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Current status of SnF_2 as an antiplaque agent

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Although it is evident that fluorides are effective in reducing dental caries, the manner in which these compounds accomplish this is still not fully understood. The concept that fluoride decreases the solubility of enamel through the formation of fluorapatite, thus protecting against bacterial acid production, has long been accepted. What defies explanation is how such small amounts of fluorapatite formed by the enamel-fluoride interaction can account for the relatively large degree of caries reduction which occurs from either topical or systemic fluorides.

The apparent paradox has spurred investigations into possible antimicrobial mechanisms which could explain how fluoride reduces caries. The purpose of this review is to describe the findings concerning the plaque-altering properties of fluoride, and specifically stannous fluoride, which have recently been noted to have important antiplaque properties.

The effect of sodium fluoride on bacterial metabolism has been known for some time and is relatively well understood. Inhibition of acid production by salivary and plaque bacteria *in vitro* has been demonstrated with less than 1 ppm F^-.[1,2] Furthermore, plaque collected from subjects living in fluoridated areas has shown smaller increases in acid production with sucrose than has plaque from subjects living in nonfluoridated areas.[3] These findings may be explained by the observation that fluoride alters the bacterial enzyme, enolase, which is essential for the degradation of simple sugars to lactic acid and is also essential for the transport of sugars across the bacterial cell membrane.[4] The inactivation of enolase is the result of fluoride binding with the magnesium component of this enzyme.[5] Fluoride ions acting in this manner could reduce bacterial-acid production and might account for some of the caries inhibition noted for this agent.

While inhibition by fluoride of acid production is not controversial, there is less clear evidence concerning the ability of sodium fluoride to reduce the quantity of plaque. Decreases in the amount of plaque polysaccharide have been reported *in vitro* with 10 and 70 ppm F^- as NaF,[6,7] yet *in vivo* studies showing the effect of fluoride on the quantity of plaque have provided only modest results. Plaque collected from subjects living in optimally fluoridated or highly fluoridated areas has been found to contain slightly less extracellular polysaccharide or slightly less visual plaque, respectively, compared to plaques collected from areas deficient in fluoride.[8,9] Birkland[10] has shown also that a weekly rinse of 0.2% NaF (1000 ppm F^-) produced a small but significant reduction in plaque dry weight. However, intensive fluoride therapy, *i.e.*, frequent applications of concentrated solutions of NaF, has provided better results. Loesche *et al.*,[11,12] besides demonstrating lower plaque and gingivitis scores in subjects frequently applying 1.23% acidulated phosphate fluoride topically, showed also that the number of *Streptococcus mutans* relative to *Streptococcus sanguis* in plaque was also lowered.

The earliest reference to the effect of SnF_2 on oral flora was that reported by Lilienthal in 1956.[13] He found that 0.01% SnF_2 (25 ppm F^-) inhibited acid formation by saliva and salivary sediments *in vitro*. Dramatic plaque-reducing properties of stannous fluoride were later observed in 1959 when König noted plaque inhibition in rats when 0.1% SnF_2 (250 ppm F^-) was applied once a day for 35 days to rat molars.[14] SnF_2 was again noted in 1976 to reduce the number of bacteria adherent to enamel *in vivo* as observed by electron microscopy. Enamel cylinders embedded in a maxillary Hawley appliance were worn by one subject for 2 or 7 days while performing various mouthrinse regimens. Since stannous fluoride reduced bacterial colonization on enamel but sodium fluoride did not, the antiplaque effect found in this limited study was believed not due solely to the fluoride ion.[15] Subsequently, rats inoculated with *Actinomyces viscosus* and *S. mutans* were reported to have a 71% reduction in plaque when treated with SnF_2.[16]

