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REDUCTION IN DENTAL CARIES INCIDENCE
THROUGH TOPICAL STANNOUS
FLUORIDE

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1. INTRODUCTION.

Dental caries has been and is still the most common dental disease to plague mankind. It can be considered as old as mankind itself. It existed as early as the pre-historic times, though the incidence and prevalence may be minimal. It affects people of all races and of all ages.

What is dental caries? The Federation Dentaire Internationale defined dental caries as a localized, pathologic process of external origin, involving softening of the hard tooth structure and progressing to cavitation.

Dental caries results from three groups of factors, all of which must interact in order for the disease to develop and progress. First, the oral cavity must harbour certain types of caries-producing micro-organisms. Second, the diet must contain carbohydrate which act as substrate for the bacteria to act upon and ferment to form acids which dissolves the inorganic structure of the tooth. And third, the tooth must be susceptible to the action of acids.

Dental caries can therefore be prevented or controlled by removing any of these factors which are responsible for its formation - that is, by reducing the bacterial
flora of the oral cavity, by eliminating the carbohydrate-substrate and by reducing enamel solubility to acids.

Dental caries is a multi-factorial disease. Because of its complex nature, it is unlikely that any one approach will completely solve the problem of its prevention and control. Efforts should therefore be directed to reducing the effects of all factors to a minimum.

Several caries-control techniques have been suggested in the past. However, only the use of fluorides as anti-cariogenic agents has been thoroughly and extensively evaluated. As a consequence of the positive results derived from these studies, the use of fluorides in preventive dentistry gained wide recognition and acceptance.

The purpose of this paper is to review the literature on the role of fluorides, specifically stannous fluoride, as caries-preventive agents.
11. BRIEF DISCUSSION OF DENTAL CARIES.

A. Theories of Etiology of Caries.

Dental caries is one of the major problems in dentistry, on account of both the wide prevalence of the disease and the important influences it has on the aesthetic values of the face, and on the efficiency of mastication and digestion.

It is generally agreed that the etiology of dental caries is a complex problem and that many factors are concerned in the initiation of the carious process. Many investigations have been carried on the cause or causes of caries. Although no single theory had yet been put forward which will explain completely all aspects of the epidemiology, histopathology, and chemistry of dental caries, there have evolved from the various investigations two chief theories. These are the acidogenic theory and the proteolytic theory. A third theory is the proteolytic chelation theory which is a modification of the proteolytic theory.

The acidogenic theory postulates that the initiation and progression of the carious lesion is brought about primarily by the destruction of the tooth substance at
the site of the lesion by acids produced by microorganisms in the plaque. Two definite processes are involved. The primary action is the demineralization of the tooth substance by acids, and the organic residue being subsequently liquefied by the enzymes of the proteolytic bacteria. Miller showed in a series of studies that some oral bacteria were capable of producing acids from certain foods and that the acids formed could decalcify sound tooth structure. He also observed that some other groups of oral bacteria were capable of liquefying demineralized dentine. According to his acidogenic theory, dental caries is characterized by a decalcification of the inorganic portion first and is then followed by a disintegration of the organic substance of the tooth.

The proteolytic theory, on the other hand, postulates that the initial attack consists of a progressive alteration of the organic matrix of the enamel and a projection of the microorganisms into the tooth substance, and that the subsequent loss of the inorganic portion of the tooth is accounted for by the effect of acids resulting from the protein breakdown and the mechanical disintegration following the loss of organic matrix.
It is generally accepted that both decalcification and proteolysis are concerned in the carious process. Both of the above mentioned theories accept this. Their main difference lies in the concept as to which process is the initiating mechanism. The acidogenic theory supports that the decalcification precedes proteolysis while the proteolysis theory holds that proteolysis of the organic matrix precedes the decalcification of the inorganic substance.

Martin and his associates\textsuperscript{2} have put forward the theory that enamel should not be considered as consisting of two separate independent systems, one inorganic and the other organic, but as a unified structure consisting of a chelate complex with coordinate covalent bonds linking the organic and inorganic components and that the carious process is brought about by proteolysis and chelation occurring simultaneously. This is the concept advocated by Martin and his associates\textsuperscript{2} in the proteolytic chelation theory.

B. Factors Which Cause or Influence Caries Formation

- Local Systemic Factors.

A discussion of prevention of dental caries necess-
icates a brief knowledge about the production or formation of dental caries and the several factors which influence it. Therefore, the following section is a short discussion on caries formation.

Microorganisms undoubtedly are the primary cause of dental caries. The maintenance of caries susceptible rats on a caries-producing diet under germ-free conditions resulted in a complete absence of caries. In order for the caries-producing micro-organisms to metabolize in such a way that caries lesions are produced, they must have suitable substrates. The primary substrates needed are carbohydrates that are readily retained in the restricted areas of the tooth surfaces where tooth decay can easily occur. These micro-organisms and the substrates upon which they are maintained together form the major part of the oral environmental milieu around the external surfaces of the tooth. Saliva is another important component of the oral environment. Invariable, when there is a diminished salivary flow large increases in caries activity are observed. However, there is little knowledge on how saliva exactly exerts its influence.

The factors mentioned above are local factors. In
addition to these, there are also systemic factors. Their major role occurs during the development of the tooth. These influences may be such as to confer a high caries-susceptibility upon the tooth which permits the tooth to succumb readily to the caries-producing forces of the oral environment. On the other hand, a high caries-resistance may be conferred upon the tooth to enable it to withstand much more severe post-developmental oral environmental influences. Some of these influences may operate through nutritional pathways. Others may be genetic in origin.

Most caries-preventing procedures will fall into two general categories, depending upon their time and mode of action. The first category includes those that operate during the development of the tooth through the maintenance of metabolic circumstances which permit the formation of the tooth of increased caries resistance. The second category includes those that act upon one or more of the components of the oral environment to reduce its caries producing potentials. Therefore, the former exerts a systemic action while the latter category is local in nature. Fluorides can fall into any of the categories depending upon the time which they were used.
III. HISTORICAL BACKGROUND OF FLUORINE.

The first important mention of the brown stain now known as dental fluorosis occurred in 1902 in El Paso County, Colorado, although in 1888 a family emigrating from Mexico to Germany had been recognized as having the same condition. In Colorado, Frederic S. McKay gave systematic attention to the mottling and brown staining he found on the tooth of many of his patients, and even hypothesized that the defect was due to the water supply. By 1908 he had studied enough cases and interested enough of his colleagues in the problem to invite Dr. G. V. Black to join him in a local study. Black's visit to Colorado gained national attention for the brown staining of enamel, and cases were reported soon thereafter from many parts of the country. The name "Colorado brown stain" gave way to that of "mottled enamel" as it is now known. The process became associated with communal water supplies, usually from deep wells, but at that time analysis of water supplies, usually from deep wells, but at that time analysis of water supplies for small quantities of fluoride had not been perfected and the etiologic agent was not identified till more than a decade later. Various degrees of mottling were identified, from the mild which involves only a few chalky white spots on the surface of the
the enamel, to moderate mottling where large areas of white are mixed with brown, and finally to the severe mottling where brown predominates and hypoplasia of the tooth becomes evident.\textsuperscript{6}

Confirmation of the Deep-well hypothesis was found in several localities. In Britton, South Dakota, in 1916 a study revealed uniform mottling of enamel among the children brought up in the town since a new deep well had been added to the communal water supply in 1898.\textsuperscript{6} In 1925, residents of Oakley, Idaho, where mottling was prevalent, undertook to test the deep-well hypothesis by changing from a warm spring-water supply to another shallower water supply. The children developed no mottling but the children brought up on the old supply were not cured.\textsuperscript{6} Also in 1925, McCollum, Bunting and others\textsuperscript{6} fed to rats an excess of the element known to occur in tooth and developed staining of the incisors after ingestion of large amounts of fluoride. Studies in Bauxite, Arkansas in 1928 led to the final discovery that mottled enamel was associated with fluoride in water.\textsuperscript{6} Churchill examined samples of Bauxite water and found that it contained 13.7 parts per million of fluoride. They translated it to McKay who arranged for reanalysis of the water supplies in the several places
mentioned above and discovered that the fluoride content of the water supply ranged from 2 to 13 parts per million. The association of fluoride with mottled enamel was therefore confirmed. Another series of studies were carried in areas where fluoride level in water was low enough not to cause mottling and where there is no appreciable fluoride. These studies showed regular decrease in caries as fluoride concentration increased from 0 up to 2 parts per million. Also other studies revealed a coexistence of low caries and mottled enamel and that the relationship between caries rate and fluoride level was in inverse one. The discovery of this relationship led to several studies which aimed towards using fluorides effectively an anticariogenic agent.
IV. SYSTEMIC INGESTION OF FLUORINE.

A. Physiology

It is necessary at this point to discuss some of the physiology and then the toxicology of fluorine if it is to be used as a preventive agent.

Fluorides in solution or in rapidly soluble salts are absorbed almost completely from the gastro-intestinal tract. The presence of calcium compounds such as those in milk may restrict the absorption of large amounts of ingested fluorides but under usual conditions these agents have little effect upon the absorption of low levels of fluoride in drinking water.

