Liquid Vehiclies:

One would obviously first list drinking water under the heading of liquid vehicles. The formulation and subsequent ingestion of home fluoridated water is a procedure which most nearly duplicates municipal fluoridation in principle. The practical details for home preparation of drinking water containing one part per million of fluoride ion is as follows: 52 (table 2a)

<table>
<thead>
<tr>
<th>Natural Fluoride ion Content of Existing Water PPM</th>
<th>0-0.25</th>
<th>0.25-0.50</th>
<th>0.50-0.75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoride Solution (1 mg. F/mL)</td>
<td>1.0 mL</td>
<td>0.5 mL</td>
<td>0.25 mL</td>
</tr>
<tr>
<td>Sodium Fluoride Tablet (0.5 mg. F/tab)</td>
<td>2 tabs</td>
<td>1 tab</td>
<td>0.5 tab</td>
</tr>
</tbody>
</table>

* Prepared by dissolving 2.20 gm. of sodium fluoride in 1 liter of water.

If this water is used for all drinking and cooking purposes, the method would duplicate communal fluoridation and as such would be expected to yield results similar to municipal fluoridation programs.

Because of the knowledge already available regarding fluoridation, it would seem that bottled fluoridated water
is the only form meriting serious consideration as a source of fluoride supplement, whereby fluoridation could immediately reach communities without a communal water supply. It is possible, however, that this vehicle, although the most ideal on such might be too costly on a source of water supply, in view of the expense of bottling and distribution. Again it would demand constant conscientious effort from parents if it were to prove effective. It is not a practical public health measure. It would almost be more feasible to provide bottled non-fluoridated water for those who objected to receiving fluoridated mains water.

Bottled fluoridated water has been sold in some areas of the United States. Some fluoridation equipment for users of private wells have been designed also which is effective if properly maintained and adjusted periodically. A competent service organization might be able to furnish this service at a cost of about $3.00 per month, given a sufficient number of customers.

It would be more difficult to control the addition of fluoride to milk than to a public water supply. No work has been done to show that fluoridated milk is effective
in reducing caries prevalence. The pros and cons of adding fluoride to milk has been discussed in a report. Erickson (1955) stated that the incomplete diffusibility of fluoride in milk may be one of the factors which delay its absorption from this vehicle. Another and perhaps more important causative factor may be the coagulation of the milk in the stomach. The liberation of calcium ions following the acidification and the digestion of the milk protein may also give rise to a precipitation of calcium fluoride which has a low solubility even in the lowest pH range occurring in the digestive tract. If a local action of fluoride in foods and beverages on enamel surface is of importance for the prevention of caries (which is indicated by some investigations: Mill & al. 1955, 1957; Noyes & al. 1957) the incomplete ionization of the fluoride milk may possibly also decrease the cariostatic efficiency according to this mechanism.

Caries inhibition has been reported in very small groups of children who used a fluoridated milk. Klindor and Caldwell (1955) noted that less fluoride was metabolically available when ingested in milk as compared to water. Light and co-workers (1958) have suggested that the use of fluoridated milk resulted in complete caries prevention in c
study involving a single family. Kopel (1961) reported that the provision of children six to ten years of age with 1 mg. of fluoride added to a half pint of milk provided with the school lunch resulted in an 80% reduction in the incidence of dental caries. Rusoff and co-workers (1962) have similarly reported a marked reduction in the incidence of caries in children given fluoridated milk. Very little data are available and much additional information is needed regarding the variation in the amount of ingestion of milk and further evidence of efficacy prior to the establishment of this procedure as a substitute for fluoridation; such a procedure is not to be recommended.  

Furthermore, the intake of milk during the first year of life would depend on the extent to which the babies are breast fed. Human milk contains only traces of fluoride, the highest concentration found in one study being 0.09 p.p.m. This means that a nursing baby drinking approximately 500 cc of milk in one day would receive only the negligible amount of 0.045 mg. of fluorine per day. This suggests that supplementary fluoride through water or baby food should be considered. Though whole fresh milk is an inadequate source of fluoride, for the developing enamel of any age, it must be pointed out that formulas made by dilution of condensed milk with fluoridated water provide substantially more fluoride than the original milk.
Next to be considered in the mechanics of mixing fluoride with a liquid food vehicle would appear to be simplest in the case of juices and soups. These vehicles are in themselves contributing valuable nutrients. In addition for low cost, they are conveniently marketed and stable and are used relatively extensively by various age groups without tending to be consumed in excess.

Food Vehicles:

The use of vehicles other than the liquid ones have been explored by Pearlman (1953)\textsuperscript{72} Much thought has been given to methods for making the benefits of fluoride available to people who cannot use a communal water supply, where the water actually used is consistently virtually free of fluoride, and utilization of the vehicle is under effective control. In 1960 fluoridated table salt was made available in about half of the cantons of Switzerland. Cases was inhibited but to a lesser degree than would have resulted from use of a fluoridated water at the same ages, in a group of 662 children whose use of the salt at the age of four or five years.

Few more investigations have been carried out concerning the efficacy of fluoridated table salt as a means of controlling dental caries. Herthaler (1961) has studied
the effect of the consumption of fluoridated salt on the permanent teeth of children in Zurich. He found a 22 percent reduction in DMF index after 4½ years use of such salt in children aged 4-4½ years at the beginning of the study. It would not be practical to be advocating this because no exact information is available with regard to the consumption of salt in various age groups. It is not even certain that this vehicle would serve the purpose in infants and young children.

One big project on fluoridated salt is on the way in Colombia being supported by a grant from the National Institute of Dental Research. Four villages, each within 30 miles of the city of Medellin, Colombia, are the sites of a long-term study to be conducted by a team of physicians, dentists and nutritionists from the University of Antioquia in Medellin. These villages are ideally situated for such a study. Natural fluoride is scarce, dental decay is universal, and rural areas lack public water supplies. Children entering school at the legal age of eight already have, on the average, more than four decayed, missing, or (occasionally) filled permanent teeth. There are few dentists to prevent or to repair so much damage.

The populations of the villages are practically
immobile and stable. They all live in the same climate, come from the same racial stock, have the same socio-economic levels, customs, occupations and food habits. The staple diet is sugarcane.

The salt used in the study is a government monopoly. It all comes from the same mines and is sold in bulk, therefore, the source is controlled and each amount is recorded. For baseline information a census has been taken and a careful dental and nutritional survey has been made in each town. The two study groups will be issued salt to which calcium fluoride will be added in one case, and sodium fluoride in the other. One group will continue to live as in the past during the several years of the project. Another group, fortunate enough to have a central water supply, will drink fluoridated water. In this way it is hoped to learn whether salt can be as effective as water in providing protection, and which variety of fluoride additive is most effective.

Participants' teeth will be inspected each year to determine caries activity, and general health status will be noted. Radiographs of the hands will be taken at regular intervals to determine whether the fluoride is effective in retarding bone thinning.
Additives for the preparation of foods may contain significant amounts of fluoride. Thus, Churchill, Rouley and Cartin\textsuperscript{34} reported 19 and 220 p.p.m. fluoride in two different samples of baking powders.

