A Study of

THE OCCURRENCE OF PIGMENTATION IN INCipient AND ADVANCED
CARIous LESIONS OF TEETH EXPOSED TO STANNous FLuORIDE:

Its Association With Caries Incidence and Oral Hygiene

By

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Submitted to the Faculty of the Graduate School of Dentistry
in partial fulfillment of the requirements for the degree,
Master of Science in Dentistry, Indiana University, September, 1960.
ACKNOWLEDGEMENTS
In the field of dental research, much inspiration and stimulation has been contributed by Dr. Joseph C. Muhler, Ph.D., D.D.S. The author wishes to thank Dr. Muhler for providing not only encouragement, but also for giving so much of his time and patience in the preparation of this thesis.

The author also wishes to express his gratitude to Dr. Ralph E. McDonald, D.D.S., M.S., for his wisdom and guidance, and to Dr. Charles L. Howell, D.D.S., M.P.H., for his support and understanding during the course of graduate studies.

Without the valuable assistance of these faculty members, the author would not have been able to justify the confidence placed in him by his Director, Dr. Douglas J. Xeo, D.D.S., M.P.H., who provided the opportunity of taking the course in Preventive Dentistry at Indiana University.

Thanks are also due to Mrs. Margaret A. Smith for the typing of this manuscript.
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FOREWORD
THE CONTROL OF DENTAL CARIES IN PREVENTIVE DENTISTRY
What a gloomy picture of dental health is presented by statistics demonstrating the decay rate of our children's teeth! The concept that health means freedom from disease often gives us a negative approach in the estimation of improved health, and particularly in the appraisal of dental health. Indeed, dental caries has become so prevalent that the significance of other oral diseases is often ignored, to the extent that our estimation of dental health is frequently based on the incidence of caries. For example, the Hagerstown survey\(^1\) demonstrated that children's teeth are becoming carious six times faster than they are being restored. Berke\(^2\) has shown that there is a 20 per cent increase in the caries experience of student entrants each 10 years over a 30 year period at the University of Minnesota.

On the other hand, many statements of the incidence of caries in the United States and Canada give variable figures; and in fact some reports show a recession of the disease\(^3\). A recent (1959) survey\(^4\) of school children of first, third, and seventh grades showed 61 per cent less extractions of permanent teeth during a 1 year period. Furthermore, many communities now supplied by fluoridated water are expected to show a decreased caries rate. In any case, whether the caries rate is increasing or declining, dental decay is still unquestionably the most prevalent chronic disease affecting the American people today\(^5\), and presents the greatest challenge to American dentistry.

As long as the disease of caries continues to be the major threat to our dental health, the primary concern of preventive
dentistry will be its elimination. Because the best restorative efforts of present dental manpower cannot possibly keep up with the decay rate of teeth, prevention is logically the only approach in the control of the disease.

Assuming caries initiation is dependent on certain oral bacteria, the most logical approach in the prevention of caries would be the elimination of the causative organisms. Accordingly, many studies in the past were interested in the causative agents of the disease and the emphasis of preventive dentistry was placed on combating the attacking agents. Inhibition of oral bacterial growth by restricting highly fermentable carbohydrates and improving oral hygiene became the order of the day.

In contrast to this, or actually in addition to it, preventive dentistry is now primarily concerned with the role of tooth resistance to the carious process. This approach is in keeping with the present trend in the biological sciences which, having abandoned the "single etiological agent" concept of disease, is now concerned with individual immunity and susceptibility in the prevention of disease.

Communal fluoridation is well established as a most successful public health measure in the control of dental caries. The increased caries-immunity associated with communal fluoridation is believed to be brought about mainly by a lowering of the acid-solubility of enamel. Fluoride ions which become available to a developing tooth are able to decrease this enamel solubility.