Fluoride is partly excreted by the kidneys and partly stored in bone or teeth. As intake increases, absorption also increases but rate of bone absorption increases only slightly due to a higher rate of excretion, likewise, as intake decreases both absorption and excretion also decreases. As fluoride level of blood decreases, there may be a partial reabsorption of the fluoride stores in bone, thereby maintaining the blood level.
Skeletal tissue has a high capacity for the storage of fluoride ion which has the ability to replace and substitute hydroxyl ions on the surface of apatite crystals in bone.\textsuperscript{8}

Because of their relatively small mass the teeth serve as a storage site for only a small fraction of retained fluoride. It appears also that fluoride in teeth is not subject to appreciable reabsorption. As highest concentration of fluoride is found in the outer surface of the enamel, it was suggested that fluoride deposition continues in the external enamel surface during the pre-eruptive period after calcification is completed and also after eruption to a lesser extent.\textsuperscript{8}

Brudevold and his co-workers\textsuperscript{9} studied the distribution of fluoride in successive layers from the surface inward in the enamel of deciduous teeth, unerupted and erupted permanent teeth of different ages and of teeth with mottled enamel. They showed that the outermost enamel layer had the highest concentration of fluoride in all of these teeth. Their findings suggested that enamel takes up fluoride during formation, pre-eruptedly after calcification and post-eruptedly.
Dental fluorosis, which has been called mottled enamel, is the most sensitive index of increased fluoride uptake.

There is little if any accumulation of fluoride in non-calcified tissue. Some fluoride is excreted in sweat and low concentration of unknown significance may appear in saliva and milk. Fluoride has been demonstrated to cross the placental barrier of animals and of humans.  

B. Toxicology.

Any plan for topical fluoride therapy of teeth, or for alteration of fluoride content of a communal water supply, requires a thorough understanding of any possible harmful effects upon human beings of doses likely to be used, or of the accidental overdoses which are possible. The importance of the matter lies in the fact that concentrated sodium fluoride powder is known as a rat poison. Fluoride produces a wide spectrum of activity in the human. It can be a nutrient, drug or a poison depending on the dosage used.

Fluoride is present in small quantities in almost all common foods. Aside from drinking water, the average
diet in the United States has been established to provide 0.2 to 0.3 milligrams of fluoride daily.\textsuperscript{6}

Acute toxicity in man probably begins about the level of 250 milligrams of sodium fluoride in one retained dose.\textsuperscript{6} Nausea and vomiting are among the first signs of acute morbidity to be expected.\textsuperscript{6} A lethal dose would probably represent from 3 to 10 grams (3,000 to 10,000 milligrams).\textsuperscript{6} With such concentration, acute gastro-intestinal irritation would develop. Nausea, vomiting, diarrhea and state of shock would follow before death.\textsuperscript{6} Table 1 gives a broad picture of the physiological effects of fluoride at a wide variety of doses, both chronic and acute.\textsuperscript{6}

Table 1. effects of extradietary\textsuperscript{a} fluoride intake in human

<table>
<thead>
<tr>
<th>Dose (mg)</th>
<th>Frequency</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Chronic effects</strong></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>daily for years</td>
<td>Increase susceptibility to Dental caries</td>
</tr>
<tr>
<td>1–2 (1 ppm in water)</td>
<td>daily for years</td>
<td>Reduced dental caries (greatest effect from pre-eruptive dosage)</td>
</tr>
<tr>
<td>3–15 (2–10 ppm daily for years in water)</td>
<td></td>
<td>Dental fluorosis of varying frequency and severity (pre-eruptive dosage only) Reduced caries</td>
</tr>
<tr>
<td>20–80</td>
<td>daily for 8 or more years</td>
<td>Crippling skeletal fluorosis, gastric disturbances. Dental fluorosis (pre-eruptive dosage only) Reduced Caries</td>
</tr>
<tr>
<td>Dose (mg)</td>
<td>Frequency</td>
<td>Effect</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>250-1000</td>
<td>One retained dose</td>
<td>Nausea, vomiting</td>
</tr>
<tr>
<td>3000 - 10000</td>
<td>One retained dose</td>
<td>Probable death</td>
</tr>
</tbody>
</table>

a = Intake above the 0.2 - 0.3 mg. usually found in normal daily diet.
V. MODE OF ACTION OF FLUORIDES.

A. Theories on Mechanism of Action of Fluoride.

The manner in which fluoride suppressed dental caries has not been fully understood. It is thought that it probably can exert its effect in one or more ways,\textsuperscript{10} namely: (1) by a direct anti-bacterial action; (2) by inhibiting the bacterial enzymes systems which convert sugars into acids in the bacterial plaque (Enzyme-Inhibitor Theory); (3) by making the enamel more resistant to acid demineralization Solubility Theory.

1. Anti-bacterial Action.

Bibby and Van Kesteren carried out "in vivo" experiments on the effect of fluorine on oral bacteria in terms of acid production and bacterial growth. They showed that fluorine concentration of less than 1 part per million can limit acid production by bacteria but concentrations in excess of 250 parts per million are needed to effect bacteria growth. Briner and Francis\textsuperscript{12} showed this too in their later study with Lactobacillus Casei.

2. Enzyme-Inhibitor Theory.
This theory had been neglected largely because the solubility theory seemed more probable since concentrations of fluoride reported in saliva seemed inadequate to exert inhibition.

Fluoride has been found in the bacterial plaque.\textsuperscript{13} However, the source is uncertain. It could probably be derived from increased uptake directly from drinking water or from transient increases in salivary fluoride concentration following the systemic ingestion of fluoride. It has been suggested that high concentration of fluoride on the enamel surface might release sufficient fluoride into the plaque to inhibit bacterial acid production. However, the fluoride acquired by enamel from topical treatments is very tightly bound to the crystal and is unlikely to diffuse into plaque but might be released along with other ions in the enamel dissolves during a carious attack. It may recombine with enamel as the plaque pH rises, thus preventing a steady fall in the enamel fluoride.

Mellberg and his co-workers\textsuperscript{14} showed in an "in-vivo" study that fluoride acquired from topical treatment of sodium fluoride appeared to be permanently bound to the enamel crystals. It is unlikely that sufficient fluoride
could enter the plaque to influence its whole thickness but a small scale release into the inner surface of the plaque might have a highly localized inhibitory effect which could be of value in reducing dental caries.\textsuperscript{13}

Acid production by bacteria of saliva and plaque is partially inhibited in vitro by concentrations of about 10 parts per million but at pH values near 5.0, lower concentration (6 parts per million) may inhibit completely.\textsuperscript{15} Two experiments have shown that inhibition after topical application may occur. One of these was done by Zwemer \textsuperscript{16} and the other by Briner and Francis.\textsuperscript{12}

Although fluoride is present in plague in concentration which, if in an ionic form, would be expected to inhibit, no satisfactory evidence of inhibition has been obtained except within a day of topical application of fluoride.\textsuperscript{13}

3. **Solubility Theory.**

The solubility theory seems to be the most probable of all three theories. Many studies have been carried in this aspect. Healy and Ludwig,\textsuperscript{17} and his co-workers,\textsuperscript{18} Finn and De Marco\textsuperscript{19} studies the relationship between
enamel solubility and fluoride concentration of water supply. The studies were carried in high and low fluoride areas. They found lower enamel solubility in high fluoride areas than in low fluoride areas. Also Dowse and Jenkins\textsuperscript{20} found that the inorganic fractions in areas of white spot caries are less soluble than intact enamel presumably because of the former's higher fluoride concentration.

Fluoride could affect solubility in one or more of the following ways:\textsuperscript{13} (1) by increasing the proportion of fluor-apatite in enamel, (2) by favouring apatite formation rather than more soluble forms of calcium phosphate during recalcification in early caries, (3) by increasing the size of the apatite crystals and, (4) by replacing carbonate from enamel.

Young and Elliot\textsuperscript{21} showed that fluor-apatite is less soluble than hydroxy-apatite and as the former increased in the enamel under fluoride treatment, the solubility decreased. Gray and others\textsuperscript{22} stated that if the acid-solubilities of hydroxy - and fluor-apatite are compared for short periods of a few minutes, no difference can be found. Only after some time does the fluor-apatite show evidence of lower solubility rate. They explained this result as the gradual formation of calcium.
fluoride, from the ions released as the fluor-apatite dissolves, which deposits on the crystals which remain undissolved and prevent the diffusion of acid to, and of the dissolved ions from, the apatite.

The second way in which fluoride might lower enamel solubility is by favouring apatite formation rather than the more soluble forms of calcium phosphate during recalcification. It is known that in carious lesion, enamel minerals are alternately dissolved and reprecipitated. Fluoride not only favours reprecipitation of calcium phosphate but also favours its crystallization as apatite rather than the more soluble salts.\(^{13}\)

The third means by which fluoride reduced solubility is by increasing the size of the crystal. This is based on the fact that high fluoride intake influences the crystallinity of apatite which results in the formation of larger crystals.\(^{23}\) The principle behind this is that larger crystals would, by preventing smaller surface per unit volume, be expected to be less soluble.

The last method is that fluoride reduces the carbonate concentration in calcified tissues during development. This in turn may lower the solubility of the enamel, and therefore caries.\(^{13}\) However, results of experiments are contradictory and the role of carbonate
in human dental caries has not been quite established yet.

