Findings:

At the end of the first year of study, in the 181 in Group C, there were 2,772 non-curious permanent teeth of which 157 became curious during the one-year study period. The attack rate of this group was 12.62 teeth per 100 teeth. Group A had an attack rate of 5.67 teeth per 100 teeth or 54.8 per cent less than Group C. Group B1 had 4,694 non-curious permanent teeth of which 259 became curious during the one-year period, thus having an attack rate of 5.52 teeth per 100 teeth or 56.4 per cent less than group C. Group B2 had 5,070 non-curious permanent teeth of which 283 became curious during the study period. This was an attack rate of 5.58 teeth per 100 teeth or 53.6 per cent less than group C.

Reversal or somewhat different record of the curious pattern of an individual by the same examiner could happen on repeated examination of the same group. It is possible to find a few teeth recorded as curious at the first examination and non-curious at the second examination. The difference might be due to actual arresting of the curious process, variations in explorer sharpness, and possibly to other unrecognized factors.
Following the critical evaluation of stannous fluoride in the laboratory was employed in a considerable number of clinical studies. The studies that evaluate the influence of topically applied stannous fluoride in the permanent teeth of children reared in the presence and absence of a fluoridated water supply presented results that 20 out of the 22 studies have been positive regarding caries reductions. Only two recent studies indicated a failure to find any significant beneficial effect of topically applied stannous fluoride, Bernier and Muhler (1966). Most of the studies have shown generally greater reductions than were noted with sodium fluoride. Meckel and Francis (1964) reported that the half-mouth experimental technic is not valid, due to the intraoral transfer of fluoride and tin to the untreated quadrant, particularly in lower quadrants wherein the reductions obtained with this experimental procedure may be somewhat lower than the actual value. When using the whole-mouth technic and comparable groups for the control values it is apparent that the beneficial effect of topical applications of stannous fluoride, as measured by reductions in subsequent caries development, is of the magnitude 40 to 60 per cent. The only one study (Muhler, 1960) reported concerning the effect of topically applied stannous fluoride upon permanent
teeth developed in the presence of an optimal fluoride (1.0 p.p.m. fluoride) in the water supply showed caries reductions of about 50 per cent after two and one-half years.

Results obtained when stannous fluoride was applied to the deciduous dentition in the presence and absence of an optimal water supply showed a caries reduction of 40 per cent and that this degree of protection is not influenced by, and is in addition to, the beneficial influence of communal fluoridation.

Studies in adults regarding stannous fluoride topical applications reported a beneficial effect in the range of 15 to 54 per cent caries reductions, showing a considerable significant benefit to adults. 6

Topical applications of stannous fluoride involve reactions of the stannous as well as the fluoride ions. Certain studies have reported greater deposition of fluoride from stannous fluoride than from sodium fluoride. Although acid solutions of sodium fluoride do cause a greater fluoride deposition than neutral solutions, the naturally acid stannous fluoride reacts with the tooth mineral and becomes firmly bound to the enamel, and therefore, significant in regard to caries reduction. The pH
will rise when stannous fluoride reacts with the tooth mineral, and insoluble tin fluoride complexes are formed which reduce the amount of reactive fluoride (Smith et al. 1957). The protection which is provided the enamel surface by this solution is unlikely to be due to the easily removable complexes, but probably results from inclusion in the enamel of tin phosphates along with the simultaneously produced fluorapatite. The yellowish brown discoloration noted in carious lesions following stannous fluoride treatments is probably due to the formation of insoluble stannous sulfide. Laboratory experiments in vitro have demonstrated that this compound will readily form in stannous fluoride treated enamel in the presence of sulfide (Brudevold et al. 1957).

On numerous occasions in the past several years, discussions have arisen relative to the agent of choice for topical applications but ultimately left the matter up to the clinician. Considerable amount of laboratory and clinical research resulted in the establishment of a recommended procedure of application (Knutson, 1948; Budding and Luhler, 1962); it would then seem only logical to compare these agents when each is employed in the recommended manner as was performed in comparable studies (Gish
et al., 1962). Similarly, one might suggest that each compound be evaluated at identical concentrations and with identical methods of application.

The results of the studies that directly compare the two compounds, sodium fluoride and stannous fluoride, indicated a very pronounced superiority of the stannous salt over the sodium fluoride. The findings of the eight studies reported to date (Bernier and Muhler, 1966) comparing these two anticariogenic agents only two studies reported that sodium fluoride was superior to stannous fluoride. By far the majority of the clinical investigations conducted indicated too that stannous fluoride is more effective in children and one must recall that said compound has been shown to be of significant value in adults and in residents of areas already enjoying the benefits of a fluoridated water supply.

Quite a number of disadvantages to the use of stannous fluoride have been pointed out in literature such as taste, gingival blanching, the instability of aqueous solutions and the aesthetic pigmentation, all of which are absent when sodium fluoride is employed. Consideration of taste have little scientific merit, since therapeutic agents are selected on the basis of efficacy rather than upon the
taste. Several investigators (Muhler, 1957; Higgason et al., 1963; Muhler, 1960) repeatedly have shown very little consequence of stannous fluoride upon the gingiva. The presence of pigmentation, as well, has been shown repeatedly (Muhler, 1960; Mercer and Muhler, 1965) and has been suggested as being due to the formation of a tin phosphate at the site of either active or incipient carious lesions and therefore, to be associated with caries arrestment. This has been noted as a dramatic advantage of stannous fluoride being able to arrest carious lesions or to prevent the subsequent development of additional carious lesions on an already carious tooth shown in recent study in adults (Scola 1965). Two recent studies (Muhler and Mercer, 1964; Scola 1965) have indicated that not only is a single application sufficient to obtain significant caries reductions but, further, that the length of application may be reduced to as little as fifteen seconds in contrast to the four-minute applications recommended for sodium fluoride application.

Multiple Fluoride Therapy

Gish and Muhler (Indiana) reported the results of clinical evaluation of three kinds of topical applications of stannous fluoride to the teeth of approximately 2,200 6 to 14 years of age in an area with a continuous optimal
Fluoride level in the water supply. There were 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 water and a control dentifrice;

3. stannous fluoride prophylaxis, topical application of an 8 per cent aqueous stannous fluoride solution and a control dentifrice;

4. stannous fluoride prophylaxis, topical application of an 8 per cent stannous fluoride solution and the home use of a stannous fluoride-calcium pyrophosphate dentifrice.

After six months and after one year, all three experimental groups showed significant reductions in dental caries ranging from 37-39 per cent when compared with the control group.

Studies using other fluoride compounds topically to assess whether or not compounds other than sodium fluoride and stannous fluoride will satisfactorily reduce human
dental decay showed; for example, lead fluoride failed to reduce the incidence of dental caries when applied topically; potassium fluoride did not appear to reduce the decay rate in children when it was applied in a similar manner; stannous chloride, incidentally, had some effect in reducing the incidence of decay in the rat, proving that tin may be effective in caries control. This was so because when various fluorides compounds when used topically are highly concentrated, as they must be for use in conventional topical procedures, the ionization of the different salts is variable and certainly it is not complete; thus limiting the availability of fluoride ions for reducing dental caries experience.

Method Applying Topical Applications of Stannous Fluoride ($\text{SnF}_2$)

1. A complete oral prophylaxis is mandatory prior to giving this treatment. Special attention must be given to the interproximal tooth surfaces which are highly vulnerable to decay. Gingival trauma during scaling procedures must be kept to a minimum.

2. Isolate one half of the mouth by placing a 6 inch cotton roll on the facial side of the lower teeth and
doubling back in the third molar area and coming forward on the facial side of the upper teeth. Place a three inch cotton roll on the lingual side. Use a cotton roll holder and saliva ejector. Dry thoroughly with warm air.