Following the discovery of fluoride therapy many substances were tested which, when applied topically to the teeth were also
capable of reducing the solubility of the enamel 9, 10. Of these substances, the action of stannous fluoride on tooth surfaces was shown to impart a dramatic decrease in enamel solubility 11-14, and to provide the greatest clinical immunity to caries 15-17. The use of stannous fluoride is becoming more and more widespread as its caries-immunizing properties become realized by the general practitioner. It has also been shown that the use of a dentifrice containing stannous fluoride, though not as effective as topically applied stannous fluoride, will provide the teeth with increased resistance to decay 18-23. Although not to be considered by any means a substitute for communal fluoridation, the use of a stannous fluoride dentifrice has become recognized as an effective agent in the control of caries 24. This caries-immunizing action has proved significant when the dentifrice is used normally without supervision 21,23, and provides the teeth with even more protection when used daily under supervised conditions 22.
INTRODUCTION
Tooth discoloration has been mentioned as an undesirable effect by some clinicians who do not understand the beneficial effects of stannous fluoride pigmentation. It seems natural for many people to attach importance to the appearance of their teeth and some seem to give more attention to this aspect than to the function of their teeth. Discoloured teeth are in fact regarded as attractive in some parts of the world, although most of us admire clean teeth which are free from discolouring films or deposits. The origin of our ideas of beauty is a question which belongs to aesthetics, and not to dentistry, and is a question which would likely meet with no agreement among aestheticians. Nevertheless, our concept of the attractiveness of clean teeth seems to be in harmony with the teaching of dental hygiene. Increased practice in oral hygiene has been found to be associated in most instances with a decrease in the incidence of dental caries, most gingivitis is caused by local irritation of which faulty oral hygiene is a most important source, and it is alleged that clean teeth give out less odour.

Many factors account for the numerous kinds of tooth discolorations. Pigmentation of a particular nature which has been observed to occur after stannous fluoride treatments, and which is associated with caries arrestment, is the object of this study. The ability to recognize a specific tooth discoloration is of course contingent on an awareness of the different types. Therefore, with this purpose in mind, a classification of tooth discolorations is offered in the review of the literature.
The estimations of pigmentation in this study of necessity have had to be subjective and made on the basis of clinical observations. To place any value on an estimation of tooth discoloration it must be assumed that sufficient accuracy is possible by subjective observation in spite of many variable factors. The evaluation of any discoloration must be judged on the basis of comparison. Although comparisons can be odious and appearances can be deceiving, it is nonetheless realized that our concept of discoloration can be said to have originated from appearances and comparisons.

Tooth discoloration is a relative concept, of which an evaluation will be purely subjective in most workers minds. For example, an area of brown on the surface of a clean white tooth would seem to have a greater colour intensity than the same shade of brown of similar area on a dark tooth. Furthermore, one single dark tooth would appear even darker than it really is, in a mouth where the other teeth are particularly white. Indeed, whether a person's skin is light or dark, and whether he has a beard, and whether his beard is light or dark, all these influence how white his teeth appear. When we think of a person's teeth being white, it is a different whiteness than, for example, the whiteness of salt or of snow. The whiteness of teeth, like the whiteness of skin is a matter of degree and not condition.

White teeth can be defined as being less dark than others of the same kind. Deciduous teeth are most generally more white than permanent teeth, and permanent teeth become darker with age.
The colour of a man's teeth, therefore, just as the colour of his skin, can be an estimate of relationship rather than of character.

Discolouration of teeth can originate from conditions within the pulp, arising either locally or systemically; in which cases the discolouration is referred to as intrinsic pigmentation. Discolouration can also be caused by extrinsic factors, from colouring agents introduced into the mouth, or from the saliva. Extrinsic factors can cause either staining or pigmentation.

In this study a distinction is made between staining and pigmentation in the discolouration of teeth. Staining is regarded as being brought about by extrinsic agents which can be readily removed; colouring agents which cause staining are deposited in enamel, usually in defects, or on the surfaces of intact enamel itself. In either case they are deposits that can be removed without involving the underlying structure in almost all cases.