B. Reaction of Stannous Flouride with Enamel

1. Reaction between Fluoride and Enamel.

Both powdered enamel and dentine react with very dilute flouride solutions to yield flour-apatite, in which the flouride ion occupies the lattice position held by hydroxide ion in the hydroxyl-apatite. The hydroxyl-apatite is the principal component of the powdered enamel and dentine. This reaction is shown in the following chemical equation:

\[
\text{Ca}_5(\text{PO}_4)_3\text{OH} + F^- \rightarrow \text{Ca}_5(\text{PO}_4)_3\text{F} + \text{OH}^-
\]

(Hydroxylapatite)(Dilute)(Flour-apatite)

At higher concentrations of flouride, the main reaction is one of metathesis with calcium flouride as a product. The chemical reaction is as follows:

\[
\text{Ca}_5(\text{PO}_4)_3\text{OH} + 10\text{F}^- + 3\text{H}^+ \rightarrow 5\text{CaF}_2 + 3\text{HPO}_4^- + \text{OH}^-
\]

(More Concentrated)(Calcium Flouride)

On the basis of electron microscopy and diffraction techniques, Gerould concluded that calcium flouride is formed on the surface of enamel slabs when immersed
in concentrated solutions of sodium fluoride for one month. McCann and Bullock\textsuperscript{26} have also mentioned the possibility that fluor-apatite may be a minor product at high concentration levels and that fluoride could also react by direct adsorption. Since magnesium and carbonate are minor components of enamel, some fluoride could also react by exchange with carbonate or precipitate as magnesium fluoride.

Both the enamel and dentine consists of calcium phosphate crystals made of hydroxy-apatite which when exposed to strong fluoride solution will break down and be changed to calcium fluoride.\textsuperscript{24} The calcium fluoride will precipitate as a fine powder on the tooth surface. Other by-products formed may wash away together with part of the calcium fluoride. By means of a tracer study, Myers and his associates\textsuperscript{27} found that about 90\% of the fluoride deposited to the tooth during topical application of F\textsuperscript{18} is removed by rinsing. This portion comes from the intact surface of the enamel. The fluoride that is not removed by rinsing is concentrated in the enamel defects.

Vrbic and Brudevold\textsuperscript{28} suggested that several trace elements normally occurring in human enamel are fluoride
complexers and that formation of such complexes may be one of nature's ways of depositing fluoride in the teeth. Some of the fluoride complexers mentioned which could be incorporated in prophylaxis pastes are aluminum, titanium, zirconium and stannic tin.\(^{28}\)

2. Reaction Between Tin and Enamel.

In an experiment carried out by Brudevold and his associates,\(^ {29}\) it was found that both tin and fluoride were taken up by enamel from solutions of stannous fluoride. It was shown that more fluoride was taken up from a sodium fluoride solution than from a stannous fluoride. If the fluoride in these compounds were the only active agents, then sodium fluoride should be more effective than stannous fluoride. But the reverse is true. Therefore, it is evident that tin acquired by enamel from stannous fluoride must play an important role too in increasing the resistance of enamel. This is possible because tin is capable of combining with other elements to form more insoluble compounds.\(^ {29}\)

Stannous ions and other cations have been shown to react with calcium phosphate solids to alter the
the properties of calcium phosphates by forming surface coatings of insoluble phosphate salts. Studies by Francis and others showed that enamel treated with stannous fluoride solution had lower acid solubility rate than the untreated enamel. They showed that tin was taken up by enamel and was confined in the superficial layers. The reaction of tin with enamel appeared to be of two kinds. One is a chemisorption type of reaction with the stannous ions held very strongly. These chemisorbed ions are responsible for the protection of enamel surface. The other reaction is a precipitation of hydrated stannous oxide which is readily removed. The reaction products consisted of calcium fluoride and a basic stannous phosphate.

The reaction of tin (II) with tooth enamel was studied by Cooley. He brushed the enamel with 0.1M tin fluoride solution and found that tin accumulated and formed a coat or layer on the surface. Initially, the reaction was rapid but after a time reached a limiting value after which additional brushing did not yield any further increase in the amount of tin taken up. The limiting value corresponded to the formation of a more tenacious coating, a tin-containing layer that worked its way into the depressions in the enamel.
and covered the whole surface.\textsuperscript{24} This stannous phosphate layer prevented further penetration of tin and also slowed the rate of which fluoride could diffuse into the enamel. This explains why fluoride uptake from tin fluoride solutions is lower than from sodium fluoride solutions. The layer mentioned cannot be seen with the naked eye. It can only be detected by electron microscopy. The layer is formed by true solution-solid reaction and is different from the adhesion reaction whereby the tin precipitate coated the surface loosely.\textsuperscript{24} Unlike the coat formed by true solution-solid process, the coat formed by adhesion process is distinctive to the eyes and can easily be recognized.

It has been mentioned above that tin is capable of combining with other elements to form more insoluble compounds. The tin compound formed have been shown to be a tin hydroxy-orthophosphate.\textsuperscript{24}

The effect of concentration of tin fluoride on the reaction rate was also studied.\textsuperscript{24} It was found that the more concentrated the solution, the faster it reacted and formed the coat. However, once the tenacious layer is formed, further increase in concentration did not yield any further increase in the formation of the coat. Also, the pH affected the
reaction. As pH increased, the tin fluoride solution hydrolyzed the enamel with large amounts of tin thus, obscuring the direct solution solid reaction. The formation of the precipitate lowered the concentration of free tin ions.

Myers gave a hypothesis explaining the caries-preventive action of tin. A mechanism for the formation of a specific basic tin phosphate in the presence of fluoride ions was given. In the presence of an acid environment, there is a considerable loss of phosphates from the apatite. However, in the presence of stannous fluoride, the amount of loss is reduced. This could probably be due to the formation of a tin phosphate compound on the enamel surface. The formation of this layer of tin compound have been mentioned earlier in the paper. Stannous ions have a strong tendency to hydrolyze water and form "Sn (OH)⁺ or Sn(OH)₃⁻ ions that would precipitate to form Sn(OH)₂.³¹ If fluoride ion is present, a complex SnF⁻₃ will form which will prevent the rapid hydrolysis of the stannous ions. The SnF⁻₃ is very stable. The fluoride ion retards the hydrolysis of the metallic ion and keeps the stannous ion in solution even at pH levels that would ordinarily cause the precipitation of Sn(OH)₂.³¹ The hydrolysis of the ions would produce hydrogen ions capable of causing dissolutions of apatite crystals. When calcium
is removed from the crystals, it reprecipitate to form calcium fluoride. The phosphate ions that remain then reacts with the stannous ions to form the insoluble tin phosphate which adds to the enamel insolvability.

Stannous phosphate, if deposited on the surface of the hydroxyapatite crystals of the enamel can lower surface energy and reduce some of the instability inherent on the crystal surface making the enamel more stable and insoluble.31

Glantz32 found in an "in vitro" study that when enamel surfaces were treated with stannous fluoride solution, its wettability was reduced and therefore less plaque would accumulate on the tooth surface. In this way, stannous fluoride solutions aid in plaque control.

Several studies were conducted to show the effect of pH or hydrogen ion concentration of the solutions on enamel solubility. Phillips and Muhler33 reported that the effectiveness of sodium fluoride in reducing the solubility of both enamel powder and whole tooth sections is increased as the hydrogen ion concentration is increased. This was confirmed too by Palmer, Overstreet and Sacks.34 The uptake of fluoride by synthetic hydroxyapatite from solution of sodium fluoride adjusted to pH 5 and pH 6 was compared with that obtained from
neutral solutions, pH 7. At pH 6, the fluoride concentration in the solid was about 50% greater than that obtained at pH 7. And at pH 5, the uptake was about double that at pH 7. Muhler and his associates studied the effect of pH, age and concentration of solutions of stannous fluoride and sodium fluoride in the uptake of fluoride. They found that stannous fluoride was much more effective in reducing solubility than sodium fluoride and that the effectiveness decreased with age of solution. Also, the greater the concentration of both the solution, the greater the fluoride uptake and the more effective in reducing solubility. However, at all levels of concentration, the tin solution was more superior. Aged solution was less effective. Fischer and his associates showed that the pH is of extreme importance in determining the rate of transformation. The rate of transformation increased as the pH decreased.

King and his co-workers showed that when stannous fluoride in dentifrice was used, phosphorus released was less. The dissolution of enamel here is evaluated as a function of phosphorus release.

Brewer, Muhler and Fischer developed two techniques to measure the permeability of intact enamel surface to inorganic ions following fluoride therapy.
Both the chemical microscopy and electrical conductance technique indicated that stannous fluoride is markedly superior to sodium fluoride in decreasing enamel permeability. Any factor which decreases enamel permeability especially to acid or decrease enamel solubility may aid in the reduction in caries incidence.

From the above sections, the caries-reducing effect of topical application of stannous fluoride is likely to be a combined effect of tin and fluoride ions, both reacting with enamel to form acid-resistant compounds. This was supported by Muhler and Day\textsuperscript{40} who found a greater caries reduction with stannous fluoride than with stannous chloride.

C. **Reaction of Stannous Fluoride with Carious Lesion.**

**Bacterial Plague and Restorations.**

The brown arrested lesions of dental caries seen in elderly persons usually begin early in life. They show first as opaque white spots\textsuperscript{42} in the enamel. This is subsurface decalcification of the enamel.\textsuperscript{41} When the carious process is arrested, these areas disappear. But if enough tooth substance is dissolved to create a cavity, they turn brown with time. These "white spots" lesions are the early stages of caries activity.\textsuperscript{41}
It has been pointed out that the caries reducing effect of topical application of fluorides may be particularly important in the earliest stage of caries initiation – The "White spot" lesion or subsurface decalcification of the enamel.