3. Gelatin capsules containing 1 gram of stannous fluoride must be kept in a jar containing a desiccant as this drug decomposes very rapidly when exposed to air and moisture. When removing capsules for treatment purposes, remove the lid from the jar for only a minimal period of time. Mix the contents of a single capsule with 10 cc's of distilled water stirring with an applicator stick so that all of the stannous fluoride goes into solution. Mix well. The resultant solution will have a colloidal appearance.

4. With a cotton applicator that is not wrapped too tightly, or a pledget of cotton held in a cotton forceps, apply solution to all teeth in the isolated half of the mouth before starting to time the four minute application. Keep the teeth moistened during this time, enough to wet the teeth and interproximal areas. After completing one half of the mouth, do the other side in the same manner.
5. After completing treatment, do not rinse out mouth and ask the patient not to eat, drink or rinse for a half hour period, (despite bitter taste).

6. Do not apply the stannous fluoride solution where an apparent untreated gingivitis is present. This results in a slight sloughing around marginal gingiva. This sloughing appears even in a small percentage of normal cases where excessive instrumentation accompanies the prophylactic procedure. When the slough does appear, it resolves itself in a day or so with no treatment and little or no discomfort.

7. A slight pigmentation may occur in carious areas and, in a sense, acts as a disclosing agent. The healthy tooth surface is not affected.

8. This treatment is also beneficial to adults when incorporated as an adjunct to their oral prophylaxis treatments.

**ACIDULATED PHOSPHATE - FLUORIDE (APP)**

Stannous fluoride has been the most commonly used agent for some time, but during the last two years acidulated phosphate-fluoride has become increasingly popular,
because it has produced promising clinical results, is
tolerated well by patients, and is easy to handle. The
following discussion will present the caries-inhibiting
effect of Acidulated phosphate-fluoride; the rationale for
its use, and to discuss the laboratory evidence for its
mode of action.

The topical studies completed with acid-phosphate-
fluoride show the following results. In the first study,
four three-minute applications of the solutions were given
to the teeth on one side, and four applications of a
similar neutral solution of sodium fluoride without phos-
phate on the other side (Brudevold et al. 1963). The
only difference in the fluoride solutions was the phos-
phoric acid which was added to one of them. Most of the
patients were re-examined after eight or nine months. The
children treated with the phosphate-fluoride solution de-
veloped 45 new lesions; the sodium fluoride group developed
92 new lesions. Thus the increment of lesions was de-
creased about 50 per cent by the addition of phosphate to
the topical solution. This difference was considered to
be a minimal estimate of the relative superiority of the
phosphate-fluoride since cross-contamination must have
occurred and would tend to equalize carious increments on
the two sides.
The second study extended over two years and involved single annual applications with a solution containing 1.2 per cent fluoride and 0.1 M phosphoric acid and having a pH of 3.2. The applications lasted four minutes and were preceded by a prophylaxis. The children were third, fourth, and fifth graders in a public school on Cape Cod. The results showed as highly significant caries reduction of 70 per cent after both the first and second year.

In a third study, a single annual application of the same acid phosphate fluoride and 8 per cent stannous fluoride were compared, again preceded by a prophylaxis. A third group, treated with water, served as a control. Subjects were third and fourth and fifth graders of a parochial school in Boston. After one year the phosphate fluoride solution reduced caries by about 50 per cent. No effect was obtained with stannous fluoride. This negative finding was unexpected, in view of the report by some investigators of a reduction in caries from 14 to 51 per cent from single annual applications. However, recent studies by Torell and Horowitz also failed to show caries reduction from single treatments with 8 to 10 per cent stannous fluoride. At any rate, it is known that considerably more fluoride is deposited from phosphate-fluoride
than from atannous fluoride, so that one would expect the former to be the more effective agent. At the end of the second year the phospho-fluoride brought about a reduction in caries of approximately 50 per cent. This result was statistically significant, but of lesser magnitude than that obtained in the second study (70 per cent), which employed the same treatment procedures and the same examiner. It was felt that this may have been due to a difference in the oral hygienes of the study groups involved. In order to explore this possibility an assessment of oral hygiene was made of the second year participants. It can be found that in both the treated and control groups, caries increments were greater in children with poor oral hygiene. In addition, the reduction of caries as a result of the fluoride treatment was considerably greater in the group with good oral hygiene (60 per cent) as compared to the group with poor oral hygiene (44 per cent). These findings suggest that oral hygiene indices should be determined in caries studies concerned with fluoride.

The fourth clinical study (Wellock, 1965) in still in progress and involves an ultra-rapid method of topical application. It was thought that a fluoride solution might be used by the dentist or dental hygienist in the dental office to rinse the teeth during operative
procedures, or while giving a prophylaxis, and that fluoride could thus be applied without adding to the treatment time needed for ordinary therapeutic procedures. This concept is being tested by giving an annual series of 30-second sprays to the mouths of children. No prophylaxis is given, and the oral hygiene of the children participating in the study is poor. The children (first and second grade 5s) did brush the teeth with a fluoride-free dentifrice prior to the first spray treatment, but the cleansing effect of the tooth brushing was so poor that this procedure was given up as ineffective. The original spray solution contained 1 per cent sodium fluoride in 0.1 M $\text{H}_3\text{PO}_4$, and was used unflavored. The results of three 30-second sprays given over a period of one year are a moderate overall caries reduction of 20 per cent obtained in the permanent teeth. The effect was greater in previously caries-free teeth, 31 per cent as compared to 14 per cent in previously carious teeth. The latter are primarily the highly caries-susceptible six-year molars. It is expected that it is possible that a cumulative effect may occur with an increased number of fluoride exposures after the second year as it is a continuing study. The concentration of the original solution was reduced to one-third and flavor was added.
The fifth study was done by McCombie in British Columbia (1965). The phosphate-fluoride was applied five times during a year by brushing with a toothbrush soaked in flavored solution. A 43 per cent reduction was obtained in the permanent teeth, but no effect was noted in the deciduous teeth.

The results of the above-mentioned Studies are summarized in the following table.

Table 6
Reduction in Caries Obtained with Phosphate-Fluoride Solutions

<table>
<thead>
<tr>
<th>Agent</th>
<th>Treatment Year</th>
<th>Treatment Duration</th>
<th>Study Period</th>
<th>Reduction DMFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pameijer, 2% NaF, 0.15 M H₂PO₄, 2% NaF in H₂O</td>
<td>4</td>
<td>3 mins.</td>
<td>3-15 mos.</td>
<td>50</td>
</tr>
<tr>
<td>Welloch, 1.2% NaF, 0.1 M H₃PO₄</td>
<td>1</td>
<td>4 mins.</td>
<td>1st yr.</td>
<td>71</td>
</tr>
<tr>
<td>Welloch, 2.7% NaF, 0.1 M H₃PO₄</td>
<td>1</td>
<td>4 mins.</td>
<td>2nd yr.</td>
<td>70</td>
</tr>
<tr>
<td>Welloch, 1% NaF, 0.1 M H₃PO₄</td>
<td>3 sprays</td>
<td></td>
<td>1st yr.</td>
<td>49</td>
</tr>
<tr>
<td>Welloch, 2.7% NaF, 0.1 M H₃PO₄</td>
<td>5 brushings</td>
<td></td>
<td>1st yr.</td>
<td>43</td>
</tr>
</tbody>
</table>

* 43% in permanent teeth; no effect in deciduous teeth.