Flour is widely used also as a carrier for nutritional supplements. According to the British Study, the consumption of cereal increased from approximately 2 oz. in the twelve year old. The consumption of bread showed roughly the same quantitative increase with age. Consequently, the average intake of fluoride, if added to flour, bread or cereal would come near to the desired increase with age from infancy to adolescence.\textsuperscript{66}

In case of sugar, it is felt that this substance is liable to wide variation and excess in usage and would neither satisfy the requirements of uniformity of use or of self-regulatory control.\textsuperscript{79}

Tablets:

Several clinical experimentations with the administration of fluoride tablets have been done almost entirely in Europe for the past twenty years in order to investigate the effectiveness of this procedure.

Beneficial effects were reported\textsuperscript{6} by Strem and
Boucot (1945) in their three separate studies using calcium fluoride tablets in both the presence and absence of vitamins C and D. The fluoride tablets contained 5 mg. calcium fluoride (1.46 mg. fluoride), while the vitamin tablets contained 30 mg. ascorbic acid and 400 I.U. vitamin D (as calciferol) in addition to the fluoride. They noted significant reductions ranging from 27.9 to 62 per cent in dental caries in all subjects receiving the tablets regardless of vitamin content and further noted that reduction in the incidence of dental caries was enhanced by the presence of vitamins. Pollak (1961) similarly reported findings of 38 per cent reduction in dental caries in 2,000 children three to five years of age who had ingested a sodium fluoride tablet containing vitamins A, D, and C for three years. However, Busefalen et al. failed to find any anticariogenic effects associated with sodium fluoride tablets containing vitamins A, C, and D and calcium.

Cobler et al. (1966) study conducted at Indiana University showed that the ingestion of chewable vitamin-fluoride tablets, containing sodium fluoride and vitamins A, C, and D and certain members of the vitamin D complex, may provide a substantial reduction in the prevalence of dental caries in the deciduous dentition, when instituted
to children ranging in age from birth to five years.

Other studies conducted on this aspect include: 6 in Hesse, Germany (1951), 22 to 40% dental caries reduction was observed among 50,000 children, six to eight years of age. Abary-Curillo (1952) reported significant caries reductions with calcium fluoride troches. Held and Piquet (1954) reported significant caries reductions after three years of ingestion of either a sodium fluoride tablet or a tablet containing bone meal in the permanent dentition of children five to six years of age at the start of the studies. Bibby and co-workers (1955) in their studies on children given sodium fluoride lozenges reported a 40.3 per cent reduction in caries, although no effect was noted in subjects provided the fluoride in a pill formulation. Binder (1958) reported a 35.1 per cent reduction; Kessler and Solth (1958) found 33 per cent reduction, following the use of sodium fluoride tablets in both studies. Arnold and co-workers (1960) found that the daily use by 121 children, 4-15 years of age, of sodium fluoride tablets containing 1 mg. fluoride, provided by dissolving a tablet in one quart of water for use throughout the day, resulted in caries reductions comparable to those provided by fluoridated communal water supplies. Held and Dubois - Provost
(1961) reported a 50 per cent reduction following the use of fluoride tablets, while Griscom and co-workers (1964) observed a 34.1 per cent reduction in caries in permanent teeth after two years of supervised ingestion of sodium fluoride tablets given during the school year only; however, a reverse finding of an effect in permanent teeth but not in deciduous teeth has recently been reported by Kamocka and co-workers (1964).

Inadequate data regarding the efficacy of the use of prenatal fluoride tablets during the period of gestation limit the use of such measure. Present preparations now available commercially and commonly prescribed contain a variety of vitamins and minerals, and many of these minerals particularly calcium, have been shown (Weddle 1954), to significantly reduce the metabolic availability of the fluoride. Feltman and Kosel (1961) made the first report on the use of prenatal sodium fluoride tablets as giving a significant reduction in the incidence of dental caries in the deciduous dentition comparable to that observed in areas of natural and artificially fluoridated water supplies. Blayney and Hill (1964) have reported similar findings after thirteen years of fluoridation in the dental caries study at Evanston, Illinois. The results of the above studies
indicate that, increasing amounts of fluoride provided in
the use of prenatal fluoride tablets and drinking fluori-
dated water during pregnancy may result in increasing
amounts of fluoride in the maternal blood, placenta, and
foetal blood, suggesting that fluoride may pass the human
placenta. However, little information has been offered to
suggest an influence of prenatal fluoride upon the subse-
quent development of dental caries later in the life of
the child.6

Kailis et al. (1965)55 reported caries inhibition
from prenatal and postnatal administration of fluoride
tablets in a random sample of 374 kindergarten children
in Perth, Australia. Of these, 142 (the control group)
had not ingested any fluoride supplement at all; 92 had
ingested sodium fluoride tablets daily from birth; and 50
had experienced daily supplements of fluoride prenatally
and had continued to ingest daily fluoride supplements
postnatally. The results of the study were as follows:

1. The pre and postnatal group had 81.5 per
   cent less decayed, extracted or filled
teeth, and 87.6 per cent less decayed, ex-
   tracted or filled tooth surfaces than the
   non-fluoride group.

2. The postnatal only group showed 55.7 per
   cent less def, and 65.1 per cent less def
than the non-fluoride group.

3. In the non-fluoride group, 19.39 per cent were clinically caries free; 34.78 per cent were caries free in the postnatal only group; and 54 per cent were caries free in the group experiencing prenatal fluoride and ingesting daily fluoride supplements postnatally.

4. The differences observed between pre and postnatal fluoride versus postnatal only, fluoride, were significant for def, defs, scores, and the number of children caries free.

These findings indicate that prenatal fluoride is beneficial in controlling the extent of dental caries in subsequent offspring.

Further research on the practicability of tablets, lozenges, pills and the like should be done before one can recommend such preparations as a substitute for communal fluoridation. Meanwhile, the amount of fluoride prescribed must be adjusted for the existing content of natural fluoride in the drinking water. Where the natural fluoride content of water is 0.7 p.p.m. or over, fluoride supplements should not be administered. It should be emphasized that this means of prescribing fluoride might
be safe within a group intimately familiar with the need for exact dosage and would not have general application except to selected patients on a prescription basis or in a supervised program. The same restrictions would hold for other potential types of prescribed fluoride, with or without other nutrients or drugs.

Tablets containing 1 mg. of fluoride have been used in two ways, either as a means of fluoridating the daily water supply at home, or taken each day as a tablet or pill. There are certain dangers in having large quantities of such tablets accessible to young children. Perhaps the greatest difficulty to this means of fluoride administration is the problem in ensuring that consistent and daily ingestion of the tablets throughout the first ten or twelve years of the child in order to obtain maximal anticariogenic benefit. If third molars are to be considered tablet supplement should be given till they erupt also.

