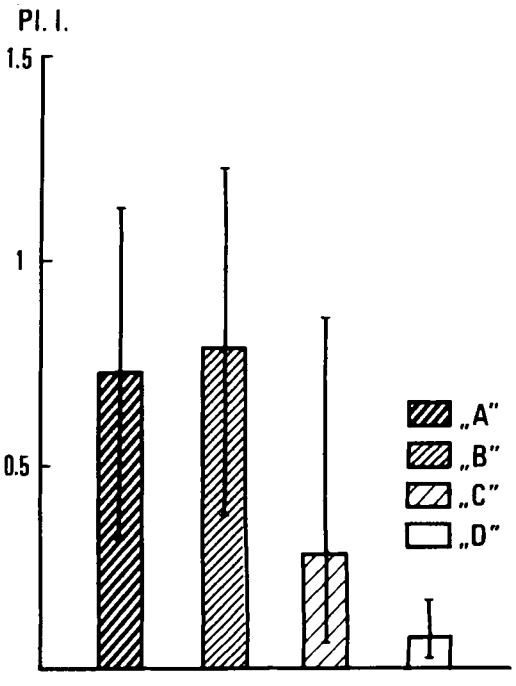

Fig. 1. The mean Plaque Index values for the dentifrices tested. The range of observations is indicated by the vertical lines

Table 1. *The Plaque Index values after the use of the dentifrices*

Test person	"A"	"B"	"C"	"D"
A.B.H.	0,83	0,66	0,28	0,07
E.H.	0,44	0,55	0,19	0,05
G.B.	0,51	0,45	0,15	0,09
J.B.	0,83	1,10	0,05	0,02
K.B.	0,92	0,63	0,36	0,04
B.J.	0,30	1,00	0,41	0,17
A.C.L.	0,73	0,75	0,56	0,67
K.K.	0,48	0,36	0,17	0,04
T.R.	0,60	0,79	0,10	0,06
E.G.	0,95	1,16	0,15	0,13
A.E.A.	1,04	1,23	0,86	0,14
A.H.	1,13	0,78	0,22	0,06
Mean	0,73	0,79	0,29	0,08
S.D.	0,26	0,28	0,22	0,05

Table 2. *The mean Gingival margin Plaque Index (GmPII) after polishing with a monofluorophosphate abrasive paste or stannous fluoride/stannous pyrophosphate dentifrice*

Test person	Toothpaste "C"	MFP abrasive paste
K.J.	25	54
Ø.B.	26	69
P.C.B.	20	55
E.G.	15	55
K.Q.	17	87
D.M.	6	51
H.P.E.	33	81
K.M.P.	24	89
Mean	21	68
S.D.	8.2	16

The results of the 24 hour plaque growth study in mentally subnormal persons are presented in Table 2. All subjects showed significantly lower GmPII values when toothpaste "C" was used, compared with the monofluorophosphate paste ($P < 0.001$).

The plaque present on teeth after use of stannous fluoride toothpaste "C" seemed to adsorb less strongly to the tooth surfaces and had a more granular appearance than ordinary plaque. This was obvious in all the experiments of the present studies.

The pilot study in mentally subnormal persons with poor oral hygiene and established periodontal disease showed no improvement in these condition when toothpaste "C" was applied in cap splints.

The water soluble content of tin in paste "C", measured as described, was determined to be 0.14 per cent whereas paste "A" only contained 0.03 per cent. The placebo paste contained less than 0.05 ppm tin.

DISCUSSION

Clinical trials on the plaque-removing or plaque-inhibiting effect of dentifrices are usually complicated by the influence of toothbrushing *per se*, a factor which shows great individual variations and which is inclined to mask possible differences between experimental toothpastes. The modification of the cap splints applicator of Strålfors (23) is thought to eliminate this problem (7). This was confirmed in the present experiment, as clear differences were observed between the chlorhexidine paste and the placebo.

The present study confirmed previous reports claiming that stannous fluoride is effective as a plaque inhibitor (8, 9, 13, 21, 22, 24), and showed furthermore that this property can be maintained in toothpastes. Since nine of the 12 dental hygienist students had participated in the clinical test using stannous fluoride mouthrinses (22), and the scoring of plaque was performed by the same examiner, it seems justified to compare the results of the two studies. The mean Pl. I. value when using toothpaste "C" was 0.29 while 0.2 per cent and 0.3 per cent aqueous stannous fluoride solutions gave 0.35 and 0.20 respectively.

The present plaque growth study showed that stannous fluoride containing tooth-

paste "C" applied directly on the teeth reduced the plaque growth for 24 hours. It thus seems likely that this paste applied by ordinary toothbrushing will exert plaque inhibiting action. Application of stannous fluoride toothpaste by cap splints in a group of patients with poor oral hygiene and established periodontal disease was insufficient to prevent plaque formation. Stannous fluoride can probably not replace chlorhexidine as plaque inhibitor in patients with poor oral hygiene, but may help to maintain a low plaque level in patients of average or good oral hygiene.

The results of the present investigation support the assumption that the stannous ion is essential in the plaque inhibition exerted by stannous fluoride. The recent experiments of Skjörland and co-workers (21) and Olsson & Glantz (18) also support this concept.

The finding that the content of water-soluble tin in the effective stannous fluoride containing dentifrice was approximately five times higher than in the non effective also provides indirect evidence in this respect. A reservation should be made, however, because the total concentration of water-soluble tin, rather than the concentration of stannous ions, was measured by the atomic absorption technique.