A three-year study was initiated in February (1965) to determine the caries-inhibiting effect of a flavored
acidulated phosphate-fluoride solution and gel. The study population is comprised by 1,100 children in Grades 5 and 6 in six rural schools in Oahu, Hawaii, who had had minimal previous exposure to fluoridated water. Group A (control) received only a prophylaxis annually; Group B received a prophylaxis annually followed by a four-minute topical application of an acidulated phosphate-fluoride solution containing 1.23% fluoride; Group C received a prophylaxis semi-annually, each time followed by the topical acid phosphate-fluoride solution; and Group D received an annual prophylaxis followed by a four-minute topical application of an acidulated phosphate-fluoride gel containing 1.23% fluoride applied in wax tray. Results after one year showed reductions in incremental DMF teeth of 17, 28 and 12% in Groups B, C and D, respectively, compared with the control Group A. Corresponding reductions for these groups in incremental DMF surfaces were 22, 27 and 14%, respectively. It was observed that benefits were greatest in each of the treatment groups on mesial-distal surfaces, ranging from 28% reduction in Group D to 39% in Group C. Benefits to buccal-lingual surfaces ranged from 8% in Group D to 30% in Group C. There were essentially no benefits to occlusal surfaces.
The development of the use of acidulated phosphate-fluoride solution stemmed out from the unique role of F in inhibiting caries and the facts known from data concerned with water fluoridation:

1. Within limits, the resistance to caries is proportional to the amounts of fluoride deposited in the enamel surface.

2. The fluoride deposited from waterborne fluoride is deposited in the enamel as fluorapatite.

The success or failure, therefore, of a topical agent would depend on the extent to which it is capable of depositing fluoride in the enamel as fluorapatite. A topical solution must do the work in terms of second and minutes.

The crystalline structure of enamel is made more stable by the acquisition of fluoride according to the following reaction:

\[
\text{Reaction (1)} \quad \text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2 + 2\text{F}^- \leftrightarrow \text{Ca}_{10}(\text{PO}_4)_6\text{F}_2 + 20\text{H}^+
\]

Enamel hydroxyapatite + fluoride $\rightarrow$ Fluorapatite + hydroxyl (low conc.)

Fluoride competes with and displaces the hydroxyl groups of the hydroxyapatite molecule to form fluorapatite.
Two practical ways of speeding up this reaction are known and have been demonstrated in the laboratory:

1. Raising the concentration of fluoride in solution.

2. Lowering the pH, thus making the solution more acid (rationale for the use of APF).

However, these manipulations may stimulate undesirable side-effects:

1. Increasing the concentration of fluoride may cause the following reaction:

   Reaction (2)
   \[ \text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2 + 20\text{F}^{-} \rightleftharpoons 10\text{CaF}_2 + 6\text{PO}_4^{3-} + 20\text{H}^{+} \]
   Enamel hydroxyapatite + high conc. fluoride \[\rightleftharpoons\] calcium fluoride + phosphate hydroxy

   Calcium fluoride has a different crystal structure than apatite and its formation is associated with the decomposition of the enamel mineral.

2. With regard to the lowering of pH, it is well known that enamel is the presence of acid may break down according to the following reaction:

   Reaction (3)
   \[ \text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2 + 8\text{H}^{+} \rightleftharpoons 10\text{Ca}^{2+} + 6\text{HPO}_4^{2-} \]
   Enamel hydroxyapatite + acid \[\rightleftharpoons\] calcium + phosphate + water
Reactions (2) and (3) are reversible and both result in phosphate as a breakdown product. It was reasoned that the introduction of a substantial concentration of phosphate would shift the equilibrium of these reactions from left to right, yielding intact hydroxyapatite as the principal reaction product. In practical terms this would mean bringing enamel into contact with high concentrations of fluoride at low pH in the presence of phosphate. Hopefully, then, rapid fluoride deposition would occur (Reaction (1)) with no significant enamel breakdown (Reactions (2) and (3)).

Brudevold et al. (1963) studied the dissolving action of acid phosphate-fluoride solutions on intact enamel. He reported that no dissolution was observed, even when the exposure time was several ten-folds that used in topical treatments. Furthermore, large amounts of fluoride were deposited after short periods of exposure, and an appreciable amount of the deposited fluoride appeared to combine with enamel to form fluorapatite.

In one experiment the fluoride uptake by enamel from comparable solutions of phosphate-fluoride and stannous fluoride was studied in two groups of extracted teeth. Approximately three times more fluoride was taken up by
the outermost enamel from the phosphate-fluoride solution than from SnF₂ of the same pH. This finding was not unexpected, since the stannous ion is known to form a coating of hydroxy stannous oxide in the surface enamel which acts as a barrier and depresses diffusion of fluoride into the enamel.

It is apparent from these findings that fluoride is readily available for uptake from acid phosphate solutions, and that in these solutions enamel tolerates high concentrations of fluoride at low pH. Evidently the phosphate in solution has the predicted dual effects of depressing both the formation of calcium fluoride (Reaction (2)) and the dissolution of enamel (Reaction (3)).²³

**Proprietary Pastes**

Early in the history of topical fluoride therapy, Bibby and co-workers⁶, 34, 6 suggested that the use of sodium fluoride in a prophylactic paste might be of significant value. They used a 4 per cent sodium fluoride added in sufficient quantity to a prophylactic pumice-hydrogen peroxide mixture. The cleaning mixture is acidulated to pH₂. They tested this to a group of school children, 6 to 15 years of age, one side of the mouth was
cleaned, in one group of 95, twice, and in one group of 47, three times during the school year, and examined after the period of a year. In those groups treated twice, a 25 per cent reduction of dental caries was observed on the treated twice. In the group treated three times, a 45 per cent reduction was observed. From their results they found only a limited degree of success considerably less than those same investigators noted with topical applications of sodium fluoride.

In 1962, Benkert (USAF) reported a study conducted in their service using atomic fluoride in a prophylactic paste. As a part of their preventive dentistry program for the thousands of people under their care a yearly oral prophylaxis for all Air Force personnel is an important part of this program. This study was made at Johnson Air Base in Japan. In their attempt to develop a method whereby the additional procedure of topical application of fluoride could be eliminated, the Dental Sciences Division, School of Aviation Medicine of the U.S. Air Force, investigated the possibility of developing a prophylactic paste with the atomic fluoride incorporated in it. The formula that proved to be cost effective was a atomic fluoride silico-silicon prophylactic paste, which in laboratory tests,
approximately nine times more effective than a 10 per cent topical application of stannous fluoride in protecting teeth. It can also chemically stable maintaining its original strength over a six month test period. The major disadvantage of the paste was the bitter taste caused by the stannous fluoride.

A field study was made to further test taste acceptance, abrasive characteristics and potential good and bad reactions. Four U.S. Air Force bases were selected as test sites for the prophylactic paste. Johnson Air Base was one of the test bases. The paste was prepared at the School of Aviation Medicine and after suitable laboratory quality control tests were sent to each of the participating bases at two-week intervals.

The formula at its present state of development is as follows:

### Solid Phase

<table>
<thead>
<tr>
<th>Substance</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stannous Fluoride 100%</td>
<td>40</td>
</tr>
<tr>
<td>Silica, extra fine</td>
<td>500 grams</td>
</tr>
<tr>
<td>Sodium borate, USP</td>
<td>50 grams</td>
</tr>
<tr>
<td>Sucreryl</td>
<td>5.0 grams</td>
</tr>
</tbody>
</table>
Liquid Phase

Silicone 20 ml
Liquid Petroleum, USP 60 ml
Oil of Peppermint (concentrated) 5 ml
Oil of Anise (concentrated) 5 ml

The instructions for using this paste are as follows:

1. Before using the paste in a polishing operation, stir paste in a container to work the liquid overly into the solid phase.

2. After placing the desired amount of paste in a deepen dish, absorb the excess liquid with a gauze sponge to desired consistency. This insures a rather dry mix that can be better controlled in the mouth.

3. Very Important: This paste, because of its fluoride content should be carefully used. It should be applied with a soft rubber cup at a relatively low speed (1,500 rpm). After each polishing interval, the mouth should be well flushed with a stream of water followed by a rinse from a cup. Repeat; after each polishing interval, the mouth should be well flushed with a stream of water, followed by a rinse from a cup. This is the same procedure as with pumice, but the suggestion is reiterated to emphasize the practice. Inadequate rinse procedures result in a lingering
bitter flavor, as well as in a greater possibility of gingival blanching.

4. Thorough stripping of the interproximal areas with the paste is necessary to insure the adequate topical application of SnF₂ to this caries vulnerable area. Unwaxed ribbon floss is recommended for use in these areas.