Gray carried out an "in vitro" study on the resistance to acid demineralization of both sound enamel and enamel with subsurface decalcification treated with sodium fluoride, stannous chloride and stannous fluoride solutions. He found that treatment with sodium fluoride and stannous chloride solutions reduced acid solubility of enamel with subsurface decalcification about the same extent with sound enamel. Stannous fluoride, however, was more effective and reduced solubility of enamel with subsurface decalcification much more than that found in sound enamel.

One of Muhler's clinical tests using stannous fluoride gave evidence that it could prevent further progress of the carious lesion. When a group of children were given single topical application of stannous fluoride, about 22% to 25% of the surface originally diagnosed as cariogenic no longer showed signs of progress of the lesion. The number of reversals in diagnosis with the use of sodium fluoride was less. This showed again the superiority of stannous fluoride over sodium fluoride.
Carious lesions which become arrested can become pigmented with a characteristic light brown color. Closer clinical examination of arrested caries lesion show that they acquire certain typical characteristics:

(a) presence of pigmentation
(b) change from a soft to a very hard texture
(c) change from a chalky whiteness to light brown
(d) no increase in size of lesion
(e) no further progress of lesion as long as pigmentation remains.

It is an established fact based upon clinical studies of Muhler that once the carious area becomes pigmented with the characteristic light brown color, the lesion will not increase in size. The smaller the size of the lesion at the time of the initial application of the stannous fluoride, the greater the chance of caries arrestment. When the pigmentation begins to disappear, then the lesion will start to increase in size too.

Several factors effect the duration of pigmentation. These are:

(a) Frequency of reapplication of stannous fluoride -- In a highly rampant caries case, the pigmentation may begin to disappear after three to four months.
However, where caries activity is low, reapplication may be done only once a year. In general, re-application should be as frequent as necessary in order to bring the case under control.

Because of the effect of stannous fluoride on partially demineralized tooth structure, the best time to apply the solution is before operative treatment. The advantage of this is that many of the incipient caries which would otherwise be restored may become arrested following the fluoride treatment.

(b) The type of dentifrice used —
The light brown stannous fluoride pigmentation of arrested caries can be removed by brushing. However, the duration of the pigmentation can be prolonged through the use of a stannous fluoride dentifrice which actually provides the enamel with a daily topical application of stannous fluoride, thus increasing the stannous fluoride content of the carious enamel.

(c) Caries susceptibility of the patient —
The more susceptible the patient is to caries, the greater the pigmentation but also the greater the loss in pigmentation. Therefore, frequent reaplication of stannous fluoride solution is necessary in these cases.
The light brown pigmentation characteristic of arrested caries is different from the dark brown to black stains in carious lesions which result after topical application of stannous fluoride solution. 43

There is definite evidence that only the carious lesion becomes pigmented and that the non-carious surface does not show color change. 44

Stannous ions are capable of reacting with oxygen and/or sulphur in the bacterial plaque to form stannous oxide or stannous sulfide which is responsible for the formation of the undesirable blackish brown stains. These reactions are illustrated in the following equations: 43
\[ \text{Sn}^{++} + \text{O}_2 \rightarrow \text{SnO}_2 \]
\[ \text{Sn}^{++} + \text{S} \rightarrow \text{SnS} \text{ (blackish-brown)} \]

It is very necessary to perform a thorough prophylaxis of the entire dentition prior to stannous fluoride topical application in order to prevent the formation of this blackish-brown stains.

Aside from carious enamel and bacterial plaque, stannous fluoride produced stainings of restorations too. 43
After an "in vitro" study, Hine and his associates reported staining of fillings after topical applications of stannous fluoride. Surfaces of silicate fillings developed stains whereas the surfaces of resin fillings did not. Marginal staining occurred in amalgam, silicate and resin fillings. However, the marginal staining of these fillings could probably be due to the reaction of stannous ions with the sulfur present in the plaque around the margins of the restorations. This reaction is similar to that which occurred in staining of teeth due to debris and plaque and has been mentioned above.

Stains in restorations can be prevented or reduced by coating the surface of the fillings with cavity varnish prior to topical applications of stannous fluoride.
VI. TECHNIQUES OF APPLICATION OF STANNOUS FLUORIDE.

In order to obtain the maximum benefit from stannous fluoride application, proper technique of application is essential. The clinical effectiveness of fluorides greatly depends upon the thoroughness of the clinical application.

A thorough scaling and prophylaxis of the teeth is necessary prior to topical application of the stannous fluoride solution. If possible, a prophylaxis paste containing stannous fluoride should be used. Detailed descriptions of the technique of prophylaxis with a stannous fluoride prophylaxis paste and the technique of applying stannous fluoride solution are given below.

A. Clinical Technique for Prophylaxis with Stannous Fluoride-Zirconium Silicate Prophylaxis Paste
(SnF₂ - ZrSiO₄) 46

Materials needed:

a) Mirror, probe, and tweezers
b) Stannous fluoride-Zirconium silicate prophylaxis paste (9-10% stannous fluoride)
c) Prophylaxis handpiece
d) Rubber polishing cups
e) Right angle handpiece  
f) Tooth polishing brushes (parallel bristles)  
g) Fine scaler point  
h) Unwaxed dental floss  
i) Saliva ejector  
j) Disclosing solution (6% basic fuschin)  
k) Cotton wool pellets  
l) Dappen dish  

Method

a) Immediately after scaling of the teeth and after the plaque control consultation, application of the paste follows. However, if it does not immediately follow, apply basic fuschin to the teeth following the procedures described by Craig and Dunn.  

b) Place saliva ejector in mouth. Apply the zirconium silicate-stannous fluoride paste to lower quadrants first, using a rubber polishing cup in a prophylaxis handpiece (stannous fluoride tends to stimulate salivary flow — it is much easier to keep the operating field in the lower quadrants free of saliva if these areas are done first). Each tooth surface should receive a 10 second application of paste, with the rubber cup rotating at slow speed. Make sure the edge of the cup reaches the free margin of the gingiva so that the enamel in this area
receives a proper application.

c) Unwaxed dental floss is used to draw prophylaxis paste through interproximal areas.

d) After completion of both lower quadrants, the patient may rinse lightly.

e) Repeat steps (b) and (c) on upper quadrants.

f) Ask patient to rinse lightly, then re-apply disclosing solution to all tooth surfaces to check whether any areas of plaque have been missed. (A fine scaler point is often quite useful for removing plaque from relatively inaccessible interproximal areas.

An alternative method is the self-application technique:

a) Application of paste should follow immediately the plaque control consultation. If not, apply basic fuschin following the procedures described by Craig and Dunn. 46

b) Prophylaxis paste is placed on a toothbrush and the facial surfaces of one quadrant are brushed with a rolling action in an occlusal direction for one minute, care being taken to keep away from the gingiva (it is best to start at the last tooth in the quadrant and work towards the mid-line).

c) More paste is placed on toothbrush and the lingual surfaces of the same quadrant are brushed in the same fashion for one minute.
More paste is placed on toothbrush and the occlusal surfaces of the same quadrant are brushed with a scrubbing motion for 30 seconds.  

Patient is allowed to rinse.  

The steps (b) and (c) are repeated on each other quadrant in turn. (Time for each quadrant = 2½ minutes. Total time for complete treatment = 10 minutes.)  

Re-apply disclosing solution to all tooth surfaces to check whether any areas of plaque have been missed. 

Patient must be warned not to swallow the paste because it can cause nausea.  

B. **Techniques of Topical Application of the Stannous Fluoride Solution - SnF₂**  

Materials needed:  

a) Mirror, tweezers.  

b) Cotton wool pellets  

c) Left and right Garmers clamps (Junior or adult size)  
   (Figure 1)  

d) Saliva ejector  

e) Scissors  

f) Air syringe  

g) Cotton rolls (6-inch length (Size 2) cut into half).
h) Stannous fluoride crystals 0.4 gm. measure for stannous fluoride crystals (small capsules containing pre-weighted amounts of stannous fluoride crystals are available commercially).

i) Distilled water.

j) 4.0 ml syringe.

Method.

a) Prepare a fresh 10% stannous fluoride solution by placing 0.4 gm. stannous fluoride crystals in a waxed paper cup, then adding 4.0 ml. of distilled water and stirring.

b) Isolate one lower quadrant with cotton rolls held in a Garmers clamp, then dry the teeth. Cutting the ends of the cotton rolls at a 45° angle facilitates their placement. The cotton rolls should be completely clear of the tooth surface so that the applied stannous fluoride solution is not absorbed. (Figure 2)

c) Apply stannous fluoride solution to surfaces of teeth with a cotton pellet held in a pair of tweezers (figure 3). Keep the teeth moist with the solution for 4 minutes.

d) Repeat steps (b) and (c) on remaining lower quadrant.

e) Isolate one upper quadrant with a cotton roll, dry the teeth, then place saliva ejector in the mouth. Repeat step (c)
f) Repeat step (e) on remaining upper quadrant.

g) Allow patient to spit out only. Patient is instructed not to eat or drink for at least half an hour after treatment.

h) The surgery procedures are repeated approximately every 6 months with children and every 12 months with adults.