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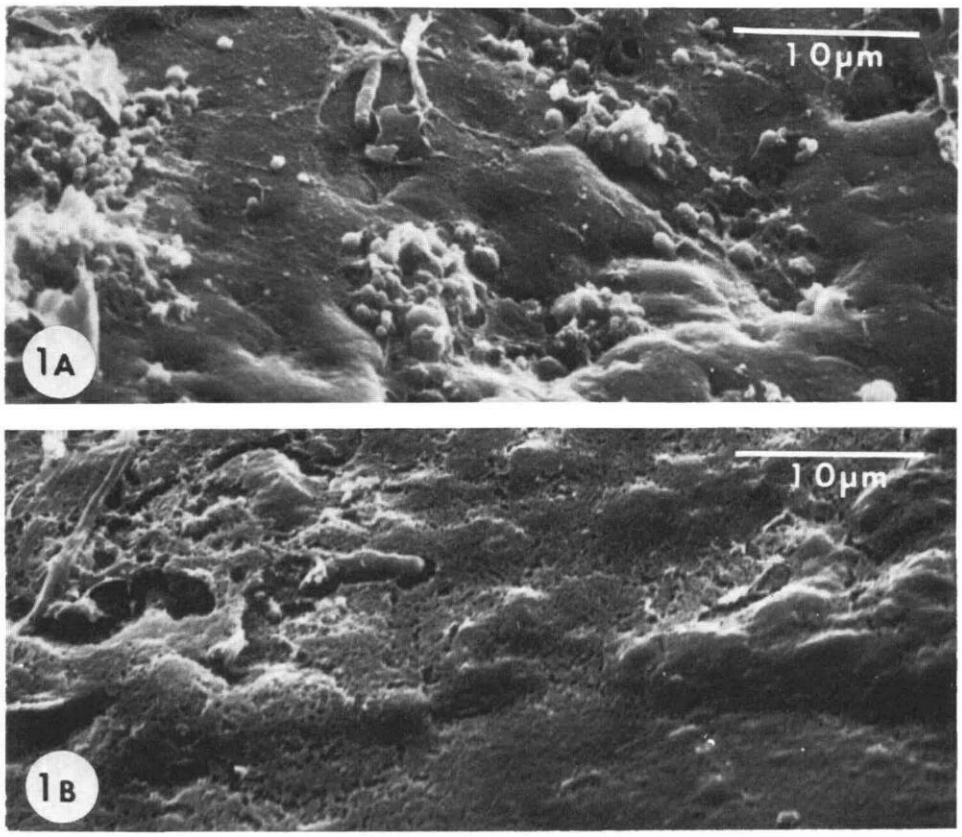

Fig. 1. Scanning electron micrographs from surface enamel placed in a Hawley appliance and worn in one subject's mouth for 2 days. Amorphous pellicle as well as reduced deposits of bacteria are present when SnF_2 (100 ppm F^-) is used as a mouthrinse once a day (*A*). When SnF_2 is used twice a day, pellicle covers the enamel, but no bacteria are apparent.

Recent studies have established definitely that SnF_2 affects the oral flora in man. Subjects using SnF_2 mouthrinse have demonstrated a reduction of bacterial acid production in salivary samples[17] and in intact dental plaque.[18] SnF_2 at high concentrations (1250 ppm F^-) used daily as a mouthrinse was also found to decrease by 99% the number of bacteria per milliliter of saliva while NaF at the same concentration had little influence on salivary bacteria.[19] Other studies have revealed a 74 to 99% reduction in the number of microorganisms in dental plaque from subjects using relatively dilute SnF_2 mouthrinse twice daily.[20, 21]

The ability of SnF_2 to reduce plaque formation has been impressively demonstrated in several clinical trials. One single application of 8% SnF_2 was found to reduce plaque weight and visual plaque scores on 27 children.[22] Another clinical study has found that toothpastes which contain SnF_2 have antiplaque properties.[23] In an experimental series in which 12 subjects used 0.2 or 0.3% SnF_2 mouthrinse twice daily for 4 days, plaque inhibition by SnF_2 was comparable to that by chlorhexidine. In a second experiment in the same report, five students who discontinued oral hygiene for 3 weeks rinsed with sucrose for 1 week to augment plaque formation and then rinsed with SnF_2 for 2 weeks. The mean Plaque Index score was a low 0.24 for this group after the third week.[24] Another clinical trial on 27 subjects who used 0.1% SnF_2 or a placebo mouthrinse twice a day for 5 days has shown significant reductions in visual plaque score, plaque wet weight, number of bacteria per milligram of plaque, and total number of bacteria collected from six representative teeth. In this study, the total number of bacteria was considered to be the best index for plaque reduction, and SnF_2 mouthrinses reduced plaque by 50% using this criterion.[25] Subsequent studies using the same experimental design and the same plaque indices, however, have found that 0.1% SnF_2 was not nearly as effective as 0.2% chlorhexidine when these agents were compared in a twice-daily mouthrinse regimen.[26]