5. Caution: This paste should not be used in cases exhibiting moderate-to-severe gingivitis—the same contraindication as applied to topical applications. In a very few cases where severe blanching is experienced (and this will occur very early in the procedure), use of regular pumice paste followed by a topical application of a 10 per cent SnF₂ solution is indicated.

6. In patients with extensive questionable silicate restorations, the paste acts as a disclosing agent by staining the defective margins.

At Johnson Air Base, this paste has been used too on all school children above the age of 13 with no evidence of staining except in decalcified areas where it, in effect, acted as a disclosing agent. There is a theoretical possibility that with the present high concentration of SnF₂, the less mature enamel surfaces of younger age groups may be more susceptible to staining. In areas of
decalcification, however, there is evidence that the stannous fluoride will arrest the caries processes.

Seven studies (1966) have been conducted using stannous fluoride in a prophylactic paste and these studies have been consistently positive with caries reductions largely between 30 and 40 per cent. Interestingly, these studies indicated a comparable degree of effectiveness in both children and in adults reared in both the presence and absence of communal fluoridation. It was stated that the use of a prophylactic paste containing stannous fluoride will afford a significant degree of protection against the subsequent development of dental caries and warrants consideration as a means of effectively providing fluoride therapy in a caries-preventive program.

**OTHER METHODS OF TOPICAL FLUORIDE THERAPY**

More recent approaches have been used on the use of topical fluoride solutions. The National Institute of Health of the United States recently presented an information of an 80 per cent reduction in tooth decay from a new technic that may revolutionize methods of applying topical fluoride. Englemaner (1967) reported that preliminary field trials with school children, after earlier successful studies with laboratory animals were highly encouraging.
Plastic Mouthpiece (solution or gel applicator)

For a six-minute period each school day, during the two-year study period, the children wore a fitted plastic mouthpiece (similar to an athletic mouthguard) filled with a jellylike material containing 1.1 per cent sodium fluoride phosphate gel. One dental hygienist was able to supervise several hundred children. An advantage of the technic is that it enables a dental hygienist to supervise many more children than is possible with current methods of topical application of fluoride.

Englander and co-workers conducted the study in Cheektowaga, N.Y., which does not have a fluoridated water supply. The naturally occurring fluoride in the town's water is far below the level recommended for the prevention of caries.

The subjects consisted of 500 children 11 to 14 years old. One group of 151 children applied an acidulated NaF gel in custom-fitted maxillary and mandibular applicators for six minutes each school day for two academic years. Another group of 154 children made the same topical applications as the first group, except that a plain NaF gel was used. The control group consisted of 195 children. All children used non-fluoride dentifrice.
After 21 months, the average child in the NaF gel groups had administered 245 daily topical treatments, and the caries increments in the two groups applying the NaF gels were significantly less than those in the control group. Children on the unneutralized NaF phosphate gel developed an average of 1.00 new DMFT and new 1.10 DMFS; those using the plain NaF gel showed 0.90 DMFT and 0.89 DMFS, whereas the children not applying NaF had an increment of 2.75 DMFT and 4.59 DMFS.

Examination of deciduous teeth shed during the study period showed a considerably higher concentration of enamel fluoride from both NaF gel preparations and tended to increase with the number of treatments received before exfoliation. Teeth exposed to the unneutralized NaF phosphate gel consistently showed a greater uptake of fluoride in enamel layers of comparable thickness than teeth subjected to a similar number of plain NaF gel applications.

Urine analysis showed no important difference in fluoride concentration, indicating that the fluoride remained in the teeth where it conferred a protective action.

Many of the children who had rampant caries when first examined developed no new cavities during the study.
Englander said that the new technic should prove especially useful for children with serious caries problems.

The advantage of the mouthguard is that small quantity of the concentrated gel is kept in intimate contact with the teeth and gingiva for a definite time and is forced into pits and fissures. During this time, the gel cannot be diluted by saliva.

A similar study is planned for children in a fluoridated area to determine if the repeated topical application by this technic confers additional protection. A third study to be conducted will determine the results obtained by weekly, rather than daily, applications.

A much earlier study resembling this method was done to a small group of about 40 patients. It consists of making a fluoride bath from hydrocolloid or similar impression material. An impression of the teeth is taken, then the mould is filled with a fluoride solution and placed back on the teeth for a period of twenty minutes or so. The results, however, were essentially negative.

**Electrophoresis**

Bibby and his associates thought of using the
electrophoresis principle for ionic application of fluoride to the tooth surfaces. They got a fairly satisfactory theoretical approach worked out. The idea however, bogs down on a practical point. They found out that the potential necessary to force any significant amount of fluoride into the tooth surface is one which the patient cannot bear comfortably because so far it has not been possible to get the tooth crown bathed in a fluoride solution satisfactorily without having a leakage of the electric current around the neck of the tooth. This causes irritation of the periodontal tissues. They tried to overcome the difficulty, but so far they have not been able to do it.

Fluoride in Filling Materials

It has been shown that soluble enamel may be made less soluble by the continuous application of fluoride-ion releasing agents. Philips (1957) suggested that fluorides be incorporated in filling materials. This would seem an excellent suggestion. His contentions were:

1. A tooth that had already decayed, demonstrates a tendency toward decay.

2. It is theoretically impossible to tell visually how much of the enamel is acid soluble or acid insoluble.
3. After the decay is removed, fill this tooth with a fluoride ion releasing filling material.

4. This fluoride ion releasing filling material will continuously release fluoride ions for a period in excess of 30 days, bathing the margins of the tooth with fluoride ions and theoretically changing these margins into acid insoluble enamel.

According to the same investigator: "The commercial products, FluorOn, resulted in a considerable reduction in (acid) solubility greater than that found for silicates".

Slack (1966) expressed his opinion that all primary teeth that have demonstrated a tendency to decay should be filled with a fluoride ion releasing filling material. These fillings would release fluoride ions over the margins of the teeth, effecting a change in the acid soluble enamel to acid insoluble enamel. Without wear it has been demonstrated that this effect exists for 30 days. However, this effect would be prolonged indefinitely, as the fillings wear slightly and new surfaces are exposed. Such an effect might even become effective on adjoining teeth, into interproximal areas, and on teeth newly erupting and on which such an effect would be increasingly valuable. Certainly all initial decay of first permanent molars should
be so filled and treated, perhaps all primary decay in permanent teeth.

In this way tooth enamel comes in direct contact with released fluorides—providing continuous contact therapy. Since fluoride is taken up in measurable quantities by the primary decalcified areas (Huhler, et al. 1955), the acid soluble enamel will become acid insoluble and less subject to decay.

The outstanding advantage of this new fluoridation method is that by continuous contact therapy, fluorides are put to work directly and for longer periods of time on those areas where decay usually recurs—the filling margins.

This newer, faster method of using fluorides in treatment filling materials augments other methods and is one more step in dentistry's goal to control caries (Philips 1966).

The following is a direct quote in support of the theory:

"The largest amounts of fluoride uptake were observed in enamel samples exposed to silicate and Fluorin. The data indicates that the fluorine content of enamel is altered by exposure to various dental materials. The data clearly indicate
that fluoride in appreciable quantities is leached out of some dental materials and that this fluoride can react with powdered enamel. Certain materials actually reduced the fluoride in the enamel. Tooth surfaces in contact with FluorOn (a resin containing sodium and stannous fluoride) and the teeth immersed in a 2 percent sodium fluoride for 24 hours exhibited the largest increases in fluoride uptake. With few exceptions the data obtained with intact enamel surfaces compare with those found with powdered enamel. FluorOn and silicate cement produced the greatest change in the fluoride content of both powdered and intact enamel. A definite relationship was found between fluoride change and acid solubility of intact enamel.

Since 1957 and the present date, a fluoride ion releasing filling material (FluorOn) has been released on a world-wide scale. Pulp safety and tolerance have been established through clinical use.