SUMMARY OF THE ANTICARI OGENIC EFFECTIVENESS OF SYSTEMIC FLUORIDES

A definite relationship between fluorides and dental caries, be it natural or artificial fluoridation, has been established relatively recently, but only after considerable field survey studies had been made.
The retention of fluoride in the developing teeth, prenatally or postnatally influences the anticariogenic property of systemic fluorides. The differences in retention if they are real may depend on many factors. Important among them may be: 79

1. Differences in absorption of the fluoride from the two sources by the gastrointestinal mucosa. Since the presence of inorganic elements in the diet or water is known to decrease fluoride absorption, these data would suggest that the inorganic elements present in the natural water and not present in the artificial fluoride source interfere with fluoride solubility and thus its availability. (The increased retention of fluoride occurring from the artificial water should not be interpreted to mean that the same would occur in a community fortifying its water supply to the level of 1 p.p.m. since such water would in all probability be similar in its major inorganic composition to that of the natural water used in these studies.) It has been shown that fluoride retention is identical regardless of whether the fluoride is derived from a "natural" or an "artificial" water supply.

2. Ability of some mineral elements like Calcium (Ca), Magnesium (mg), Iron (Fe), Phosphorus (P)
in the water to affect fluoride retention. The degree of reduction of dental caries afforded by the artificial addition of fluoride to communal water supplies containing different interfering inorganic ions is of particular interest. The result of such interference may be an inactivation of the metabolically available fluoride sufficient to affect the degree of protection against dental caries significantly. Because of this possibility, the inorganic composition of the communal water supplies that are being fluoridated may need more attention than it has been given heretofore in order to insure the availability of enough fluoride to obtain maximum dental-caries reduction. It may be that the amount of fluoride added to communal water supplies will need to be increased in communities served by water having high inorganic ion content in order to maintain significant anticariogenic benefits. The data from the Wagner and Humler study apply to this problem, since they strongly suggest that when fluoride is added to water supply containing Ca++, Mg++, Fe++, or PO₄⁻ ions together, significantly less fluoride is retained in the whole rat carcass than when similar amounts of fluoride are added to a mineral-deficient water. However when Ca++, Mg++, Fe++ or PO₄⁻ ions are tested
separately and measuring fluoride retention in the whole carcass, no significant changes are noted. The contribution of individual inorganic ions in producing the collective effect in the first result is not clearly defined. As a result, further study is needed of combinations of ions common in communal water supplies to determine the unique properties of the ion combination that make it capable of significantly affecting fluoride absorption or retention.

3. Period of great effectiveness - from the nutritional viewpoint, the fluorine of food is of greatest importance to the child during the period of the formation of dental enamel which is attributable to:

(a) The age of the child during which the enamel of certain teeth is calcifying and maturing, and another item to be considered is

(b) the importance of the teeth for mastication and their relative susceptibility to carious attack are further factors which are needed in order to judge the ages of the child so that one can determine the optimum total daily intake of fluorine from all sources.
(c) There may even be a significant sex difference in the ages for the maximum dental benefit to be derived from fluorine.

4. Environmental factors - In comparison with the long-indicated adjustment of the levels of fluoridation of water on a seasonal basis rather than on geographical areas on the basis of mean annual temperature, the amounts of fluorine supplied by food is not much affected by environmental conditions. With increasing temperature less food is generally required, and with very high temperature, activity will be diminished and consequently the caloric requirement will be lessened. The younger the child, the less important are environmental factors as far as the amount of food fluorine is concerned.

Furthermore, the younger the child, the fewer the varieties of foods that must be considered as sources of fluorine. Thus, milk becomes prominent as a source of fluorine as it is the sole source of nutrients to the newborn infant. As indicated above, however, which teeth are forming and the amount of enamel are essential factors to consider in attempting to assign the age of the child for receiving maximum benefit from fluorine of water and of food. Because of the natural limitation of varieties of
food consumed by young children and because of customs determining such foods, the fluorine content of food may have some influence in determining the levels of fluoridation of water for different communities.79

Another important point to consider is the indications that the established threshold of dental fluorosis varies with major fluctuations in climatological conditions. In Georgia, Dean (1951) examined 12 to 14-year-old children at Brunswick (0.50 p.p.m. fluoride) and Moultrie (0.70 p.p.m. fluoride) and noted that there are incidences of the mildest type of dental fluorosis at levels of 12.6 and 9.0 per cent respectively. It is indicated that such incidences would normally be associated with the consumption of domestic water which contained approximately 1 p.p.m. fluoride under climatological conditions prevailing in the Chicago area, with its mean annual temperature of about 49°F.

A study by McClure (1943) estimated that a quantity of water-borne fluorides equal to approximately 0.5 to 1.0 mg. of fluorine daily needed to be present in the average diet from the first to the eighth year of life in order to reduce dental caries incidence to the degree noted with naturally fluoride-bearing water. He noted, further, that these approximations applied to
children's drinking habits extending over an entire year in a temperate climate and that average quantities drunk would vary somewhat with the climates.

Physiological adjustments of man to high environmental temperatures have been studied extensively in the adult (Adolph, 1947) and some work has been done on the effect of environmental temperature on infants and children, but not enough is known to serve as an absolute guide in establishing optimal seasonal fluoride concentrations where such procedure is desirable. Levin and Cox (1950) showed that an infant growing from 0 to 1 year of age varied in water consumption from 1.75 to 10 oz. per 10 lb. of body weight as the mean daily temperature increased during the summer from 70 to 84 degrees. Among other observations, they noted that the water intake of infants living in a home where the temperature was thermostatically controlled at 74°F. remained constant at about 1.75 oz. per day per 10 lb. of body weight during the winter months.

The question of optimum concentration of fluoride is one that will require no small amount of study and investigation. Should levels higher than 1.50 p.p.m. fluoride be employed in some places during the winter
season as suggested by Cox (1950). In many States there are natural fluoride areas. It should be possible to carry on studies on dental fluorosis, caries experiences, climatological and socio-economic factors and other areas of interest, so that from all the information obtained it might be possible to establish a pattern of fluoride levels.\textsuperscript{34}

Experimental ground for adoption of seasonal fluoride variations was made at Charlotte, North Carolina by Shaw et al. (March 1950). Charlotte, North Carolina, the mean annual temperature in 60-62\textdegree F, and was concluded that fluoride levels which were satisfactory in more northerly places would not necessarily hold at Charlotte. It was obvious that more water was consumed, hence more fluoride ingested, over a longer period at Charlotte than in the northern part of States. The investigators sought out possible water uses which might serve as a reliable index of seasonal variations of water consumption. Water consumption figures for bottlers of soft drinks indicated that the figures had a direct bearing on the seasons, with the total water used in production having a fairly constant relation to the total output of product. The month-by-month figures, monthly were averaged for three years for six large
bottlers and the monthly averages closely paralleled the curve of the mean monthly air temperature. The relationship was emphasized by the curve of monthly sales variations of a bottler of spring water which also paralleled the mean monthly air temperature for that season. With this a guide a schedule of periodic fluoride levels was established. The prescribed fluoride levels range from: 90 (Table 3)

July = 0.60 p.p.m. fluoride
January and February = 1.10 p.p.m. fluoride.