There are alternative methods for isolating teeth for topical fluoride application. For the isolation of both upper and corresponding lower quadrant at the same time, a long facial cotton roll (Size 2, 6 inch length) held in a Garmers clamp can be used. (Figure 4) The lingual cotton roll is kept the same length as it would be if only one lower quadrant was being isolated. Care should be taken to prevent the long facial cotton roll from impinging on tooth surfaces during the topical fluoride application. An entire upper or lower arch may be isolated by using a long cotton roll (Size 2, 6-inch length) held in position by a check retractor (Figure 5 and 6.)
Figure 1. Left - Adult size Garmers clamp for lower left quadrants. Right - Junior size Garmers clamp for lower left quadrants. (From Craig and Dunn, 1971)
Figure 2. Position of cotton rolls in Garmers clamp for the isolation of a lower right quadrant. (From Craig and Dunn)\textsuperscript{46}.

Figure 3. Topical application of a stannous fluoride solution to a lower right quadrant with cotton rolls and a Garmers clamp in position. (From Craig and Dunn, 1971)\textsuperscript{46}
Figure 4. Position of the long facial cotton roll in a Garmers clamp for the isolation of an upper and lower right quadrant at the same time. (From Craig and Dunn, 1971)
Figure 5. Isolation of an entire upper arch using a long facial cotton roll held in position by a cheek retractor. (From Craig and Dunn, 1971)\textsuperscript{46}

Figure 6. Isolation of a lower arch by a long facial cotton roll held in position by a cheek retractor. A suction tip is used to keep the lingual areas free of saliva and retract the tongue. (From Craig and Dunn, 1971)\textsuperscript{46}
Stannous fluoride occurs as an odorless, white crystalline solid which is very soluble in water and only slightly soluble in alcohol. Aqueous solutions are relatively acid and deteriorate within several hours with formation of a white precipitate. Because of this instability in water, which is probably due to hydrolysis, solutions should be freshly prepared and used promptly.

Stannous fluoride has an astringent taste and patient should be warned about it. However, discomfort can be minimized by exercising care during application. Each quadrant should be properly isolated with cotton rolls and the solution painted on the teeth by using a cotton wool pellet held in a pair of tweezers instead of with an applicator stick. Also, patients must be warned not to swallow any solution as this may produce nausea too.

Flavouring agents should not be added to the solution to mask the taste. A study done by Van Juysen and Muhler showed that when stannous fluoride was used in combination with a solution containing flavouring and preservative agent instead of an aqueous solution, the flavoured solution interfered somewhat in the solubility protecting value. Duddling and Muhler contra-indicated, too, the addition of flavouring or colouring agents. Any of these agents added to the solution significantly
decrease the anticariogenic properties.

Muhler described a single application technique for topical application of an 8% stannous fluoride solution. A thorough prophylaxis is done before the application of the solution. It has been pointed out by Massler, Tapia and Zwemer that a fresh surface of enamel provides the best conditions for interaction with fluoride. The technique of applying the solution is the same as has been described above. The treatment is given in a single application where tooth is kept moist continuously for four minutes.

In the four-application technique, the entire treatment is not given in just one application but in a series of four applications. The four applications are completed within ten to fourteen days. Prophylaxis is done only before the first of the four series of applications. A 4% stannous fluoride solution is used here and the teeth kept moist with it for four minutes.

In all of the above techniques, the teeth were kept moist with the fluoride solution for four minutes. Mercer and Muhler, however, found no difference in the effectiveness between a thirty-second and a four-minute application given semi-annually. Several studies conduc-
ducted by the United States Navy showed that topical application of 10% stannous fluoride solution for fifteen seconds gave results comparable to a four-minute application.53-55
VII. DIFFERENT FORMS OF STANNOUS FLUORIDE AVAILABLE FOR TOPICAL APPLICATION.

Clinical studies conducted in the past decades have evaluated the effectiveness of topical fluorides as anti-cariogenic agents. These studies have led to the development of several forms of topical stannous fluorides, most common and widely studied of which are the stannous fluoride solutions, the prophylaxis pastes, and the dentifrices.

A. Stannous Fluoride Solutions - SnF₂

1 — Comparative Studies with Sodium Fluoride Solutions.

Most workers would agree that a 30 to 40% reduction in the incidence of new dental caries in previously non-carious teeth will result from the topical application of an unbuffered aqueous 2% sodium fluoride solution. A 40% reduction in dental caries in children was reported by Bibby in one of his studies using sodium fluoride. Knutson and Armstrong observed a 40% reduction in caries with the use of 2% sodium fluoride solution. Galagan and Knutson derived a 41% reduction with four applications of the same solution. A minimum of four applications of a 2% sodium fluoride preceded by a dental prophylaxis is required to obtain a maximum of 40% reduction in caries incidence. The two main
techniques of application are those described by Knutson and Bibby.

The American Dental Association recommends that in those communities which undertake water fluoridation, topical application of fluoride should be continued for those children whose teeth were calcified or erupted at the time fluoridation was initiated. However, there are very few data to support the continued use of topical fluorides in areas with optimum fluoride concentration in the community drinking water.

Downs and Pelton reported no dental benefit for children who lived in natural fluoride area and received topical applications of sodium fluoride. Galagan and Vermillion also failed to demonstrate any increase in anti-cariogenic effectiveness of topical sodium fluoride on children living in areas of optimum concentration of fluoride.

The partial prevention of dental caries through the use of topically applied sodium fluoride solutions has stimulated search for other agents which might prove of greater value in reducing caries experience. A number of agents, both fluorides and other compounds, have been found to be more effective in reducing enamel solubility in "in vitro" tests than sodium fluoride.
but failed in clinical tests. However, evidence have been presented which suggests that stannous fluoride may be superior to sodium fluoride as a topical anti-cariogenic agent.

Muhler and other workers\(^65\)–\(^67\) demonstrated solutions of stannous fluoride which contained half the combined fluoride content of sodium fluoride to be more than twice as effective as sodium fluoride in reducing acid solubility of powdered tooth enamel.

McLaren and Brown\(^68\) undertook a clinical study of stannous fluoride in 1952. Topical applications of sodium and stannous fluoride solutions and a placebo solution were administered to children in groups as nearly homogenous as possible in characteristics which might be associated with caries experience. Treatments were allocated at random within blocks of three children matched as to age, sex and race. The age group used was the 6–11 years. The fundamental principle used in this method of randomized blocks is that for each block, the circumstances concerning treatments should be as similar as possible. Findings showed that both solutions reduced caries incidence considerably but that stannous fluoride was more effective than sodium fluoride in inhibiting the incidence of dental caries. Also, there may be diminishing effect in the protection
afforded by topical fluoride application with a lapse of more than one year after they are administered and that topical fluoride applications were relatively of greater effect when administered to teeth of younger children. The two-year study supported the evidence of the greater effectiveness of stannous fluoride than that of sodium fluoride as topical agent for partial prevention of dental caries.

Gish and his associates found that at the end of three years of their study, a single application of a freshly prepared solution of 8% stannous fluoride applied annually was more effective in reducing caries than a series of four applications of a 2% sodium fluoride solution.  

Howell and his co-workers conducted a comparative study between sodium fluoride and stannous fluoride among six hundred twenty school children using two groups. They used Knutson's technique of application. The sodium fluoride and stannous fluoride solutions were applied with cotton applicator to the teeth of the group whose teeth were to be treated with sodium fluoride and to the teeth of one-half of the group whose teeth were to be treated with stannous fluoride, respectively. The stannous fluoride solution was applied by spray to the
remaining half of the stannous fluoride group. The results at the end of the second year is summarized in Table 2 and 3.

Table 2. Average Caries Increment for Two-Year Period.

<table>
<thead>
<tr>
<th>Group</th>
<th>Subject Average effects</th>
<th>DMFT</th>
<th>In previous Caries free teeth</th>
<th>In previous DF teeth</th>
<th>Average Proximal surface of teeth</th>
<th>Occusal surface of teeth</th>
<th>Occ Brissling DMFS Total DMFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>139</td>
<td>2.84</td>
<td>3.83</td>
<td>0.69</td>
<td>2.19</td>
<td>2.24</td>
<td>0.09</td>
</tr>
<tr>
<td>A*</td>
<td>92</td>
<td>2.17</td>
<td>2.38</td>
<td>0.50</td>
<td>1.70</td>
<td>0.98</td>
<td>0.21</td>
</tr>
<tr>
<td>B+</td>
<td>194</td>
<td>0.48</td>
<td>1.84</td>
<td>0.02</td>
<td>1.59</td>
<td>0.38-0.11</td>
<td>1.86</td>
</tr>
<tr>
<td>C‡</td>
<td>195</td>
<td>1.11</td>
<td>1.99</td>
<td>-0.43</td>
<td>1.31</td>
<td>0.44-0.19</td>
<td>1.56</td>
</tr>
</tbody>
</table>

Table 3. Percentage Difference or Reduction in Increase of New Caries Compared to Those of Control Group.

<table>
<thead>
<tr>
<th>Group</th>
<th>DMFT</th>
<th>In Previous Caries free teeth</th>
<th>In Previous DF teeth</th>
<th>Proximal Surfaces Occlusal surfaces</th>
<th>Total DMFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>23.6</td>
<td>37.9</td>
<td>27.5</td>
<td>22.4</td>
<td>56.2</td>
</tr>
<tr>
<td>B</td>
<td>83.1</td>
<td>52.0</td>
<td>97.1</td>
<td>27.4</td>
<td>83.0</td>
</tr>
<tr>
<td>C</td>
<td>60.9</td>
<td>48.0</td>
<td>100.0</td>
<td>40.2</td>
<td>80.4</td>
</tr>
</tbody>
</table>

* Sodium fluoride by cotton applicator
+ Stannous fluoride by cotton applicator
‡ Stannous fluoride by spray, continuously applied
From the table, it appears that sodium fluoride afforded less protection for decayed and filled teeth than it did for caries free teeth. Stannous fluoride, on the other hand, showed considerably greater effect on decayed and filled teeth than on caries-free teeth. It was notices that many of the regions which were diagnosed as being carious at the first examination were diagnosed as being non carious at the second examination. These occurrences are referred to as reversals in diagnosis. This study also showed that the number of reversals in diagnosis from carious to non-carious between the first and second examinations are significantly greater in the stannous fluoride groups than in the sodium fluoride. This phenomenon may be associated with arrested incipient carious lesions.