The mechanisms responsible for alteration of plaque formation by SnF_2 are, as yet, not well understood. Some information on the way SnF_2 reduces plaque has been derived from observations by electron microscopy of the enamel cylinders worn *in vivo* during mouthrinse procedures. When SnF_2 was used as a mouthrinse once daily for 2 days, the number of bacteria on the enamel appeared greatly reduced; when SnF_2 was used twice daily, the bacterial colonization was essentially eliminated (Fig. 1). Rinsing for 7 days with SnF_2 produced a thick amorphous pellicle on the enamel with the bacteria generally appearing as a nonaggregated layer on the enamel (Fig. 2). Based on

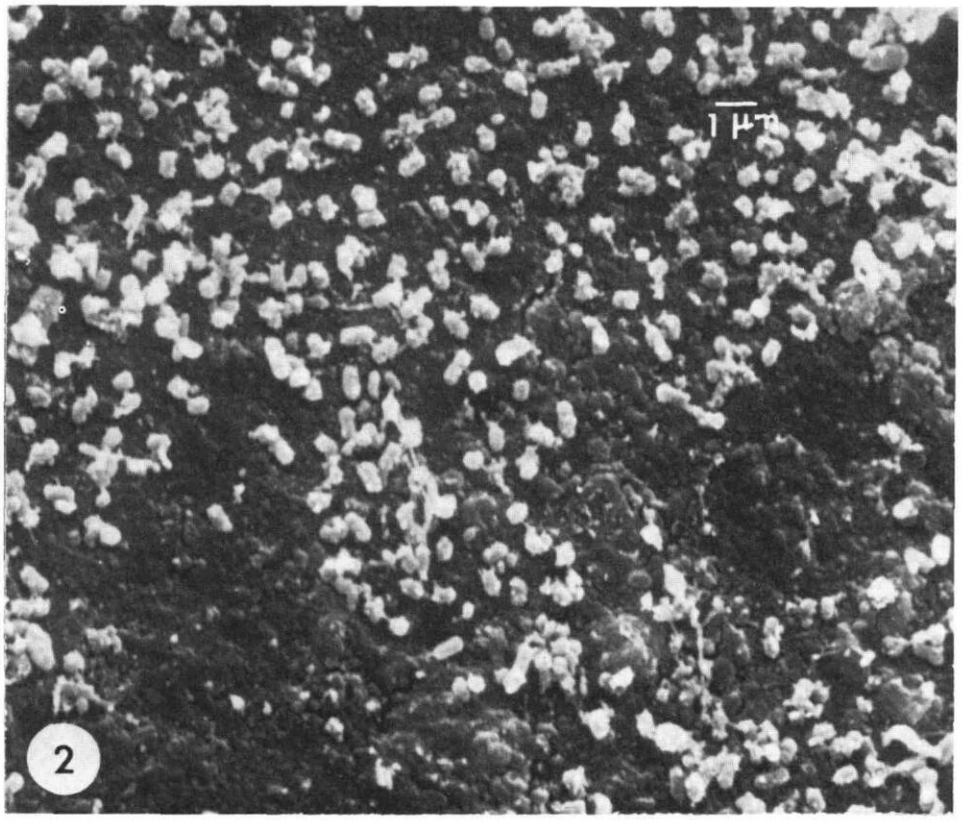

Fig. 2. Scanning electron micrograph of enamel worn in the mouth for 7 days using SnF_2 mouthrinse twice a day. Only a monolayer of nonaggregated coccal bacteria is evident.

these observations by electron microscopy, it has been postulated that the variation in colonization noted with SnF_2 may be due in part to altered adhesion of bacteria to enamel or altered cohesion of bacteria.[15]