providing an average fluoride level for the year at slightly less than 0.9 p.p.m. This schedule of seasonal fluoride levels has been followed at Charlotte, North Carolina, since March 1950, without any difficulty. It is considered a preliminary approach to the problem of optimum fluoride levels under specific climatological conditions.
<table>
<thead>
<tr>
<th>Annual Average of Maximum Daily Air Temperatures</th>
<th>Recommended Control Limits F Concentrations in Parts per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>50.0 - 53.7</td>
<td>Lower 0.9  Optimum 1.2  Upper 1.7</td>
</tr>
<tr>
<td>53.8 - 58.3</td>
<td>Lower 0.8  Optimum 1.1  Upper 1.5</td>
</tr>
<tr>
<td>58.4 - 63.8</td>
<td>Lower 0.8  Optimum 1.0  Upper 1.3</td>
</tr>
<tr>
<td>63.9 - 70.6</td>
<td>Lower 0.7  Optimum 0.9  Upper 1.2</td>
</tr>
<tr>
<td>70.7 - 79.2</td>
<td>Lower 0.7  Optimum 0.8  Upper 1.0</td>
</tr>
<tr>
<td>79.3 - 90.5</td>
<td>Lower 0.6  Optimum 0.7  Upper 0.8</td>
</tr>
</tbody>
</table>

* Public Health Service

+ Based on temperature data obtained for a minimum of five years.

The great value of fluoridation of water supplies as a health measure to prevent dental caries has been amply and conclusively demonstrated. The best summary of findings on fluoridation was made by the WHO Expert Committee on Water Fluoridation in its report in 1958 (WHO Technical Report, Series No. 146) as follows: 73

1. Dental caries is one of the most prevalent and widespread diseases.
2. There is no hope of controlling the disease by present treatment methods alone.

3. Among the numerous preventive methods, the fluoridation of drinking water supplies is the most promising.

4. The effectiveness, safety, and practicability of fluoridation as a caries-preventive measure has been established.

5. 1 p.p.m. fluoride has been shown to give maximum benefits first by epidemiological studies where fluoride occurs naturally in the water, and, secondly, where fluoride has been added at optimum concentration through mechanical means.

6. Hundreds of controlled fluoridation programs are now in operation in many countries. Some have been in progress for the past 12 years, so that conclusions are based on experience. No other public health procedure, during the initial stages of its application, has had such a background in time or extent.

7. The biological effects of fluorides have been described in nearly 3,000 clinical and experimental reports in the past 20 years. This literature is not only extensive but of broad scope.
8. Fluorides penetrate cells and in sufficiently high concentrations inhibit certain enzymes, but no evidence of enzymal inhibition has been found in persons drinking fluoridated water containing concentrations of fluoride optimal for dental health.

9. Most of the fluoride absorbed into the system is rapidly excreted, principally in the urine, the rest is deposited in the minerals of the bones and teeth.

10. When large doses or excessive amounts of fluoride are ingested for protracted periods (many years), the skeletal system exhibits structural changes. The clinical manifestations are classified as

(a) Crippling fluorosis (20-50 mg. of fluorides or more per day for 10 to 20 years; calcification changes in bone together with calcification of ligaments);

(b) Asymptomatic osteosclerosis (more than 5 mg/l of urine excreted daily for five to ten years; hypercalcification in one or more bones without disability); and

(c) Rotted enamel or dental fluorosis (drinking water containing 2 to 8 p.p.m. fluoride or more during the first eight years of life; interference with enamel formation, stained or in severe cases irregular enamel surfaces).
Adequate factors of safety guarantee the absence of these changes when water containing 1 p.p.m. fluoride is drunk.

11. Toxic doses of fluorides (50 times that used in controlled water fluoridation) injure the kidneys. There is no evidence of kidney injury or of any effect on concurrent kidney disease in the populations drinking fluoridated water where fluoride concentrations range up to 5 p.p.m.

12. No relation between thyroid dysfunction and naturally fluoridated water has been established. In animal studies, daily doses in excess of 50 p.p.m. in the diet produced structural and functional changes in the thyroid. In humans, drinking water containing 1-5 p.p.m. fluoride is without demonstrable effect on the thyroid.

13. Growth and development, somatic and psychic, are normal in drinking water containing optimal concentrations of fluoride is consumed.

14. Over three million people in the United States, over half a million in England, and large population groups in other countries have, during their lifetime,
consumed water containing 1 p.p.m. fluoride or more. Mortality and morbidity rates for five leading causes of death are comparable for cities in the United States with fluoride and non-fluoride and arthritic changes in bone has been found, nor have confirmed cases of allergy to water containing 1 p.p.m. fluoride been described.

15. The addition of fluorides to public water supplies has proved to be similar to other routine mechanical procedures widely employed in waterworks practice. Suitable equipment has been developed, reliable analytical procedures are available, and appropriate safeguards have been established.

16. No other vehicles or techniques for the prophylactic application of fluorides can at present replace the fluoridation of drinking water as a public health measure. Where water fluoridation cannot be used, research into other vehicles and improved methods of topical fluoride application should, however, be encouraged.

In view of these findings, the Committee started on the premise that fluoridation of public water supplies is not only acceptable but desirable and, therefore, there is
no need to undertake further studies and investigations concerning its safety as a health measure.

The reports of Bleyney and Hill (1964), Tank and Storvick (1964), Arnold and associates (1953, 1956), and Feltman and Kessel (1961) support the thesis that the combined administration of prenatal and postnatal fluoride is more effective in inhibiting caries than fluoride administered only postnatally. Only Feltman reported a pronounced anticariogenic effect of fluoride when administered prenatally alone. This finding, however, awaits confirmation. Carlos and co-workers (1962) and Morens (1965) found no effect of prenatally and postnatally administered fluoride on the deciduous teeth when compared with the postnatal effect alone. No evidence appears to be available that prenatally administered fluoride has any effect on the permanent first molars, the only tooth of the permanent dentition showing any evidence of calcification before birth. 6

Studies in the rat have indicated that administration of concentrations of fluoride up to 25 p.p.m. in the drinking water during gestation and lactation conferred no cariostatic effect on the teeth of the offspring. At a concentration of 40 p.p.m. fluoride, however, some carious inhibition occurred.
The enhanced mineralization and reduced solubility of prenatally fluoridated teeth in the rat and the increased fluoride content of deciduous teeth in the human being are consistent with the proposition that prenatally administered fluoride in the human being may afford some anticariogenic effect to deciduous teeth. Though more studies are necessary to consolidate this position, available data do not contraindicate the administration of 1 mg. fluoride per day to pregnant women.  

Dental caries and the consequences thereof constitute by far the major proportion of the total dental problem which confronts us. "Dental caries" has most recently been defined by a group of 134 scientists related to the field at a workshop at the University of Michigan 1947 as follows:

"Dental caries is a disease of the calcified tissues of the teeth. It is caused by acids resulting from the action of microorganisms on carbohydrates, is characterized by a de-calcification of the inorganic portion, and is accompanied or followed by a disintegration of the organic substance of the tooth."