There are clear indications of parallel mechanisms in the plaque inhibition of chlorhexidine and stannous fluoride. Both are strong cations and both are retained in the oral cavity for many hours after application (1, 2, 19). However, the clinical effect of chlorhexidine is strongly reduced at about pH 3, indicating that carboxyl groups are essential binding sites (1, 7). Aqueous solutions of stannous fluoride and toothpaste containing this agent exhibited plaque inhibition and retention of tin at pH levels where the clinical effect of chlorhexidine would presumable be reduced. It seems possible that more acidic groups, e.g. phosphate- or sulphate groups may be important in the binding of the stannous ions in plaque and on the oral mucosa.

It has been suggested recently that the cell wall component lipoteichoic acid (LTA) may be the "glue" which binds the first bacterial colonizers to the tooth surface through its influence of the surface potential of the bacterial cells (3, 16, 20). The stannous ion will obviously interact strongly with this polyphosphate and change the surface potential of the bacteria. It may be speculated that this is one aspect of the plaque inhibition of the stannous fluoride preparations. Binding of tin to acidic groups on the pellicle surface may be another.

Significant caries reduction has been demonstrated in numerous clinical trials with stannous fluoride containing dentifrices. The mechanism of this caries inhibition is not fully understood (10). The results of the present study indicate that the plaque-inhibiting effect of stannous fluoride/stannous pyrophosphate may be a part of this mechanism.

REFERENCES

1. Bonesvoll, P. Retention of chlorhexidine in the human oral cavity. A thesis, University of Oslo, 1977
2. Bonesvoll, P. & Rölla, G. Retention of Sn after mouth rinses. Caries Res. 1978, 12, 112
3. Ciardi, J.E., Rölla, G., Bowen, W.H. & Reilly, J.A. Adsorption of Streptococcus mutans lipoteichoic acid to hydroxyapatite. Scand. J. Dent. Res. 1977, 85, 387–391
4. Clark, J.W., Jurand, J.G. & Miller, C.D. Effectiveness of conventionally practiced oral hygiene in the prevention of dental-deposit-mediated disease. In: Surface chemistry and dental integuments. Ed. by A. Lasslo & R.P. Quintana. Charles C. Thomas Publisher. Springfield-Illinois USA 1973, pp. 193–275
5. Fanning, E. A., Gotjamanors, T. Vowles, N.J. The use of fluoride dentifrices in the control of dental caries: Methodology and results of a clinical trial. Aust. Dent. J. 1968, 13, 201–206
6. Gjermo, P. & Rölla, G. Plaque inhibition by antibacterial dentifrices. Scand. J. Dent. Res. 1970, 78, 464–470

7. Gjermo, P., Bonesvoll, P., Heljord, L.G. & Rölla, G. Influence of variation of pH of chlorhexidine mouth rinses on oral retention and plaque-inhibiting effect. Caries Res. 1974, 18, 1–9
8. Glantz, P.O. On wettability and adhesiveness. A study of enamel, dentine, some restorative dental materials, and dental plaque. A thesis. Odontol. Revy, 1969, 20, suppl. 17
9. Gross, A. & Tinanoff, N. Effect of SnF_2 mouthrinse on initial bacterial colonization of tooth enamel. J. Dent. Res. 1977, 56, 1179–1183
10. Grön, P. Chemistry of topical fluorides. Caries Res, 1977, 11, 172–191
11. Harrap, G.J. Assessment of the effect of dentifrices on the growth of dental plaque. J. Clin. Periodontol. 1974, 1, 166–174
12. Hefferen, J.J., Zimmerman, M. & Koehler, H.M. Reactions of stannous fluoride with some inorganic compounds. J. Dent. Res. 1966, 45, 1395–1402
13. König, K.G. Dental caries and plaque accumulation in rats treated with stannous fluoride and penicillin. Helv. Odontol. Acta 1959, 3, 39–44
14. Lilienthal, B. Inhibition of acid formation from carbohydrates by stannous fluoride and stannous chlorofluoride. Aust. Dent. J. 1956, 1, 165–173
15. Löe, H. The gingival index, the plaque index and the retention index systems. J. Periodontol. 1967, 38, 610–616
16. Melvær, K.L., Helgeland, K. & Rölla, G. A charged component in purified polysacchride preparations from Streptococcus mutans and Streptococcus sanguis. Arch. Oral Biol. 1974, 195, 589–595
17. Naylor, M.N. & Emsli, R.D. Clinical testing of stannous fluoride and sodium monofluorophosphate dentifrices in London school children. Br. Dent. J. 1967, 123, 17–25
18. Olsson, J. & Glantz, P.O. Effect of pH and counter ions on the zeta-potential of oral streptococci. Arch. Oral Biol. 1977, 22, 461–466
19. Rölla, G. & Melsen, B. On the mechanism of the plaque inhibition by chlorhexidine. J. Dent. Res. 1975. Special number B 54, B 57 – B 62.
20. Rölla, G. Inhibition of adsorption – general considerations. In: Proceedings "Microbial aspects of dental caries" Microbiol. Abstr. Ed. by H.M. Stiles, W.J. Loesche & T.C. O'Brien, Special Suppl. 1976, 1, 309–324
21. Skjörland, K., Gjermo, P. & Rölla, G. Effect of some polyvalent cations on plaque formation in vivo. Scand. J. Dent. Res. 1978, 86, 103–107
22. Svatun, B., Gjermo, P., Eriksen, H.M. & Rölla, G. A comparison of the plaque-inhibiting effect of stannous fluoride and chlorhexidine. Acta Odontol. Scand. 1977, 35, 247–250
23. Strålfors, A. Disinfection of dental plaques in man. In. Caries Symp. Zürich. Ed. by H.R. Mühlemann & K.G. König. Hans Huber, Berne & Stuttgart, 1961, 154–161
24. Tinanoff, N., Brady, J.M. & Gross, A. The effect of NaF and SnF_2 mouthrinses on bacterial colonization of tooth enamel: TEM and SEM studies. Caries Res. 1976, 10, 415–426