Some authors have suggested that the tin component of SnF_2 may be responsible for the antiplaque properties. The stannous ion conceivably could compete with calcium for acidic groups on bacterial surfaces or acidic groups on teeth and thus inhibit plaque formation.[24, 27] There is some evidence also that a cell wall component in Gram-positive bacteria, lipoteichoic acid, may be the "glue" which binds bacteria to tooth surfaces,[28, 29] and divalent cations (*i.e.*, Sn^{+2}) possibly may interact with this highly negatively charged polymer thereby changing the surface potential of bacteria.[23, 30] Demonstration of the divalent cation effect was noted in a clinical study in which mouthrinses comprised of either aluminum, zinc, and magnesium or stannous salts reduced plaque formation.[31] However, divalent cations cannot explain entirely the substantial antiplaque properties of SnF_2. Stannous chloride mouthrinse equimolar to SnF_2 was noted to have some effect on plaque in the *in vivo* plaque model system previously mentioned, but the reduction in plaque was not as dramatic as that found with SnF_2.[15] Other studies have observed also that $SnCl_2$ is not as effective as SnF_2 in reducing the amount of plaque which adheres to enamel *in vivo*[31] or *in vitro*,[32] or in inhibiting pH changes in dental plaque.[33] One hypothesis mentioned for the decreased effectiveness of $SnCl_2$ is that it rapidly hydrolyses in water.[33] It is possible also that since fluoride is known to become bound to plaque bacteria[34] as well as to enamel,[35] the fluoride ions in SnF_2 may enhance the retention of tin in plaque and thereby make this agent more effective as an antiplaque agent.

The possibility that SnF_2 may depress selectively specific organisms responsible for caries formation has been examined also in reports by Keene *et al.*[36, 37] Interproximal tooth sites in humans were tested for presence or absence of *S. mutans* after 4 days of twice-daily flossing in conjunction with topical application of 10% SnF_2 (24,000 ppm F^-) or saline. It was noted that there was a significantly greater change of positive *S. mutans* sites to negative *S. mutans* sites in the SnF_2-treated group.[36] The results reported, however, may not represent truly a selective action against *S. mutans* but, rather, a generalized plaque depression since other studies have not shown any change in the ratios of organisms due to SnF_2.[20, 21]

To date, the studies that have examined the plaque-inhibitory effect of SnF_2 have been too short in duration to observe changes in gingival health in humans,[25, 38] and a question still remains as to the

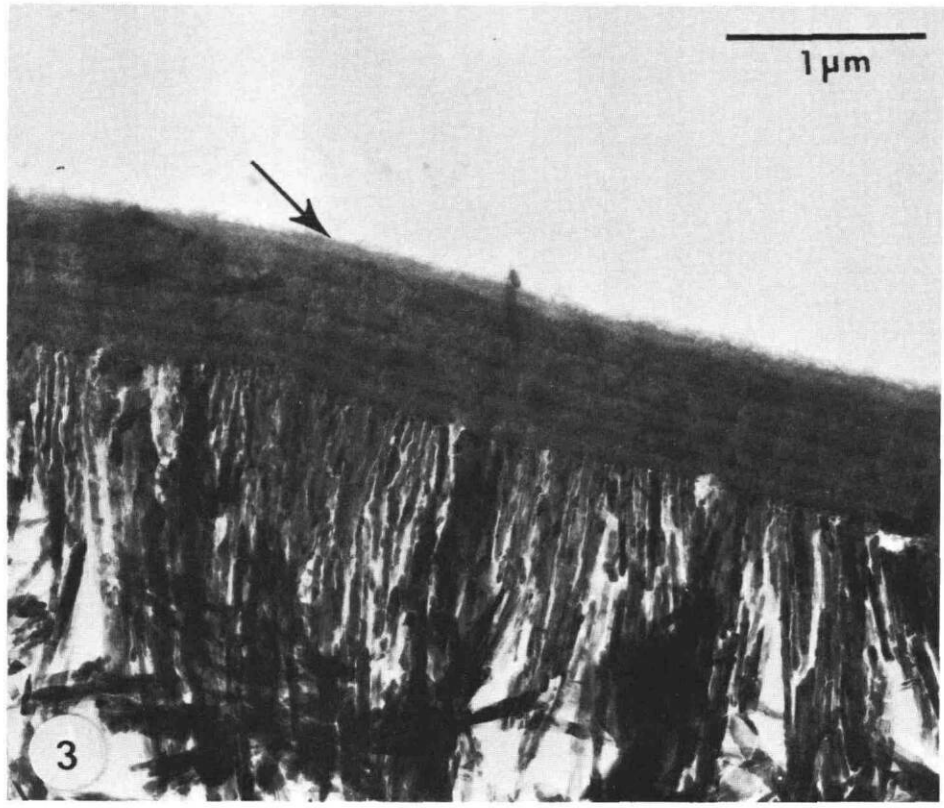

Fig. 3. Transmission electron micrograph of enamel worn in the mouth for 7 days with SnF_2 mouthrinsing twice a day. A thick, laminated deposit (pellicle) is found on the enamel surface (*arrow*).