Perhaps as a result of highly successful commercial salesmanship it is widely accepted that various oral hygienic practices will reduce the probability of development of
dental caries. Included in this category is the use of
toothbrushes, dentifrices, miscellaneous mouthwashes,
lozenges, medicated chewing gum and professional dental
prophylaxis. However, it should be noted that the cumu-
latative effects of all these mechanisms have proved to be
insufficient to prevent caries in the unfavorable environ-
ment created by modern cariogenic diets. The importance
of highly calcified teeth to dental health has been particu-
larly emphasized in health education programs, but there is
no evidence that the high consumption of calcium-rich dairy
products and of Vitamin D supplements in the Western world
has reduced dental caries. The only nutrient which has
proved to be effective in this respect is fluoride.

Simply knowing that fluorine reduces tooth decay is
not necessarily enough, for it is equally as important to
find the mechanism by which fluorine acts. Only better
knowledge of its behavior can we make full use of its
potentialities. As we understand it today, fluorine does
reduce solubility of the enamel, but exactly how the flu-
orine is incorporated into the tooth structure is still
unsolved.

Before elaborating further on the mode of action of
fluoride in inhibiting caries, special attention will be
given to surface enamel, since it is the site of the initial carious attack, and because it appears to be more resistant to the carious process than subsurface enamel. The present paper, therefore, attempts to show the anti-cariogenic effects of fluorides.

At the present time, fluorides are available for prevention of caries in roughly two broad classifications:

1. Through systemic means as in fluoridation of water supply or in the ingestion of fluoride-containing food and tablets.

2. Topical application using various fluoride solutions and various fluoride-containing pastes.

It is now well established that surface enamel is normally more resistant to caries than subsurface enamel. It has many characteristics which from time to time have been thought to be important in decreasing caries solubility.

In view of the reduction of caries obtained from water fluoridation, the following data are of great interest. Here is shown the distribution of fluoride in enamel of persons under 20 years of age who had continuously used drinking water containing 0.1, 1.0, 3.0 and 5.0 p.p.m. of
fluoride respectively. Isaac et. al. (1958) reported

Table 4

<table>
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<th>3.0</th>
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<td>889</td>
<td>1,930</td>
<td>3,370</td>
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<td>2</td>
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<td>152</td>
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that the concentration of fluoride increases by 390 p.p.m. in the surface enamel when the level of the water is raised from 0.1 to 1.0 p.p.m., while the corresponding increase in the sixth layer (about one-half way into the enamel) is only 87 p.p.m. The decrease in caries seen as a result of drinking fluoridated water must be related to the fluoride increment in the enamel surface. It is likely that fluoride is located primarily on the surface of the apatite crystals and that failure of the fluoride ion to penetrate into the body of the crystals precludes high concentrations. 19
The reasons for the greater rate of dissolution below the enamel surface are not fully understood. One causative factor which is important may be that, the acid solubility of enamel increases from the surface towards the dentine. A relationship was found between the concentration of fluoride in the different layers and the resistance to acid action.⁸⁹

The action of fluoride in reduced solubility, may be deduced from the deposition of the fluoride ion prenatally and postnatally to the enamel of the teeth. The deposition of fluoride occurs in three stages:⁸³

Stage 1: During the period of enamel calcification when fluoride is deposited profusely, concomitantly with crystal formation.

Stage 2: After calcification is complete, but before eruption, when more fluoride is taken up by the external surfaces of the enamel from tissue fluids.

Stage 3: After eruption and throughout the life span of the teeth, when fluoride from the drinking water, food and saliva is taken up by the enamel surface.
The rate of acquisition of fluorides is governed by two factors:

1. The first is the period of fluoride exposure of the tooth at the different stages of fluoride deposition. The subsurface enamel becomes increasingly blocked from contact with tissue fluids as calcification proceeds and thus is subjected to fluoride exposure for only a short period of time. The surface is exposed to fluoride both pre-eruptively and post-eruptively and accordingly will acquire much greater concentrations with time.

2. Another factor is the concentration of fluoride in the tooth environment. With increased fluoride ingestion there is a marked increase in the deposition of fluoride in the surface enamel. As already has been shown in the data presented earlier that the concentrations of fluorides in the surface and the body of the enamel with different levels of fluoride in the water supply cause a more pronounced increase in the deposition of fluoride in the surface than in the subsurface enamel.

The uptake of fluoride is very rapid during the first years following enamel formation and then tapers off at a level closely related to the concentration of environmental fluoride.
Two mechanisms have been offered suggesting a hypothesis as to the manner in which fluorides reduce the incidence of dental decay.\textsuperscript{36}

1. One is that the fluoride combines in some manner with the inorganic portion of the tooth enamel, rendering this tissue less soluble in the organic acids produced by bacterial carbohydrate degradation in the oral cavity. Ingested fluoride is deposited in the enamel as fluorapatite so that it is believed that the formation of this stable mineral is the principal mechanism by which fluoride inhibits caries.

2. The other is that the fluoride poisons or inhibits specific bacterial enzyme systems, thus permitting the existence of a bacterial flora which does not elaborate acids sufficient to decalcify tooth structure. Bibby et al. (1940) reported that fluoride concentration likely to be encountered in the oral cavity will not interfere with bacterial growth but that they are capable of reducing the formation of acid from foodstuffs. Moreover, the extent of interference with fermentation appears to be proportional to the concentration of fluoride used. In addition to the effect of fluorides have in inhibiting acid production in
the oral cavity by interfering with lactobacilli, fluorides also appear to interfere markedly with phosphatase activity. It has long been recognized that phosphatases (alkaline and acid) play in the calcification process because of their hydrolytic action on phosphoric acid esters but in the presence of even relatively low concentrations of fluorides their activity is inhibited.

The aspect of the benefits of fluoridation has not received due recognition, nor has it been sufficiently stressed by public health workers or orthodontists. Reduction of malocclusion in the dentition of children who consume fluoridated water has been shown by Salzmann and Ast (1955) and by Ast, Allaway and Draker (1962).

The reduction of malocclusion in children who consume fluoridated water is not caused by any intrinsic osteogenic or osteologic changes in the jawbones or by an improvement in jaw development but by a decrease in tooth loss and occlusal contact deficiency caused by caries.

It is not to be expected that fluoridation will eliminate the need for orthodontic treatment. The causes of malocclusion are many and varied, and tooth loss is
only one etiologic factor among countless others.

Douglas and Coppersmith (1966) assert that the reduction of caries in children achieved by fluoridation will tend to counterbalance the inadequacy of dental manpower. They further state that "..... the shift away from major attention to caries is leading to gather attention to periodontal treatment and interceptive orthodontics".32
PART II

Topical Fluorides:

"First a new theory is attacked as absurd; then it is admitted to be true, but obvious and insignificant; finally it is seen to be so important that its aversaries claim they themselves discovered it."

William James -
TOPICAL FLUORIDES

The chemical common denominator of topical agents, that are effective in partially reducing dental caries, is fluoride. The three solutions used most prevalently as topical agents in caries prevention are: 18

1. Sodium fluoride (2 per cent) (NaF)
2. Stannous fluoride (8-10 per cent) (SnF₂)
3. Acidulated fluoride phosphate (APF)

A number of methods have been devised for bringing about a reaction between fluorine and the tooth surface. The approach which has been most used is to make "topical application" of relatively concentrated solutions of fluorides on tooth surfaces which have been previously cleaned and dried. Other methods include the use of prophylactic cleaning pastes, dentifrices, mouthwashes, troches or lozenges.