Rationale: A tooth that presents a cavity exhibits a tendency toward decay. Such a tooth presents varying areas of acid soluble enamel. Fluoride ion releasing filling materials have been shown to change acid soluble enamel to acid less soluble enamel. Possible Solution: Fill all primary cavities with a fluoride ion releasing filling material. (Philips et al. 1961) 70, 71

DENTIFRICES

A dentifrice is a substance designed to help the toothbrush clean the accessible surfaces of the teeth. Some dentifrices may contribute to the establishment or maintenance of a normal structure or function of the mouth. 36
On August 1, 1960, the Council on Dental Therapeutics of the American Dental Association announced the official "recognition" of a brand of toothpaste containing stannous fluoride as an effective anticaries dentifrice that can be of significant value when used in a conscientiously applied program of oral hygiene and regular professional care. This was for the first time that the use of a dentifrice as a caries-preventive agent was "accepted" by a scientific professional body.27

Since 1960 the American Dental Association has recognized the clinical effectiveness of four commercial fluoride dentifrices and has approved one as an "A" product (crest) and classified the three others as "B" products (Gue, Fact, SuperStripe).28, 29, 30 The difference in rating does not imply difference in effectiveness or action, but reflects the fact that the "A" dentifrice has been subjected to a greater number of clinical trials.62 Listing of products in Group "B" according to the Council, means that there is insufficient evidence to justify their present acceptance, but there is reasonable evidence of their usefulness and safety. It will be noted that all recognized dentifrices contain SnF₂ and that NaF formulation has been given a "B" rating, meaning that there is no evidence that they are effective (Braudevald and Cron, 1967).24
During the past decade much effort has been directed toward development of a therapeutic dentifrice. Dentifrices containing Ammonium and Urea compounds, penicillin, chlorophyllin, tetracyclaines, antienzymes and fluorides (organic and inorganic) were developed and marketed for varying periods of time. Of the various dentifrices formulations, only those containing fluorides have survived rigorous clinical trials (Nikiforuk, 1966).\textsuperscript{44} The reported benefits range from 25-50 per cent.

In 1960, the American Dental Association recognized the stannous fluoride-calcium pyrophosphate containing dentifrices as "an effective anti-caries dentifrice that can be of significant value when used in a conscientiously applied program of oral hygiene and regular professional care". Many investigators (Hord and Ellis, 1951; Held et al., 1951)\textsuperscript{58} have shown that topical applications of fluoride will increase slightly the content of fluorine in the enamel. By means of radioactive fluoride, it has also been demonstrated that fluoride can be taken up by the enamel surface from fluoride toothpaste (Nauman, 1952).\textsuperscript{79} More recently, dentifrices containing fluoride compounds other than stannous fluoride have been tested with promising results.
Finn and Jamison (1963)\textsuperscript{40} reported approximately 25 per cent fewer new decayed-filled surfaces in a group using a dentifrice containing 0.76 per cent of sodium monofluorophosphate, 1 per cent sodium lauroylsarcosinate and insoluble sodium metaphosphate, as compared to a group using a dentifrice containing either 0.4 per cent stannous fluoride and calcium pyrophosphate or 2.0 per cent lauroylsarcosinate and dicalcium phosphate dehydrate.

In a separate study (Coaz et al., 1963)\textsuperscript{43} a daily application by means of a toothbrush of a 6 per cent solution of sodium monofluorophosphate to teeth resulted in a significant caries reduction. At the end of a one-year study, the unsupervised use of a dentifrice containing sodium fluoride and acid orthophosphate in a calcium-free base was found to be more effective than a dentifrice containing stannous fluoride and calcium pyrophosphate (Brudevold et al. 1964).\textsuperscript{22}

Sodium fluoride was the first fluoride agent incorporated in a dentifrice. However, three clinical studies of NaF dentifrices conducted in the period 1945 to 1955 failed to show effects. The lack of effect in this studies could be due to incompatability of the abrasive with NaF. CaF\textsubscript{2} is known to form rapidly from a mixture of NaF
and calcium carbonate and therefore, reduces the availability of the fluoride ion. The negative findings in these early studies point to the importance of excluding from dentifrice formulations ingredients which complex with or inactivate NaF, but they do not prove that NaF generally is ineffective as a fluoride component.

It is now known that a stannous fluoride dentifrice can offer considerable help in the struggle to control dental caries, and two factors have contributed to the success of SnF₂ dentifrices:

1. They have been used in a more compatible formulation than NaF from the beginning;

2. The pH of the dentifrice has been on the acid side, between four and five in order to minimize hydrolysis and inactivation of the stannous ion. This low pH favors the deposition of F in the enamel and thus enhances the F effect.

With the stannous fluoride formulation the final pH of the product is about 4.8, slightly acid to avoid hydrolysis, and yet not so acid as to dissolve Ca⁺ from the abrasive. The product is deaerated during manufacture so oxidation by air is prevented. Each of the raw materials, particularly the abrasive, calcium pyrophosphate, is carefully
tested to make sure that it is compatible; that is it will not react with stannous fluoride. The purpose of the stannous pyrophosphate in Crest dentifrice is to serve as a reservoir of stannous ions to make up for any slight reduction in stannous ion availability that might occur by reaction of trace impurities with stannous fluoride. The stannous ion is very reactive and can react with many substances. Both stannous and fluoride ions are taken up by enamel. The compound probably protects enamel by forming calcium fluoride and stannous hydroxy phosphate, both of which are insoluble in mouth acids.\textsuperscript{47}

The results of the SnF\textsubscript{2} dentifrice (Crest) testing can be summarized as follows:\textsuperscript{27}

1. Normal brushing with SnF\textsubscript{2} (about once per day) will reduce tooth decay about 25\%.

2. Regular practice of good oral hygiene procedure, which means brushing about three times per day with Crest will result in 50\% fewer cavities than those same practices using an ordinary toothpaste.

3. The combination of a SnF\textsubscript{2} topical every six months using normal brushing technique SnF\textsubscript{2} dentifrice will reduce decay almost 60\%.
Acid dentifrice, containing NaF:

Findings obtained in a clinical study of a slightly acid dentifrice containing NaF have been reported recently by Brudevold et al. (1966). The fluoride level is 0.22 per cent NaF. The abrasive used is insoluble sodium metaphosphate, contains no calcium and is compatible with the incorporating NaF. The pH of the product is between 4.8 to 5.2 which is in the same range as the SnF₂ formulation. The ages of the participants in this study range from 11 to 17 years. The toothbrushing was done at home on a voluntary basis. The results after two years show a significant reduction in DFS suggesting that the fluoride in these dentifrices was most readily available with the calcium-free formulation. Caries reductions of approximately 20 per cent was observed which are closely similar to those obtained from unsupervised brushing with SnF₂ dentifrices.

It appears from all these findings that compatibility with F is the important factor in regard to effectiveness, and that the type of fluoride agent used is of less significance, at least at the present stage of development of dentifrice formulations.

Clinical Testing of Stannous Fluoride Dentifrices:

Clinical testing of stannous fluoride dentifrices in
different formulations have been reported by various investigators in the United Kingdom. Slack et al. (1967)\textsuperscript{81a} reported the results of a double-blind controlled unsupervised clinical testing lasting three years to test the efficacy of a stannous fluoride insoluble metaphosphate dentifrice in preventing dental caries. Eight hundred girls in the County of Kent at the starting age of 11 years were the participants. After three years, significant differences of 27 per cent were shown by clinical analysis for DFS and D.F.T. of erupting teeth. However, the radiographic analysis showed highly significant reductions of approximately 30 per cent in caries increment, representing about one and one-third approximal surfaces. It is possible that the preventive fillings would mask the beneficial effect of the agent being tested. This may account, in the clinical analysis, for the fact that the difference is significant when considering the newly erupting teeth, but this would also tend to depend on the treatment services available in the trial area. The findings in this study support those of Horovitz and Petersen (1966)\textsuperscript{50a} who showed that the protective effect of fluoride was found to be more strikingly apparent on approximal than on occlusal or buccal and lingual surfaces.