It has been mentioned above that some studies of sodium fluoride topical application of teeth of children living in optimal fluoridated areas failed to show any decrease in caries incidence. However, Horowitz and Heifetz 71 showed that annual four minute application of an 8% stannous fluoride solution to children born and raised in fluoridated areas produced a 21% reduction in incremental decayed, missing and filled teeth (DMFT) and in decayed, missing and filled surfaces (DMFS).
2. Comparative studies with Acid Phosphate Fluoride Solutions.

Cartwright and his co-workers\textsuperscript{72} evaluated the clinical findings obtained during a two-year study concerning the relative effectiveness of topically applied stannous fluoride and acid-phosphate fluoride solutions. Their study revealed that groups receiving stannous fluoride or acid-phosphate fluoride experienced significant reductions in caries increments when compared to the control group. However, the acid-phosphate group showed reductions which were superior to the stannous fluoride treated group. Studies by Brudevold and others\textsuperscript{73-75} showed that the acid-phosphate fluoride was more effective than either sodium fluoride \textit{proxima} or stannous fluoride solutions and that the acid-phosphate solution produced a 50 to 70\% reduction in caries with an annual four-minute application of a solution containing a fluoride ion concentration of 1.23\%.

Horowitz \textsuperscript{76-78} conducted a three-year study among Hawaiian children to test the effectiveness of topically applied acidulated phosphate-fluoride. He found that at the end of two years, the children who were given two annual applications of acidulated phosphate fluoride solution had 26\% fewer DMF teeth and 33\% fewer new DMF
teeth and 36% fewer new DMF surfaces than the control group. At the end of three years, the children who had been given three annual treatments had 26% fewer new DMF teeth and 28% fewer new DMF surfaces than did children in the control group. The corresponding percentage differences were greater among those children who had been given six semiannual treatments of the solution. Their reductions in new DMFT and DMFS compared with the controls were 38% and 41% respectively.

Mercer and Gish,79 however, pointed out the fact that the question of superiority of acidulated phosphate fluorides is still unresolved at present and that more clinical testings are necessary.

B. **Prophylaxis Paste - Stannous Fluoride - Zirconium Silicate Prophylaxis Paste (SnF₂ - ZrSiO₄)**

1 - Studies on Effectiveness of the Stannous Fluoride-Zirconium Silicate Prophylaxis Paste.

One of the most widely used procedures in the dental office is routine dental prophylaxis for removal of stains, materia alba, and debris. A dental prophylaxis paste should be sufficiently abrasive to effectively remove all types of accumulations from tooth surface without imparting undue abrasion to the enamel, denture
or cementum. In addition, it must have the quality of endowing the hard tissue with a highly polished, esthetic appearance.

The use of an abrasive as a constituent of a dentifrice is to aid in the removal of debris and stain on the tooth. This too, is the function of abrasives incorporated into prophylaxis paste. The clearing and polishing efficacy of the abrasive should be balanced with its high abrasiveness. The particle size should be of the size and hardness that it will clean and polish the tooth surface optimally, yet not abrade the enamel. These requirements of a good abrasive limit the type which can be incorporated into the prophylaxis paste. The goal then, is to have an abrasive which will clean very well with minimum or no damage to the teeth and which will provide a high polish. It would be ideal if the prophylaxis paste can serve as an anticariogenic agent at the same time, in addition to being a cleaning and polishing agent. This would be possible by adding fluorides into the prophylaxis paste.

Several stannous fluoride pastes have been developed in the past. Two of these are the stannous fluoride silix-silicone prophylaxis paste and the aqueous stannous fluoride-lava pumice paste. Peterson and his co-
workers reported a reduction in DMFS of 41.9% following the use of prophylaxis paste containing 17.5% stannous fluoride applied to silex as the abrasive.\textsuperscript{81} The second paste mentioned used lava pumice as the abrasive. Laboratory and clinical tests have shown that stannous fluoride incorporated into compatible prophylaxis paste containing lava pumice as the polishing agent was effective in reducing dental caries.\textsuperscript{82} Pumice was the most common abrasive used. However, due to insufficient clinical evidence on their effectiveness, these compounds have been set aside until further investigation.

There are a great number of pastes available to which fluoride have been added. Recently, two prophylaxis paste have been introduced commercially and these are the acidulated phosphate fluoride – silicone dioxide paste and the stannous fluoride–zirconium silicate prophylaxis\textsuperscript{62} paste. The stannous fluoride–zirconium silicate has the published evidence of therapeutic value.

Commercially available prophylaxis paste were evaluated in terms of maximal efficacy in reducing dental caries, in cleaning ability and in polishing with minimal abrasion.\textsuperscript{83} The study showed that of the products made available commercially as therapeutic prophylaxis paste, only those containing stannous fluoride
appear to be of significant value. The data obtained showed that the use of stannous fluoride with a particular formulation of zirconium silicate would more nearly meet all the desired objectives of providing therapeutic value along with effectiveness of cleaning and polishing enamel without abrasion.

Zirconium silicate has been reported to be an inert material without any toxic effects in the biological system.\textsuperscript{84} Also, a series of studies have been conducted and the data from these indicated that a thorough oral prophylaxis with zirconium silicate prophylaxis paste was without any toxic effects to the gingival tissues of the rat.\textsuperscript{84}

Several clinical tests have been done which showed that the zirconium silicate was the most effective in removing several forms of tooth stains and pigmentations.\textsuperscript{80} The zirconium silicate crystals used in the prophylaxis paste had a rough surface such that they acted as an abrasive at the start of the prophylaxis. However, as prophylaxis goes on, the crystals became smaller and as such produced a polishing effect on the tooth surface. Other tests have shown that prophylaxis with zirconium silicate was most effective in delaying pellicle formation.
Shannon has published the results of a laboratory study which showed that freshly prepared zirconium silicate stannous fluoride prophylaxis paste was highly effective in protecting human dental enamel from acid decalcification. It has been established by studies that the zirconium silicate prophylaxis pastes in general provide more protection from acid dissolution. Data showed that zirconium silicate is almost 99% compatible with fluoride provided by stannous fluoride. Comparison of the most effective combinations of fluorides and phosphates suggest that sodium fluoride are only one-half as effective as stannous fluoride pastes. Also, enamel solubility data indicated a marked superiority of tin-containing over non-tin containing systems.

2 — Composition of Stannous Fluoride-Zirconium Silicate Prophylaxis Paste — ZrSiO₄.

The traditional approach to the administration of topical fluoride is that each patient be treated individually by the dentist of the hygienist. This is well-adapted in private practice but undoubtedly not in public health programs which aim to treat as many children as possible. It would require the dentist or hygienist about thirty to forty minutes to administer the prophylaxis and the topical application. Therefore, it would be advantageous for both the dentist and the
patient to develop a single technique whereby the prophylaxis and the topical application would be combined in a single treatment.\textsuperscript{86}

One of the major challenges to preventive dentistry is the development of a single low-cost anticariogenic technique that can be used for children living in non-fluoride areas and that can be administered to large groups at a single time. Such procedures have been developed with the self-applied or the patient applied stannous fluoride zirconium silicate prophylaxis paste.

In a clinical study of two-hundred seventy-six children in Virgin Islands, Muhler and his associates\textsuperscript{87} reported the clinical effectiveness of stannous fluoride zirconium silicate patient-applied prophylaxis paste at the end of one year. He showed that there was a 41\% reduction in new DMFT and a 64\% reduction in DMFS. It was suggested that this technique be used as an anticariogenic agent in children on a mass treatment basis. This technique would be suitable for public health programs.

The composition of the self-applied stannous fluoride-zirconium silicate prophylaxis paste is as follows:\textsuperscript{88}
Constituent                          Percentage by Weight.
(a) Zirconium Silicate              48.63% 
(b) Stannous fluoride               9.00  
(c) Sodium Dihydrogen Phosphate     9.00  
(d) Tin oxide                       5.40  
(e) Distilled water                 12.16 
(f) Humectants                      11.29 
(g) Binders                         1.78  
(h) Flavouring and colouring agents 2.74  
The paste is provided for use in a specially lined tube. The composition of the dentist-applied stannous fluoride-zirconium silicate paste is similar to the self-applied one. Both contain 9% stannous fluoride.

C. Dentifrices-Stannous Fluoride Dentifrice and Non-Stannous Fluoride Dentifrice.

It is recognized that the main function of a dentifrice is to aid in the cleaning of teeth and gingival tissues. There has been constant and continued efforts to find some substance that could be incorporated into the dentifrice which would be beneficial in the prevention or inhibition of caries. The discovery of the value of fluorine led to studies on different forms of fluorides. After it was demonstrated that water fluoridation and topical application of fluorides reduced dental caries
incidence, investigations were conducted to determine the effectiveness of these substances when incorporated into the dentifrice.\textsuperscript{90}

It is well established that sodium fluoride added to fluorine-deficient water supply or applied topically to erupted teeth of children will reduce the incidence of dental caries.\textsuperscript{91}

In an attempt to find fluoride compound with greater anticariogenicity than sodium fluoride, considerable number of experiments were carried. Some of these have been mentioned earlier.