effect of topical SnF_2 on gingivitis. Two studies in dogs have shown reductions in gingival inflammation with intermittent SnF_2 rinses.[39, 40] Furthermore, SnF_2 has been reported to be the most effective fluoride agent against some known periodontopathic microorganisms.[41] Clinical trials on human populations utilizing the experimental gingivitis models need to be conducted. If such trials demonstrate that SnF_2 reduces gingivitis, then further studies should be undertaken to examine long-term effects of SnF_2 on the development of periodontal disease. Long-term studies need to be performed also to observe changes in the oral flora and any possible side effects caused by the drug. The use of disclosing dyes to visualize plaque area, however, does not appear appropriate in studies with SnF_2 since nonbacterial deposits (Fig. 3) accumulate readily when teeth are exposed to SnF_2, and the deposits may look similar to plaque.[15, 42]

Based on its demonstrated plaque inhibition, SnF_2 may be useful for suppression of plaque following periodontal surgery. The advantages of maintaining oral surgical sites plaque-free have been documented,[43, 44] and the ability of one antiplaque agent (chlorhexidine) to improve periodontal surgical results has been well established.[43, 45] Comprehensive clinical trials are needed to document the clinical impression that SnF_2 rinses improve healing following periodontal surgery.

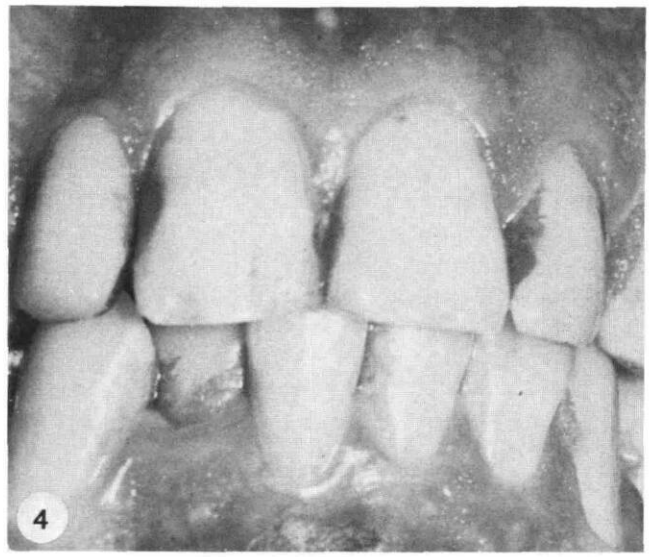

Fig. 4. Subject who rinsed twice a day for 6 months with SnF_2 (100 ppm F^-). Note stain on proximal, cervical tooth surfaces and around anterior restorations.

Since clinical usage of SnF_2 preceded the strict drug guidelines now in effect in the United States, this agent has not gone through rigorous trials to establish safety. However, the only reported side effect in its many years of use is staining of teeth (Fig. 4). This

stain, however, is said to be less tenacious than that attributed to chlorhexidine, and in most cases, it is easily removed by a professional prophylaxis.[24] There is some objectionable taste associated with SnF_2; yet, when flavored commercial products are diluted to mouthrinse concentrations, the astringent metallic taste is minimal. Also important to remember is that SnF_2 has poor stability as an aqueous solution, and therefore, it should be used soon after it is mixed with water. Commercial products most often have a glycerine base, and consequently, they have an indefinite shelf life before they are diluted with water.

It is well established that SnF_2, as well as other fluoride agents, is effective in caries prevention. The development of a mouthrinse capable of reducing plaque formation, while at the same time increasing the resistance of teeth to demineralization, may constitute an important advance in prevention of both caries and periodontal disease.

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