By 1960 only five of clinical trials on dentifrices
had been reported and there was considered at that time a need for independent trials to be carried out in the United Kingdom. Therefore, three independent trials were planned in 1961 and were commenced in 1962: one was in Buckinghamshire, another in Essex and a third in Yorkshire. In each study both the control and experimental dentifrices were made and packed under normal operating conditions. In each trial the age of the subjects was in the range of 11 to 12 years of age and home visits were used to enhance co-operation and distribution of dentifrices.

James and Anderson (1967)\textsuperscript{54b} reported the results of a double-blind clinical trial to determine the effect on dental caries incidence of the use of stannous calcium pyrophosphate dentifrice among children aged 11 and 12 years in Buckinghamshire school. Lower dental caries increment was consistently demonstrated over the three year testing period than the control children. Reductions of approximately 35 per cent in boys and 49 per cent in girls were obtained. Dark staining of debris and plaque material was significantly higher in the test group children.

Slack et al. (1967)\textsuperscript{81b} supported previous findings and that radiographic analysis enhanced significant beneficial effects of the stannous fluoride-calcium pyrophosphate
dentifrice. In a double-blind controlled clinical trial of the unsupervised use of the dentifrice among 961 girls in the County of Essex significant caries reductions were observed after three years. After one year, bitewing radiographs showed a 17 per cent difference of DMFS in the posterior approximal tooth surfaces, a 31 per cent reduction after two years and a 36 per cent difference after three years.

The last of the three independent trials was conducted by Jackson et al. (1967)\textsuperscript{34a} in the West Riding of Yorkshire in order to test the claimed anticariogenic properties of a stannous fluoride-calcium pyrophosphate dentifrice. The trial was a double-blind three-year testing carried out on 438 experimental subjects. The participants were encouraged by continuous dental health education to clean their teeth regularly. After three years the only certain reduction in caries increment was observed on the mesial and distal surfaces of incisor teeth and here there was a reduction of 50 per cent. It was considered that the placing of fillings at a very early level of caries progression (possibly preventive fillings) masked any effect which the dentifrice may have had on pit and fissure caries. It was also observed that in spite of the
fact that the study incorporated a dental health education program, there was no observable improvement of oral cleanliness or of gingival health from the baseline condition.

Another double-blind controlled clinical trial of three years duration done in London (Naylor et al. 1967)²⁵ to test the effectiveness of the unsupervised use by 11 to 12 year-old children of tooth pastes containing stannous fluoride and sodium monofluorophosphates. The results showed that both these pastes produced significant reductions in caries experience as compared with the control pastes, the reductions being greatest in respect of new carious surfaces in teeth which erupted during the study. Greater reductions were demonstrated in the monofluorophosphate group, than the stannous fluoride group, but the differences between the two fluoride pastes were not significant.

A double-blind controlled clinical trial has also been conducted with the use of stannous fluoride and sodium monofluorophosphate dentifrices in Adelaide, Australia (Gottmanos et al. 1967). The group to be studied, ranging in age from 11 to 16 years at the beginning of the trial, was specifically selected because the maximum number of permanent tooth surfaces are at risk to dental caries within this age group.
The trial extended over three years, the subjects being examined twice in 1964, once in 1965 and once in 1966. The purpose of the first examination was to determine the existing caries experience, so that the children could be assigned to comparable groups according to their D.C.P. surface scores.

The results reported in the first year of the trial none of the incremental differences between the groups using different dentifrices is significant. On the other hand, during the second year and over the two-year period, the increase in caries is significantly lower in groups using otannous fluoride and sodium monofluorophosphate dentifrices than in the group using the control dentifrice. The findings showed that the two fluoride dentifrices, when compared with the control, resulted in 25% to 30% fewer new decayed tooth surfaces on the average after the study.

**FLUORIDE TOUGHRASIES**

Bibby and co-workers\textsuperscript{11} envisioned a procedure which would not only be more effective but would also be simpler so that it could be more generally used both in dental practice and as a public health method. They initiated laboratory and clinical investigations on other methods of topical
application of fluorides and the use of fluoride mouthwash was one.

Atkins first recommended the use of a sodium fluoride mouthwash. He used a mouthwash containing about four parts per million of fluoride applied after a thorough brushing after meals. He reported that on the twenty patients he observed, he found 87 per cent reduction in the lactobacillus count in the group. Bibby et al. set up another study, using 31 students with a mouthwash they prepared. The mixture was made with a buffered sodium fluoride solution at pH 4, with a control mouthwash at pH 4 without the fluoride, and the students used it. This time they had the idea of acidulated fluoride. It was pretty potent because they received complaints from the students and their landladies were complaining that it etched the sinks where they washed their mouths. The results in this group of 31 patients were negative when compared with 29 controls; no reduction of dental caries.

Not entirely discouraged by their first result and thinking that the effect of fluoride might be more potent in youngsters than in mature students, Bibby and co-workers felt it necessary to set up a study with a younger age group. In this study they had a more acceptable mouthwash.
compounded by the Upjohn Company, who supplied it for them. The mouthwash was very pleasant; it tasted very much like orange juice, and they were a little bit frightened that children might want to drink it, for it tasted so nice. The mouth washing was done under supervision. A period of one year, 187 children used this mouthwash under supervision; they had a group of 157 children who used a fluoride-free acidulated mouthwash as control. The examinations were double checked by examiners who didn't know what groups they were examining. What results did they get? After the use of this mouthwash for one year, there was not a decrease, but an increase of 32 per cent in the mouthwash group, a 32 per cent increase in DF teeth in the group using the acidulated fluoride mouthwash. These results contradict the laboratory studies that the solubility-reducing effect of fluoride was stepped up when used with an acid medium. Basing on the clinical findings and animal studies they made, it would seem that the acidulated fluoride used as mouthwash, or used as direct applications on the enamel, is deleterious to the teeth. They accounted this thing on the studies on the mode of action of acidulated sodium fluoride on enamel (Sae and Clegg) have shown that a precipitation or a layering of calcium fluoride occurred on the tooth surfaces, and this layering of
calcium fluoride on the tooth surface presumably has resulted from their treatments with acidulated fluorides, and is not effective in reducing dental caries. They further commented that perhaps if neutral fluoride solutions were used they may get what other investigators have maintained, a change of the hydroxyapatite of the tooth surface to a fluorapatite. And this is the structure that resists dental caries.

A certain study conducted by Weiss, wherein he reported caries reductions of 80 to 90 per cent after two to ten years of regular usage of a 0.25% sodium fluoride mouthwash twice daily in children 5 to 9 years of age.

Berggren and Welander reported their results on the use of a 1 per cent sodium fluoride solution applied nine times during two consecutive school years for four minutes each time using a toothbrush as caries reductions of 25 to 39 per cent at the end of the study period, although it was noted that the reductions occurred largely in the maxillary teeth. Torrell and Siberg (1962) reported caries reductions of 21.3 per cent in school children after one year's use of a mouthwash containing 0.25% sodium fluoride. The mouthwash was used once each month for a three-minute period under supervision. In the same study the same
investigators failed to find any beneficial effect from the use of a 0.2 per cent potassium fluoride. Torell and Ericsson (1965) reported a 34.4 per cent reduction in caries in a two-year study in children following the daily use of a 0.05 per cent sodium fluoride mouthwash, but only a 7.6 per cent reduction when a 0.2 per cent sodium fluoride mouthwash was used at two-week intervals.

The most prevalent method of using fluorides against caries in Sweden is mouthwashing with a sodium fluoride solution, often in connection with visits to the dentists of the Public Dental Health Service. Mouthwashes also are administered by teachers and nurses. Generally, they are given every second week.