Experiments have been carried in the past to determine the anti-cariogenic effectiveness of stannous fluoride-containing dentifrice in both children and adults when the abrasive used was calcium pyrophosphate. Some of these studies will be mentioned below.

The effectiveness in caries reduction of a stannous fluoride and a sodium fluoride-containing dentifrice were compared.\textsuperscript{92} Both dentifrices used the same abrasive. The study was carried among grade-school children by Muhler and his associates.\textsuperscript{92} The results showed a small reduction in caries rate after six and twelve months
with the use of sodium fluoride dentifrice compared to the stannous fluoride one. The latter one produced a 44.7% reduction in caries rate after six months and a 36% reduction after twelve months. The reductions were much greater compared to the reductions brought by the sodium fluoride dentifrice.

Table 4. presents the results of this one-year study.  

Table 4. Dental Caries Increments during the One-Year Test Period.

<table>
<thead>
<tr>
<th></th>
<th>After 6 months</th>
<th>After 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>NaF</td>
</tr>
<tr>
<td>DMFT Increment</td>
<td>0.700</td>
<td>0.644</td>
</tr>
<tr>
<td>Percentage Reduction In Caries Rate</td>
<td>---</td>
<td>8.0</td>
</tr>
<tr>
<td>Probability</td>
<td>---</td>
<td>0.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>After 6 months</th>
<th>After 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.177</td>
<td>1.009</td>
</tr>
<tr>
<td>Percentage Reduction In Caries Rate</td>
<td>---</td>
<td>14.3</td>
</tr>
<tr>
<td>Probability</td>
<td>---</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Muhler, Radike, Nebergall and Day 92 showed that the unsupervised use of stannous fluoride-containing dentifrice produced at 53% reduction in DMFT and 72% reduction in DMFS after six months. After twelve months, the reduction
was 51% in DMFT and 49% in DMFS. They did a similar study among Indiana University students using stannous fluoride and a control dentifrice for a one-year period. The unsupervised use of the stannous fluoride dentifrice for a year produced 53.7% reduction in DMFT and 41.6% in DMFS. These results are summarised in Table 5.
Table 5. Average Increase in Dental Caries Experience in Indiana University Students Using a Stannous Fluoride and Control Dentifrices for a One-Year Period.

<table>
<thead>
<tr>
<th>Caries Increment in Terms of Seven Indices</th>
<th>New DMFS In Previously Caries Free Teeth</th>
<th>New DMFS Carious Teeth</th>
<th>New DMFS Occlusal Surfaces</th>
<th>New DMFS Buccal and Lingual Surfaces</th>
<th>Total New DMFT</th>
<th>New DMFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Month Period</td>
<td>Group 1 180 subjects Control Dentifrice</td>
<td>0.656</td>
<td>0.694</td>
<td>0.839</td>
<td>0.317</td>
<td>0.194</td>
</tr>
<tr>
<td></td>
<td>Group 11 179 subjects SnF₂ Dentifrice</td>
<td>0.497</td>
<td>0.173</td>
<td>0.369</td>
<td>0.196</td>
<td>0.106</td>
</tr>
<tr>
<td>12 Month Period</td>
<td>Group 1 157 subjects Control Dentifrice</td>
<td>0.860</td>
<td>1.153</td>
<td>1.229</td>
<td>0.478</td>
<td>0.306</td>
</tr>
<tr>
<td></td>
<td>Group 11 165 subjects SnF₂ dentifrice</td>
<td>0.727</td>
<td>0.448</td>
<td>0.667</td>
<td>0.297</td>
<td>0.212</td>
</tr>
<tr>
<td>% Reduction</td>
<td>6 month 24.2</td>
<td>75.1</td>
<td>56.0</td>
<td>38.2</td>
<td>45.4</td>
<td>55.0</td>
</tr>
<tr>
<td>In Caries Rate</td>
<td>12 month 15.5</td>
<td>61.1</td>
<td>45.7</td>
<td>37.9</td>
<td>30.7</td>
<td>53.7</td>
</tr>
</tbody>
</table>
In another study, Muhler and Radike\textsuperscript{96} showed that after two years of unsupervised use of a dentifrice with stannous fluoride as the active anticariogenic ingredient and calcium prophosphate as the abrasive, a statistically significant reduction of 30\% DMFT and 34\% in DMFS in dental caries incidence in adults have been observed. These results are in agreement with earlier studies showing similar reductions when the same dentifrice was used by children.

So far, the several studies mentioned above were carried without supervision of the use of the stannous fluoride dentifrice. Some studies have also been carried out among children where the toothbrushing using the dentifrice were supervised.

Jordan and Peterson\textsuperscript{97,98} carried out a one-year and a two-year supervised toothbrushing studies among schoolchildren. These studies showed that at the end of one year, the reduction in various surfaces incidence was 34\%.\textsuperscript{97} At the end of two years, the percentage reduction was 21\%.\textsuperscript{98} A third of the children in the second study did not brush in school with the test dentifrice. The data obtained also showed reduction in caries. However, no conclusions can be made concerning the influence of brushing in school until further clinical investigations, and trials.
A comparison of a stannous fluoride-calcium pyrophosphate dentifrice with a placebo dentifrice used by children aged 6 to 10 years in a community a non-fluoridated water supply indicated that the use of stannous fluoride dentifrice either at home alone or once a day in school as well as at home produced about a sixth to a fifth reduction in dental caries increment over three years. Children who brushed with the stannous fluoride dentifrice once a day on school as well as at home derived no additional benefits for caries control compared with the benefits gained by children who brushed their teeth only at home with the same dentifrice. Children who brushed with the stannous fluoride – calcium pyrophosphate dentifrice for three years had 39.4% reductions in caries compared with children who used a placebo dentifrice.

A series of studies in the effectiveness of stannous fluoride-calcium pyrophosphate dentifrice in the reduction of dental caries have been done. These are summarized in Table 6.

Table 6. Previous Clinical Tests With a Stannous Fluoride-Calcium Pyrophosphate Dentifrice.
The above table shows that there is a definite caries reduction with the use of this dentifrice but it also shows that there is a decrease with time in the anticariogenecity effectiveness. It has been suggested that this decrease may be partly due to the protective mechanism which produces an initial benefit but does not increase this benefit with continued use of the product.

2. Composition of Stannous Fluoride-calcium Pyrophosphate Dentifrice.

The Crest stannous fluoride dentifrice contains stannous fluoride as its principal active anticariogenic ingredient and the calcium pyrophosphate as the abrasive. The following is the Crest formulation:102
Stannous fluoride 4.4%
Calcium pyrophosphate 39.0%
Glycerin 10.0%
Stannous pyrophosphate 1.0%
Water 24.9%
Miscellaneous Formulating Agents 4.63
Sorbitol 20.0%

The calcium pyrophosphate which is the abrasive acts as the cleaning and polishing agent. Glycerin is the humectant and prevents the product from drying out.\textsuperscript{103}

3. \textbf{Studies of Effectiveness of Different Combinations of Fluoride and Abrasives Incorporated in the Dentifrice.}

Clinical evidence for the anticariogenic effectiveness of a specific dentifrice formulation containing stannous fluoride and calcium pyrophosphate had been presented. However, other studies indicated lack of effectiveness of dentifrices containing sodium fluoride and calcium carbonate. In 1953, a similar combination was shown to have no anticariogenic effect, another dentifrice containing sodium fluoride and dicalcium phosphate failed to show reduction in caries. A combination of sodium fluoride and calcium pyrophosphate was ineffective. A fifth study showed that a dentifrice containing stannous fluoride was ineffective when the
abrasive used was dicalcium phosphate. All these studies are briefly summarized in Table 7.  

Table 7. Summary of Clinical Caries Tests of Dentifrices containing Stannous Fluoride. *

<table>
<thead>
<tr>
<th>Dentifrice Combination</th>
<th>Fluoride</th>
<th>Abrasive</th>
<th>Clinical Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NaF</td>
<td>Calcium carbonate</td>
<td>(-), (-)</td>
</tr>
<tr>
<td></td>
<td>NaF</td>
<td>Dicalcium phosphate</td>
<td>(-)</td>
</tr>
<tr>
<td></td>
<td>NaF</td>
<td>Calcium pyrophosphate</td>
<td>(-)</td>
</tr>
<tr>
<td></td>
<td>SnF₂</td>
<td>Dicalcium phosphate</td>
<td>(-)</td>
</tr>
<tr>
<td></td>
<td>SnF₂</td>
<td>Calcium pyrophosphate</td>
<td>(+), (+), (+), (+)</td>
</tr>
</tbody>
</table>

* (-) Indicates that no statistically significant protection against caries was observed.

(+ ) Indicates that a statistically significant protection against caries was observed.
VIII. Multiple Fluoride Therapy.

It is no longer a problem to prevent one cavity or many cavities. The problem is to prevent them by methods acceptable to the patient and by a means which does not make prevention more expensive in dental treatment time than restoration of the carious tooth which otherwise would have occurred. Therefore, if caries is to be prevented, it must be done in less time.