The reasons for believing the action of fluorine on the external surfaces of the teeth was important in preventing caries. It was shown that fluorine concentrations sufficient to interfere with acid formation on the teeth were not maintained in the tooth environment; that fluorine combined rapidly with enamel to reduce its solubility in organic acids and that deviations from the normal
tooth-to-tooth occurrence of caries under the influence of fluoride-containing water suggested the importance of external affects.

Although the mechanism by which fluoride reacts with the external surfaces of the teeth to reduce caries has not been definitely established, information accumulated during recent years has contributed to our understanding of the reactions involved. Several mechanisms have been suggested.

1. One is that fluoride affects the permeability of the teeth. However the only scientific work which has been directed to this possibility has failed to produce any support for this theory (Armstrong et al., 1951 and Berggren et al., 1951).

2. It has also been suggested that fluorine in the teeth might act on the oral bacteria and enzymes on the tooth surfaces to prevent acid formation. The failure to demonstrate reductions of lactobacillus counts after topical applications of fluoride which reduced the incidence of dental caries on the same patients and failure to demonstrate any changes in the biochemical capacity of the saliva seemed to indicate that tooth fluorides have little effect on acid formation.
3. The remaining possibility that the fluoride content of the tooth affects caries activity as a result of changes in solubility is supported by a much greater mass of evidence.

Considerable evidence has accumulated which confirms the observation that exposure of enamel particles to fluoride solutions produces an increased resistance to the action of acids.

One finding shows that the solubility-reducing effect depends more on the pH of the acid used for decalcification than on the type of acid to which the enamel is exposed. The fluoride effect was approximately the same when using different organic acids, but there was no effect with highly dissociated inorganic acids of the same strength. This demonstrates that the fluoride effect disappears at a low pH. The importance of pH is also suggested by experiments in which fluoride treated and untreated enamel samples were shaken in unbuffered acid until equilibrium was obtained. Decalcification ceased at pH 4.8 for the fluoridized enamel and at pH 5.7 for the untreated enamel. This finding, therefore, showed that a greater concentration of acid is required to decalcify fluoridized
enamel, and maybe is important in determining whether de-
calcification will take place under the influence of
acids formed on the tooth surfaces (Ericson, 1950).

Because of the variations in solubility from tooth to
tooth and even from place to place or area to area on the
same tooth, it is difficult to establish a quantitative
effect of fluorine on enamel surface solubility (Brudevold,
1948).

It is of interest that the solubility-reducing effect
of fluoride is more pronounced on surfaces that have been
etched with acid before exposure to the fluoride solution
than on untreated enamel surfaces (Brudevold, 1951). 16
According to this finding, application of fluoride may be
most effective in beginning carious lesions of the enamel.

There is some evidence that the fluoride uptake in-
creases with repeated applications. There is also an in-
dication that increased uptake may be achieved by prolong-
ing the application time, but after 15 to 20 minutes ex-
posure the rate of uptake decreases rapidly. In addition,
it has been found that acidulated fluorides produce a
greater uptake than neutral fluoride solutions. Little or
no fluoride is taken up from alkaline fluoride solutions. 79
SODIUM FLUORIDE

The effectiveness of topical treatments depends not only on the amounts of fluoride deposited, or in the case of stannous fluoride, the amounts of tin and fluoride deposited, but on the extent of penetration of these ions, the types of compounds formed, and the reversibility of the reactions taking place. Sodium fluoride solution, which will be considered first, will cause superficial decomposition of the enamel apatite at the concentrations of 1 per cent or more employed in topical applications. The solubility of calcium fluoride is exceeded at much lower concentrations (about 0.01 per cent) and therefore, calcium fluoride (CaF$_2$) will precipitate according to the equation:

$$\text{Ca}_{10}^{10}(\text{PO}_4)_6(\text{OH})_2 + 2\text{NaF} \rightarrow 10\text{CaF}_2 + 6\text{Na}_2\text{PO}_4 + \text{NaOH}$$

There is evidence that the calcium fluoride deposited on the tooth surface will not be permanently retained. Some of it will be removed by saliva and food, and being only slightly soluble, the remainder will furnish low concentrations of fluoride ions which will react with the enamel apatite as follows:

$$\text{Ca}_{10}^{10}(\text{PO}_4)_6(\text{OH})_2 + \text{CaF}_2 \rightarrow \text{Ca}_{10}^{10}(\text{PO}_4)_6\text{F}_2 + \text{Ca(OH)}_2$$

Fluorapatite
This reaction, in which hydroxyl groups are exchanged with fluoride (Newman, 1950), is the same as that occurring between fluoridated drinking water or tissue fluids and the tooth. Contrary to the reactions taking place with strong fluoride solutions, the enamel apatite is not broken down, but is transformed from hydroxyapatite to the more insoluble fluorapatite. Isotope studies have shown that this reaction takes place in three steps, involving the hydrated spaces between the apatite crystals, the crystal surfaces and the body of the crystals respectively.

First phase — fluoride diffuses into the hydration shell. This process is extremely rapid, it is reversible, and the fluoride is not firmly bound.

Second phase — Fluoride assumes the positions of hydroxyl ions on the crystal surfaces. The rate of this reaction is slower than that of the first phase and the attached fluoride is firmly bound.

Third phase — final phase, fluoride may penetrate into the crystal and exchange with hydroxyl groups located in the body of the crystal. This reaction is exceedingly slow and has no significance in topical application.
Only small amounts of fluoride are acquired by enamel in topical application, a fact consistent with the theory that the crystal surfaces and not the bulk of the crystal react with the fluoride. It follows that the penetration of fluoride into the bulk of the enamel must be mediated through the water of hydration, and not by diffusion through the crystal proper. For this reason partly decalcified areas, cracks and lesions will permit diffusion, but the slight penetration constantly found in fluoride exposed enamel cannot be dependent on the presence of defects. Diffusion could occur through the interprismatic substance and the strata of reticulum, as involve in the prism as well. In either case, it must take place between individual enamel crystals in the water spaces which, in fully calcified enamel, approach atomic dimensions. Highly charged ions, such as fluoride, do not readily pass through, presumably because they tend to be trapped by electrostatic forces on the surfaces of the crystals. The narrower the spaces, i.e., the more highly calcified the enamel, the stronger will be the electrostatic field, and the more unlikely the passage of the fluoride ions.