It appears that subsequent research may indicate mouthwashes to be of value in the control of dental caries. We should note, however, that the presence of such mouthwashes containing relatively high concentrations of fluoride in the home may represent a potential health hazard from a toxicity viewpoint and therefore should not be used indiscriminately. Proper precautionary measures must accompany the mouthwashes whenever dispensed.
SUMMARY ON THE ANTICARIGENIC EFFECTIVENESS OF TOPICAL FLUORIDES

In order to give some idea of the relative effectiveness of the most frequently used topical agents, the results of studies involving the various techniques in which they are employed have just been presented although not very detailed.

Several laboratory and chemical studies conducted to test the effectiveness of the different agents and that they indicated some advantages and disadvantages over one another. Exposures of the teeth surfaces to topical fluoride agents somehow show a like difference in reactivity in different teeth and in different areas on the same tooth. Few important factors that contribute to tooth reactivity on topical applications are:

1. Tooth age - fluoridization was found to be more pronounced in teeth of persons under 18 than in persons over 20 years of age.

2. It was observed also that removal of bacterial plaques and deposits from the tooth surfaces by means of an abrasive substantially increased the uptake of fluoride.
3. It has also been demonstrated that acid etching of the enamel surface prior to fluoride exposure increases the uptake of fluoride which probably results from the removal of organic matter from the enamel surface as well as from increase in surface area brought about by the abrasive or the etching.

It is therefore convenient to review after the information on fluoride uptake by the enamel surface the mechanism of fluoride fixation. It was originally believed that the mechanism of fluoride fixation by the enamel was primarily one of absorption. Considerable evidence has subsequently accumulated suggesting that a chemical reaction is also involved and that the nature of the reaction depends on the concentration of the fluoride solution, which could be summarized as:

1. High fluoride concentrations result in deposition of fluorine as calcium fluoride.

2. A different mechanism of fluoride fixation has been found to operate when the concentration of fluoride is low, that is, fluorine has been found to be deposited as fluorapatite and not as calcium fluoride even in severely mottled enamel.
It may be that topical application of fluoride brings about a slight increase in the fluoride content of the surface enamel. There is evidence to show that the reaction involved is based on an ion exchange between the fluoride reagent and the enamel hydroxylapatite with formation of calcium fluoride and fluorapatite. The mechanism by which fluoride exerts its topical effect to reduce dental caries has not been conclusively established but the theory that it is primarily one of reducing the acid solubility of enamel has been strongly favored.

Important variables to consider in the use of topical agents include therefore the following:

1. age of the group
2. fluoride solution used
3. concentration of the solution
4. presence and absence of dental prophylaxis.

Birby found that as the pH of the solution was lowered, fluorides were absorbed more effectively. He also found that of the several fluoride solutions tested, sodium, potassium and ammonium appeared to have the same absorption qualities, whereas calcium fluoride was ineffective. Philips and Muhler also showed that as the pH of the
sodium fluoride is lowered, the amount of fluoride absorbed is increased. They concluded that the optimum pH was about 2.6, and that this pH was not low enough to damage tooth tissue.

Many agents which have been effective in reducing enamel solubility ultimately have failed to reduce caries in clinical trials, as can be seen from the following table, which lists various topical agents according to effectiveness. For example, stannous sulfate has been reported to protect enamel against acid dissolution as effectively as SnF$_2$.$^{45}$ Yet only the latter is capable of reducing caries. Among the different fluorides, ferric fluoride, Zirconium fluoride, stannous fluoride, and lead fluoride have been shown to reduce acid solubility of enamel to a greater extent than NaF, but none of these fluorides, with the possible exception of SnF$_2$, have been more effective against caries than NaF. It also seemed apparent that the acid solubility tests often used in the laboratory for the screening of potential topical agents may be inadequate; (Table 7).
### Table 7

**Fluoride and Fluoride-Free Salts Used in Topical Treatments**

<table>
<thead>
<tr>
<th>Effective</th>
<th>Ineffective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium fluoride</td>
<td>Silver nitrate</td>
</tr>
<tr>
<td>Potassium fluoride</td>
<td>Zinc chloride</td>
</tr>
<tr>
<td>Lead fluoride</td>
<td>Lead fluoborate</td>
</tr>
<tr>
<td>Stannous fluoride</td>
<td>Stannous sulfate</td>
</tr>
<tr>
<td>Zirconium fluoride</td>
<td>Indium nitrate</td>
</tr>
<tr>
<td>Ferric fluoride</td>
<td></td>
</tr>
</tbody>
</table>

There is evidence that a preliminary prophylaxis or thorough cleaning of the teeth greatly increases the effectiveness of the treatment program. The actual technic of application does not seem to be very important although there is some evidence that the use of careful drying and meticulous application procedures gave somewhat better results than procedures of a simpler sort. Although it has always been demonstrated that topical fluoride applications will be more effective in newly erupted than in old teeth, there is good evidence shown that the procedure is effective in adults.\(^{56, 77}\) The period of time between fluoride applications may have some bearing on the type of results obtained, but there is ample evidence that the procedure of giving single applications at intervals of three or four
months will be as beneficial as that of giving four treatments in a period of a few weeks following a single prophylaxis.

Patients should be told that topical fluoride treatments should not be expected to prevent all dental decay but merely to reduce its activity by approximately 40 percent; if a greater reduction is expected, disillusionment is certain. The period of time over which fluoride treatments will exert a beneficial effect is not definitely known, but it has been shown that some beneficial effects persist for more than three years after a series of treatments. 10

The possibility of fluoridated mouthrinse, prophylactic paste or a dentifrice used for any prolonged period of time in dental caries reduction have not yet been significantly demonstrated when employed solely for the purpose. Because toothbrushing in most populations is an irregular and somewhat haphazard procedure, the use of therapeutic dentifrices applied by toothbrushing tends to yield results which are considerably less than anticipated on the basis of initial laboratory evaluations. In spite of the limitations of present efforts to reduce dental caries by the use of dentifrices, it is highly possible that improved
formulations will be developed and that therapeutic 
dentifrices will become a more effective means of partially 
reducing dental caries. For the present the use of Dentifrices which contain and do not inactivate fluoride ion in 
conjunction with regular and judicious toothbrushing may be 
expected to produce modest but significant reductions in 
dental caries.79

The therapeutic and anti-caries properties of fluoride 
dentifrices cannot be deduced or based on the evidence 
indicating the effectiveness of fluoridation, fluoride 
dietary supplementation or topical fluoride application 
using solutions. All claims for effectiveness should be 
supported by adequate clinical trials. There are published 
evidences which could support the claim made for dentifrices 
currently available in the United States, United Kingdom and 
Australia. By "Adequate" - the Australian Dental Associat-
ion meant that the evidence must be derived from a proper 
clinical trial and as a guide to such trial the body 
recommends the conditions which have been set out in 
publication "The Testing of Caries Preventive Agents", 
prepared by the Council on Dental Therapeutics of the 
American Dental Association.69

Most of the studies show a reduction of dental caries
in varying degrees and therefore lend credence to the value of fluorides in dentifrices. A maximum anticaries-genic effect is obtained when the fluoride dentifrice is used in conjunction with topical application of fluoride. The uses of fluoride toothpaste likewise appear to add to the benefit derived from the systemic ingestion of fluoride from communal water supplies. The latest study indicates another big step in dentistry's effort to eliminate dental caries by utilizing a fluoride phosphate combination which was proven to be effective than the present stannous fluoride both for topical application and as an ingredient in dentifrice.

Galagan (1959)\textsuperscript{90} summarized the situation concerning topical applications of fluoride:

"... there has been confusion and doubts about the place of topical fluoride treatments today, and they have not been used as extensively as they should have been.

If topical fluoride treatments are to be used effectively to reach more of the 29,000,000 children (in U.S.A.) children not covered by water fluoridation (not even considering those who could benefit to some limited extent by topical fluoride treatments during the early years of community water fluoridation program), we shall have to take action in the following ways:

1. Allow auxiliary personnel legally and actually to apply solutions, and provide
for the necessary training of the additional personnel required for more extensive use.