It has been established that fluoridation of water supply reduces dental decay. In an attempt to reduce caries prevalence even further, topical application of sodium fluoride in children whose teeth calcified while they lived in a region with an optimal level of fluoride in the water was evaluated in the hope that combination of these two procedures would produce additive effects. The studies showed that there was no added benefit. Stannous fluoride was superior to sodium fluoride in that topical application of the former in children whose permanent teeth had calcified in a community with optimal level of fluoride in the drinking water has shown added benefits. These findings suggested that the use of other techniques in addition to topical application may give even further benefits. Thus, the "multiple therapy" approach consisting of use of stannous fluoride prophyl-
laxis paste, topical application of stannous fluoride solution and a stannous fluoride dentifrice for home use.

The effectiveness of this "multiple therapy" has been tested. The United States Navy undertook several studies to determine the cariostatic effectiveness of these three agents, used singly or in combination. It was proven that dentifrice when used in conjunction with stannous fluoride solution, demonstrated additive reduction in caries and that the three-agent treatment using all three forms of the fluoride was most effective. In another study among the adult naval personnel, the cariostatic effectiveness of an annual topical application of stannous fluoride prophylaxis paste containing 17.5% stannous fluoride, a 10% aqueous solution and a dentifrice with 0.4% stannous fluoride was evaluated. After two years, the group that received the three agent agents had the greatest reduction. The groups that received stannous fluoride in only one or two forms had caries reduction which were lesser than those experienced by the group who received the three agent treatment.

Bixler and Muhler conducted a study among children ranging from five to eighteen years who have been permanent residents all their lives in Bloomington, Indiana where the communal water supply has a fluoride
content of 0.05 micrograms per milliliter. The children were divided into five groups each given different combinations of three stannous fluoride treatments. The results of the study showed that the children given all three forms of stannous fluoride treatment had the highest reduction in dental caries. In another clinical study conducted during three years in a non-fluoridated area, children were given treatments using different combinations of stannous fluoride again. Findings were similar to previous studies. The results of this study are summarized in Tables 8 and 9.

Table 8. DMFT Increment and DMFS Increment at 24 months.

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Mean</th>
<th>standard deviation of the Mean</th>
<th>% Mean</th>
<th>Standard deviation of the Mean</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>181</td>
<td>3.80</td>
<td>.222</td>
<td></td>
<td>8.06</td>
<td>.476</td>
</tr>
<tr>
<td>Pf</td>
<td>166</td>
<td>2.66</td>
<td>.188</td>
<td>30.0</td>
<td>5.30</td>
<td>.352</td>
</tr>
<tr>
<td>Pf+Df</td>
<td>175</td>
<td>2.78</td>
<td>.190</td>
<td>26.8</td>
<td>5.30</td>
<td>.334</td>
</tr>
<tr>
<td>Pf+Tf</td>
<td>158</td>
<td>2.24</td>
<td>.171</td>
<td>41.4</td>
<td>4.77</td>
<td>.338</td>
</tr>
<tr>
<td>Pf+Tf+Df</td>
<td>180</td>
<td>1.60</td>
<td>.133</td>
<td>57.9</td>
<td>3.00</td>
<td>.249</td>
</tr>
</tbody>
</table>

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Table 9. DMFT and DMFS Increment at 36 months.

<table>
<thead>
<tr>
<th>Group</th>
<th>DMFT Mean</th>
<th>Standard Deviation</th>
<th>% Reduction of the Mean</th>
<th>DMFS Mean</th>
<th>Standard Deviation</th>
<th>% Reduction of the Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5.19</td>
<td>.279</td>
<td>---</td>
<td>10.95</td>
<td>.642</td>
<td>---</td>
</tr>
<tr>
<td>$P_f$</td>
<td>3.50</td>
<td>.223</td>
<td>32.5</td>
<td>7.12</td>
<td>.469</td>
<td>35.0</td>
</tr>
<tr>
<td>$P_f + D_f$</td>
<td>3.44</td>
<td>.241</td>
<td>33.8</td>
<td>6.86</td>
<td>.454</td>
<td>37.4</td>
</tr>
<tr>
<td>$P_f + T_f$</td>
<td>2.64</td>
<td>.185</td>
<td>49.0</td>
<td>5.75</td>
<td>.411</td>
<td>47.6</td>
</tr>
<tr>
<td>$P_f + T_f + D_f$</td>
<td>2.28</td>
<td>.180</td>
<td>56.0</td>
<td>4.76</td>
<td>.325</td>
<td>58.4</td>
</tr>
</tbody>
</table>

Another study was done but this time in an area with the history of continued optimal fluoride level in the water supply. Nine hundred children were divided into four groups and received one of the following treatments:

1. prophylaxis without stannous fluoride, topical application of water and a control dentifrice,
2. stannous fluoride prophylaxis, topical application of 8% stannous solution and control dentifrice,
3. stannous fluoride prophylaxis, topical application of water and a control dentifrice,
4. stannous fluoride prophylaxis and solution, and stannous fluoride dentifrice. The results showed that all three experimental groups experienced significant reductions in caries compared to the control group and that the group with all the three forms of treatment had the greatest reduction.
IX. Conclusion.

Water fluoridation is the most efficient and effective method of preventing caries in public health programs. However, fluoridation has not been and is not likely to be available to all segments of the child population, although there is a slow and steady increase each year in water fluoridation programs. Inspite of the gains in the extension of caries control program through fluoridation of the water supply, there still is need for a dental caries preventative agent such as the topical fluorides in order to reach the segment of the population not benefited by the fluoridated water supply.

The topical application of fluorides has become established as a second line of defense against dental caries. The use of these fluorides in a variety of forms have been accepted. However, in every use of fluorides, drawbacks in its utility are recognized.

A variety of interrelated factors are responsible for retarding the acceptance of typical fluorides. Some of these are: high cost of the treatment, restrictive licensure laws, intangibility of the treatment which make it hard for the dentist to ask for a fee, possibility
of failure of the treatment, and the promotion of water fluoridation has overshadowed topical fluoride treatment.

If topical treatment is to be used more effectively and to reach more of the population, then some steps will have to be taken to overcome all these difficulties or problems.

Fluoridation of communal water supply or the topical application of fluorides will not prevent all dental caries. They are only aids to prevention and are not the cure. Good oral hygiene, proper diet and dental care are still very essential in the promotion and maintenance of good oral health.
X. Summary.

Dental caries is indeed one of the biggest dental health problems. In order to find measures of controlling or preventing the disease, a thorough knowledge of the carious process is necessary. A very brief discussion of the etiology and formation of dental caries have been given.

One of the most significant caries control techniques ever developed is the use of fluorides either by addition in diet through water fluoridation and food supplement, or by topical application on the tooth surfaces of prophylaxis pastes, solutions or dentifrices.

A short historical background on the discovery of this fluorine as a caries-preventive agent was given. The physiology and toxicology of fluorine was briefly discussed too.

The exact mechanism of action of fluorides in preventing caries is still not known. However, several theories have been presented. Most significant of these are: the antibacterial effect, the enzyme-inhibitor theory and the enamel solubility theory. It is believed that fluoride can act in one or more of the above ways.
The first fluoride to be used was sodium fluoride. However, stannous fluoride has now been proven to be more effective than sodium fluoride. Numerous studies have been conducted in past decades to determine the anticariogenicity of stannous fluoride. It is established that the reduction in enamel solubility brought about by stannous fluoride is due to both the stannous and the fluoride ions and not merely on the fluoride uptake by the enamel. Several studies have also been conducted to determine the effect of such factors as age of the solution, hydrogen–ion concentration of pH and the concentration of the solution on its effectiveness. Stannous fluoride has been found to be capable also of arresting existing carious lesions. However, great care could be taken with the use of stannous fluoride in topical application as it can cause staining of the bacterial plaque and restorations such as amalgams and silicates, which is very unsightly and undesirable.

There are several techniques of applying stannous fluoride solution. The standard technique is the four-minute application. However, studies have shown that the thirty-second and the fifteen-second applications are just as effective clinically. A clean and dry surface is most suitable for application because it affords the best condition for fluoride uptake by enamel. Therefore a thorough prophylaxis prior to topical application
is a must. Failure to do so may lead to failure of the treatment.

Stannous fluoride comes in a variety of forms. The three most common forms are the stannous fluoride prophylaxis paste, solution and dentifrice. Comparative studies between stannous fluoride and sodium fluoride solutions or the acid-phosphates showed that stannous fluoride was superior. Nothing definite could be concluded with acid-phosphate solutions until further investigations. Several studies have also been conducted on the stannous fluoride-zirconium silicate prophylaxis paste. Different combinations of fluoride and abrasive used were studied and these showed that stannous fluoride when used with zirconium silicate was most effective. Therefore, its use was advocated. The paste comes in two forms; the self-applied or patient applied and the dentist applied prophylaxis pastes. The compositions of each of these pastes were given. The superiority of the stannous fluoride-containing over the non-stannous fluoride-containing dentifrices have been proven clinically, and that the right combination of abrasive is necessary. Of all the different combinations studied, only the stannous fluoride and calcium pyrophosphate combination was effective. The composition of this dentifrice was also given in the paper.
The "multiple fluoride therapy" involves the use of all three forms (stannous fluoride prophylaxis, followed by topical application of solution and use of a stannous fluoride dentifrice at home). Treatment with all three forms produced the greatest reduction in dental caries.
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89. Personal Communication.