One additional reaction of fluoride is likely to be involved in topical applications. It has been observed
that dilute solutions of fluoride (0.1 to 1 p.p.m.) will accelerate precipitation of apatite from solution of calcium phosphate (Brudevold et al. 1961). The stability of supersaturated solutions such as saliva is markedly decreased by the presence of fluoride ions, causing crystallization of apatite to take place more readily. The increase in enamel hardness found after topical application may be produced by the deposition in the enamel of additional mineral, as a result of this process.6

Many workers have used a variety of approaches to the problem of preventing dental caries by the topical application of concentrated fluoride solutions. All have indicated some reduction in this disease when an aqueous sodium fluoride solution is applied post-eruptively to the teeth of young children. Knutson and co-workers65 have done much study in this area and have stimulated several other more, but there still remain many unresolved factors relative to the following:

1. proper fluoride solution;
2. time of contact of the solution with the teeth;
3. concentration of solution;
4. pH of the solution;
5. method of application.
Single technic

The first clinical study with sodium fluoride was reported by Bibby in 1942 and indicated that the use of the half-mouth technic in which two quadrants of each mouth served as control for the two treated quadrants and a series of three applications of 0.13 sodium fluoride solution. His preliminary results on the use of the solution applied topically for caries prevention to the teeth of 89 children, aged 10 to 13 years, at intervals of four months over a period of one year. He noted that during the year following the treatment series, 95 carious surfaces occurred in the permanent teeth of the treated quadrants while 135 new carious surfaces occurred in the permanent untreated teeth. This is approximately a 30 per cent reduction in one year in caries experience using his method of evaluation. Later Bibby (1943) reported on the results at the end of two years' study of the same children and noted that the protectiveness still remained but had decreased somewhat over that of the first year. At the end of the second year only a 26 per cent reduction was shown. McCauley and Dale (1945) report an increase in caries in 21 children, ages 2 to 13, within the year following the cessation of a one year course of fluoride applications. These authors also applied a 0.1 per cent sodium fluoride solution 3 to 11
times by moistening the teeth with a pledget of absorbent cotton, keeping the surface wet continuously for at least one minute. Bibby and Turesky (1947) reported on the duration of caries inhibition produced by fluoride applications from their studies in a group of 39 patients in which one quadrant of teeth had been treated six times during a two-year period with 0.1 per cent solution of sodium fluoride; there was 36 per cent reduction in new decay when re-examined three years after the cessation of such topical treatments. Although it appears from the above data that in order to maintain dental caries reduction effectiveness it is necessary to retreat the teeth periodically, in all the above studies it is somewhat unsafe to draw an opinion due to the small numbers in each study. 65

Knutson and Armstrong (1945) used a large sample of 615 children, aged 7 to 15 years, to test the effectiveness of topically applied aqueous 2 per cent sodium fluoride solution (approximately 9,050 p.p.m. fluorine). The treatment group consisted of 289 children who received the topical application to the teeth in the upper left and lower left quadrants, while the second group, the control children, consisted of 325 children, who did not receive any fluoride treatment. Each group was given a prophylaxis, the fluoride was applied to the respective quadrant, the
teeth of which were isolated by cotton rolls and allowed to dry in air for four minutes. The children were given two applications weekly to a maximum of 15 applications and a minimum of 7 applications, the number given each child being determined largely on the basis of the number that could be conveniently administered during the experimental period. An analysis of the data at the end of one year, which was confined to the dental caries experience in the erupted permanent teeth present at the time of the first examination, indicated that in the treated group there were 39.8 per cent less new carious teeth than in the untreated teeth, while the number of new carious surfaces in teeth previously attacked by caries was not significantly different in the treated and untreated teeth. It was also reported that the incidence of dental caries in teeth in the untreated quadrants of the treated group was similar to that in teeth in the comparable mouth quadrants of the control group. This finding indicated to them that for the first year following treatment the caries-inhibiting effect is local and limited to those teeth to which the fluoride is topically applied. They noted that the relative reduction in the incidence of dental caries in treated teeth was appreciably greater in the upper than in the lower arch. At the end of the second year, 46.6 per cent less
teeth became carious in the fluoride-treated group than in the teeth of the untreated children. Knutson and Armstrong reported the caries experience, in the permanent teeth of the treated group of children, expressed in terms of numbers of teeth and tooth surfaces initially attacked during two-year period and numbers of additional tooth surfaces attacked in teeth which were carious at the time the first dental examination was made. It was shown that the total number of new carious teeth in both treated quadrants is 164 and for both untreated quadrants is 280. This is a difference of 41.4 per cent less teeth attacked by dental caries in the treated than in the untreated teeth. This finding compared closely with the 39.8 per cent difference reported for the first year study. At the end of the third year, the number of permanent teeth initially attacked by caries was 22.2 per cent less in the fluoride-treated teeth than in the untreated controls. This indicated some loss in protectiveness over that observed for the first two years.

Klinkenberg and Birkby (1950) reported from their studies on the application of a 1.0 per cent solution of sodium fluoride (F concentration about 4.500 p.p.m.) and a 0.06 per cent solution of lead fluoride (F concentration
about 100 p.p.m.) to 139 dental students, ages 15 to 40 years, using a half-mouth technique similar to the method employed by Knutson and Armstrong (1943). The initial topical application was made at the first examination, and at approximately three monthly intervals thereafter single applications of the two salts were repeated. After approximately fourteen months, the quadrants receiving sodium fluoride showed 56.6 per cent less new carious surfaces than did the untreated control quadrants, while the quadrants treated with lead fluoride showed 38.5 per cent less new carious surfaces than their control quadrants. The maxillary teeth appeared to show a greater reduction than the mandibular teeth in both the sodium and lead fluoride groups. This finding apparently supports the work of Knutson and Armstrong (1945). Both Klinkenberg and Bibby stated "The higher caries reduction shown in this study as compared with those using other procedures, despite the possible disadvantage of a spaced treatment program and a weaker fluoride solution, suggests that the most commonly advocated procedure for giving topical fluoride treatments for caries control may be a long way from the most effective possible method". They believed that more optimal conditions are yet to be found, and when they are discovered, a more effective topical program will result. They
expressed that their results may be attributed, in part, to the use of dehydration agents prior to fluoride application; they suggested that more attention be given to determine the effects of mucin solvents, dehydrating agents, and wetting agents in increasing the applicability of this technique.

Galagen and Knutson pointed out in their 1947 Public Health Report that four topical applications of sodium fluoride preceded by a dental prophylaxis affords maximum reduction in dental caries experience. Jordan, et al., tested the effectiveness of 1, 2 and 3 topical applications of a 2 per cent sodium fluoride solution without a dental prophylaxis and reported 5, 10, and 21 per cent reduction, respectively, in caries incidence. Knutson, Armstrong and Feldman (1947) reported the results of varying the number of treatments of a 2 per cent sodium fluoride solution was used throughout and in which the applications were not preceded by a dental prophylaxis. Their data indicated that the incidence of initial caries in permanent teeth which were noncarious at the time of treatment was 9.3, 20.1 and 21.3 per cent less in teeth treated with 2, 4, 6 applications of 2 per cent sodium fluoride, respectively, than in untreated teeth. However, Christzberg
(1947)\textsuperscript{26} presented evidence that when a 2 per cent solution of sodium fluoride was applied topically to non-caries permanent teeth of children the incidence of new decay was reduced by 40 per cent, but the same degree of reduction was obtained by eliminating the dental prophylaxis and substituting two weeks of supervised toothbrushing instruction before the first topical application. These data are summarized as follows: Table 5

<table>
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<th>Effect of Topical Fluoride Applications in Children Which Were Preceded By a prophylaxis or Toothbrushing Technique</th>
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<tr>
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<tr>
<td>Number Unattacked Teeth Percent-</td>
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<td>of Permanent Children Teeth During Teeth the Year Attacked</td>
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<tr>
<td></td>
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<tr>
<td>Group 1 (brushing, NaF treated)</td>
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<tr>
<td>Group 2 (prophylaxis, NaF treated)</td>
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<tr>
<td>Group 3 (untreated; control)</td>
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</table>

* Christzberg data, 1947.