2. Develop simpler and more effective techniques of application.

3. Develop more community programs to bring the benefits of topical fluoride therapy to large groups of children on an economical and practical group basis."

Young and Striffler (1964) reckoned that there are three serious drawbacks to the program of topical application:

1. it is not as effective as water fluoridation;
2. it is costly in terms of dollars; and
3. it requires the services of trained people who may be in short supply.
SUMMARY

Dental caries, probably man's most common ailment, generally begins soon after the teeth erupt and mounts steadily and relentlessly as long as teeth remain. Teeth become carious in the average person at a rate of about one per cent in children and young adults, with the rate slowing down thereafter to about one fourth per year, partially because, fewer teeth remain eligible for attack.

In the protection of oral health there are only two approaches:

First, to prevent the dental disease and;

Second, to provide treatment once the need arises.

It is obvious to all of us that we can never in our lifetime attempt to control dental disease by means of corrective treatment after the patient is afflicted. The solution to the problem of conquering dental disease obviously lies only in the mass application of preventive dentistry techniques to the people of the world which do not require the professional skills of the dentists but only their leadership and guidance.

Control of dental caries could be accomplished by
1. decreasing the forces which tend to cause caries, or

2. by increasing the resistance of the tooth to the attacking forces.

One example, the limitation of fermentable carbohydrates in the diet or the practice of good oral habits may decrease the attacking forces, and the use of fluorides systemically or topically may increase tooth resistance.

A definite relationship between fluorides and dental caries has been established relatively recently, but only after considerable field survey studies had been made.

The pioneer of fluoridation studies were carried out in Grand Rapids, Michigan; Newburgh, New York; Brantford, Ontario; and Evanston, Illinois. Their success has already been noted, but little attention has been paid to the patterns or degree of caries inhibition which resulted.

It is also maybe expected that children born in a community with a fluoridated water can expect a lifelong protective effect, provided they continue to use a water with optimum fluoride (1 p.p.m.). Studies of adult populations living in areas where the water contains an optimal concentration of natural fluoride showed a similar
decrease in the prevalence of decay, and that the effects of fluoride in reducing decay continue into adult life without diminution.

Fluoridation is endorsed by:

THE WORLD HEALTH ORGANIZATION.

In the United States of America:

The United States Public Health Service
The American Medical Association
The American Dental Association
The National Research Council
The Commission on Chronic Illness
The Association for Advancement of Science

In Canada:

The Ministry of Health
The Canadian Medical Association
The Canadian Dental Association
The Canadian Public Health Association

In Great Britain:

The British Ministry of Health
The British Medical Association
The British Dental Association
The Royal Society for Health

In New Zealand:

The New Zealand Health Department
The New Zealand Dental Association
The New Zealand Medical Association

In Australia:

The Australian Medical Association
The Australian Dental Association
The Australian National Health and Medical Research Council
All the State Health Departments with the exception of Victoria.
This public health measure has also been endorsed in Holland, Singapore, Taiwan and other countries.

The safety, effectiveness and practicability of controlled fluoridation of the drinking water as a public health procedure for reducing the incidence of dental caries by two-thirds is firmly established. The procedure was approved by the FDI in 1953 and continues to be the first choice method where communal water supply systems are available. Although the alternative vehicles for using fluorides for dental caries prevention are much less supported by research and experience than water, their selective use is approved by the FDI and should be actively promoted where piped drinking water is not available or where the communal supply is not being fluoridated.

Fluorides can be used to prevent dental caries by means of one or several of the alternatives to water fluoridation as shown in the following table:

<table>
<thead>
<tr>
<th>Fluoride Administration</th>
<th>Systemic</th>
<th>Topical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>Fluoride tablets</td>
<td>Fluoride solutions</td>
</tr>
<tr>
<td>Group</td>
<td>Fluoridated salt, flour, bread, rice, milk or sugar.</td>
<td>Rinsing or brushing of the teeth with F mouthwash and F toothpastes.</td>
</tr>
</tbody>
</table>
Although the most exacting method of providing a measured amount of fluoride through the ingestion route is by the use of fluoride tablets or drops, the requirements of individual attention and supervision, the cost and the problems of distribution sharply limit the public health effectiveness of this alternative method. The anticariogenic value of tablets has been demonstrated, however, and their selective use is recommended.

In general the staple foods, such as salt, flour, bread and rice, are the preferable alternative vehicles for the systemic administration of fluorides because they give most promise of simulating the effects of water-borne fluoride. Among these salt is the universal nutrient; it has been most extensively tested and is the current choice.

Topical applications of fluoride to the teeth (fluoridization) offer the most effective preventive measure available for community use in the absence of water fluoridation. The two most popular solutions used for this purpose are sodium fluoride and stannous fluoride. The results of the studies that directly compare the two compounds indicated a very pronounced superiority of the stannous salt over the sodium fluoride. By far the majority of the clinical investigations conducted indicated that
stannous fluoride is more effective in children, as measured by reductions in subsequent caries development within the magnitude of 40 to 60 per cent in both deciduous and permanent teeth. One must recall too that that said compound has been shown to be of significant value in adults as well and in residents of areas already enjoying the benefits of a fluoridated water supply at the optimal level; that the degree of protection is in addition to the beneficial influence of communal fluoridation.

Partial substitutes for community water fluoridation and topical application of fluoride in some communities include dietary fluoride supplements, fluoride tablets, fluoridated mouthwashes, dentifrices and the like which could either exert systemic or topical effect. It would seem then, that dentists have a responsibility to encourage such measures when the best source of fluorides, community water fluoridation, is not practical.

The results of investigations too numerous to mention testify to the value of providing optimum levels of water-borne fluoride to children during the period when their permanent teeth are calcifying and maturing for reducing the prevalence of dental caries. The increasingly widespread utilization of communal fluoridation should
ultimately alter the dental health of the nation, especially for the children using such water. It would logically follow that such an alteration in a large segment of the population would result in changes in dental practice. Dentists in fluoridated areas were placing less emphasis upon repair and more upon prevention and maintenance and pedodontists reported that fluoridation enabled them to see more children in their practices since they required only minimal treatment. Because of this, the pedodontists were able to devote more time to interceptive orthodontics, growth and development work, and other preventive aspects of dentistry.
CONCLUSIONS

I have attempted to present a series of studies which have tried to conquer dental decay in the human race with the use of fluorides. None of these is new; it simply reviews what other people have said. It is becoming, however, that each year there are growing accomplishments toward this goal.

While it is evident that fluoridation is the method of choice for the partial prevention of dental caries for children living on a communal water supply, there remains an increasing number of children who are not benefiting from drinking a water supply with optimum fluorides. Most of these children live in rural or suburban areas. Topical applications of fluoride to the teeth (fluoridization) offer the most effective preventive measure available for community use in the absence of water fluoridation.

The selection of preventive or therapeutic measures involves:

1. first, the consideration of safety, since caries is not a fatal disease, and people can live without their teeth, it is not justifiable to use drastic methods or drastic materials to control caries. Therefore, it should be harmless;
2. the simplicity of the method is important;
3. it should be acceptable to the public;
4. the procedure should be available to the public.

Fluoridation of the water supplies will affect only perhaps half of the population because only about half of the people get their water from a general public supply. Any advice that is given out with regard to tooth brushing, the use of a fluoridated mouthwash or a dentifrice; oral hygiene, will only affect about a quarter of the population, or perhaps a little more at this time because only about a quarter of the people brush their teeth regularly. Topical application of fluoride in the dental office would be available only to those who visit their dentists.

Caries-prevention does not in itself lead to oral health. The single or multiple use of preventive methods, still leaves one remaining fact. Children's teeth still decay! Fluoridation, despite its overwhelming advantages, is no cure-all. Even if we find a completely effective means of preventing caries, the dentist will still be needed. Methods known to be effective should be used until better methods are established through the continuing
process of research. Any method for control of caries must be accepted by the profession and the public before it will be practically effective.
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