Galagan and Knutson (1948)\textsuperscript{42} reported that the application of a 2 per cent solution of sodium fluoride to the teeth of children ages 6 to 16 years, followed immediately by a 5 per cent solution of calcium chloride, does not increase the caries-prophylactic effect over that accomplished by sodium fluoride alone. They noted also that an increase in the time interval between applications of the
fluoride solution in a given series of applications from one or two a week to one each three or six months decreases the caries-prophylactic effect. Their work appears also to indicate that a concentration of 1 per cent sodium fluoride is equally as effective in inhibiting new carious lesion as a 2 per cent sodium fluoride solution. These workers indicate further that the application of the fluoride solution to the teeth by means of spray appears to be as effective as when application is made by cotton applicators.
Topical Fluoride Armamentarium demonstrates the required apparatus for applying sodium fluoride to the erupted teeth of young children. The necessary materials include cotton rolls and cotton roll holder to isolate the mouth, flour of pumice for prophylaxis, saliva ejector, cotton applicator or air-spray bottle, hand air syringe or compressed air, and 2 per cent unbuffered sodium fluoride solution.
Illustration A. — Dental Prophylaxis — cleansing of the coronal surfaces of the teeth. A motor-driven rubber cup and fine pumice paste may be used to accomplish this part.
Illustration B. — Isolate with cotton rolls. Half the teeth, those in an upper quadrant and in the opposing lower quadrant may be isolated at one time. When the cotton rolls are positioned properly they are clear of the teeth so they do not absorb the applied solution.
Illustration C. — Dry with compressed air. From 15 to 20 pounds of pressure is used to facilitate adequate drying of the interproximal tooth surfaces.
Illustration D. — Coat crown surfaces with sodium fluoride. A cotton applicator or light spray may be used to apply a 2 per cent solution of sodium fluoride to the dried enamel surfaces of the tooth.
Sodium Fluoride Solutions:

Technic for Application to the Teeth (Knutson, 1948)

Cleanse the Teeth. – The first in the topical application of sodium fluoride described here consists of a thorough cleansing of the coronal surfaces of the teeth. A motor-driven rubber cup and fine pumice paste may be used to accomplish this part (Illustration A). Only the first in the series of four applications is preceded by dental prophylaxis.

Isolate with Cotton Rolls. – The cleansed teeth are blocked off or isolated with No. 2 cotton rolls. Half the teeth, those in an upper quadrant and in the opposing lower quadrant, may be isolated at one time as illustrated in B. Cutting the ends of the cotton rolls at 45 to 60 degree angles facilitates their proper placement. Rolls used in the lower part of the mouth are held in position with cotton roll holders. When the cotton rolls are positioned properly they are clear of the teeth so they do not absorb the applied solution.
Dry with Compressed Air. — After the teeth have been isolated with cotton rolls they are dried with compressed air. From 15 to 20 pounds of pressure is used to facilitate adequate drying of the interproximal tooth surfaces (Illustration C.).

Wet Crown Surfaces with Sodium Fluoride. — The fourth step in the procedure consisting of applying a 2 per cent solution of sodium fluoride (C.P. sodium fluoride in distilled water) to the dried enamel surface of the teeth. A cotton applicator or light spray may be used (Illustration D.). When the solution is applied properly it visibly wets all surfaces including the interproximal surfaces. The applied solution is permitted to dry in air for approximately three minutes. On completion of the procedure, the mouth may be rinsed with water. However, rinsing with water is not an essential or important part of the procedure and may be dispensed with if desired.

The second, third and fourth applications of the solution of sodium fluoride are made at intervals of approximately one week. As stated previously, in the series of four applications. Only the first is preceded
by dental prophylaxis; that is, the first step is omitted in making the second, third and fourth applications.

In order to provide a practical basis for rendering topical applications of fluoride to the teeth of children, it is suggested that a series of applications be given at the ages of 3, 7, 10 and 13 years. These ages should be varied in accordance with the tooth eruption pattern of the individual child. An application at 3 years of age would provide protection for the deciduous teeth. Subsequent applications would provide protection for the permanent teeth during the period of changing dentition. The incisors and first molars at age 7, the bicuspids and cuspsids at age 10 and the second molars at age 13.

REACTIONS FLUORIDE

The importance of the stimulant ion in protecting the tooth surface against acid dissolution has been mentioned repeatedly by a number of investigators (Mehler, Neborgall and Day, 1954; Brudoyd and al., 1956; Mehler, 1960; Cooley, 1961). To find a more effective fluoride compound in order that more than 40 per cent reduction can be brought about led Bibby and many others to investigate different fluoride compounds which could be more effective than the use of
sodium fluoride. Laboratory evidence on powdered dental enamel on whole tooth sections and from laboratory animals\(^ {63,12}\) has suggested that stannous fluoride is superior to sodium fluoride.

**Multiple Methods:**

In order to test the effectiveness of stannous fluoride compound in reducing caries experience in children, Gish, Smiley, Howel and Kuhler applied a 2 per cent solution of the compound to the teeth of a group of children in Bloomington, Indiana. Approximately 1,200 children, ages 6 to 16, were divided into groups and the technique of topical application, with certain modifications as to the methods of application of the fluoride, was used to treat topically the erupted teeth by the method described by Knutson.\(^ {65}\) It was intended that the children's grouping should be:

**Group A** - 250 children were to receive a 2 per cent aqueous unbuffered solution of sodium fluoride (9,050 p.p.m. F) applied by cotton applicators.

**Group B\(_1\)** - 450 children were to receive an aqueous unbuffered 2 per cent
stannous fluoride solution (4,500 p.p.m. F), applied by cotton applicators.

$B_2$ - 450 children were to receive the stannous fluoride solution applied by means of a spray bottle.

Group C - 227 children served as controls and received no treatment except an oral examination.

Both groups $A$ and $B_1$ received the fluoride treatments by means of the whole mouth technique and the solutions were applied once and allowed to dry for four minutes. Group $B_2$ had the teeth kept moist throughout the entire four-minute treatment using also the whole mouth technique. The entire procedure, for both groups, was repeated four times in such a manner as to space the applications from two to seven days apart. All solutions were prepared fresh each morning and any remaining from the previous day was discarded.

The pH of the sodium fluoride solution was 6.8 and the stannous fluoride was at pH 2.9. It is important to note that the fluoride concentration of the sodium fluoride was exactly twice that of the stannous fluoride solution.