Pigmentation, on the other hand, is considered as being associated with a change in the composition of tooth substance and as such cannot be removed without involving the structure of the pigmented area. In this sense we consider pigmentation to be a physiological response of the enamel to its environment and as such is considered to be a beneficial process. Pigmenting agents which arise from intrinsic sources are incorporated into the structure of the tooth. In cases of pigmented areas of demineralized enamel, the pigments are believed to alter the chemical structure of the demineralized enamel.
REVIEW OF THE LITERATURE
Some early investigators classified any discolouration of teeth according to the actual colour and intensity of the colour that appeared on the tooth surfaces\textsuperscript{32}. Present classifications are based on the review published by Miller (1894)\textsuperscript{33} who arranged tooth discolourations according to how they were produced. Later summaries, for instance by Valotton (1945)\textsuperscript{35}, and Stones (1951)\textsuperscript{34}, elaborated on our knowledge of the subject. In the following review of the literature, an attempt is made to further broaden our knowledge of tooth discolourations, with special reference to a specific type of enamel pigmentation.
A. DEVELOPMENTAL FACTORS ASSOCIATED WITH TOOTH DISCOLOURATION
Although it is accepted that tooth morphology is genetically determined, certain nutritional and other metabolic disturbances during growth and development are known to alter the form of any vital organ. Furthermore, after growth and development each organ possessing a metabolism of its own can be changed in some of its physical and chemical properties while still functioning in the body.

Teeth can be said to have a definite metabolism. They can be considered dynamic structures, subject to change by environmental influences throughout life. The permeability of enamel helps the tooth to maintain its vital dynamic state in the oral cavity. The vitality of the enamel was suggested in a study by Jansen and Visser by the use of a fluorescent dye, Trypsaflavin. When they applied a solution of Trypsaflavin to the enamel surface of a dog's tooth, the dye permeated the whole depth of the enamel. Penetration of dye is undoubtedly by way of the organic part of the enamel; on the other hand, penetration of inorganic ions and radioactive inorganic tracers is believed to be through the inorganic constituents of the enamel.

1. NORMAL TOOTH PIGMENT.

During tooth development the ameloblasts and the odontoblasts deposit a certain amount of pigment. This naturally-occurring pigment is present in all enamel and dentine, providing the teeth with a characteristic pearly yellow-orange appearance. The colour intensity is more pronounced in the dentine than in the enamel and occurs in the deciduous teeth in smaller amounts than
in the permanent teeth. The amount of normal pigment deposited during enamel and dentine apposition varies among individuals, and although the function of this pigment is not understood, it has been associated with possible caries-immunity, natural and acquired.

Pigmentation of the incisor teeth of the rat has been the subject of much study for the past twenty five years. Enamel of the rats' maxillary incisors is normally more pigmented than the mandibular incisors and varies from yellow to orange-brown. The pigment responsible, still not identified, is described as orange-yellow granules formed in the ameloblast cells and deposited in the enamel during apposition. Certain metabolic disturbances induced in the rat can prevent the normally observed enamel pigmentation. In fact, pigmentation of the incisors can be used as an index of various metabolic diseases. The suggestion that this pigment is "removed" from the teeth and the term "depigmented areas" used by some authorities has been criticized. It is pointed out that in these cases no pigment is deposited, therefore "lack of pigmentation" would be better terminology. This lack of pigmentation is either caused by a disturbance which affects the ameloblasts so they do not produce a normal amount of pigment, or the ameloblasts may keep producing a normal amount of pigment, but the disturbance prevents its normal deposition in the enamel. Metabolic disturbances resulting in little or no pigmentation can be brought about by feeding the animal excess amounts of fluorine. Certain vitamin deficiencies, such as
vitamin A deficiency\textsuperscript{43}, and vitamin E deficiency\textsuperscript{42}, can also bring about whiter incisor teeth in the rat. The only mineral deficiencies known to affect enamel calcification in the rat is the lack of iron\textsuperscript{44}, and lack of calcium\textsuperscript{56}.

Similar studies of metabolic disturbances in an effort to produce a lack of pigmentation have not been shown to occur in humans. However, the effects of metabolic disturbances during tooth development in humans have been studied extensively\textsuperscript{45,46,75}.

Enamel hypoplasia is caused by a developmental abnormality and is particularly susceptible to discoloration as soon as an affected tooth appears in the oral cavity.

2. ENAMEL HYPOPLASIA.

HYPPOPLASTIC ENAMEL is the result of incomplete or defective amelogenesis during the formative stage of enamel development\textsuperscript{48}. Although the causes of these defects are not always known, they seem to be related to birth difficulties and brain injuries\textsuperscript{49}.

Enamel hypoplasia is seen as pits or grooves in the surface of enamel or as areas lacking normal translucency. These defects are more permeable to inorganic ions than normal enamel\textsuperscript{40} and tend to become more discoloured and less permeable with continued exposure to the oral environment\textsuperscript{50}. When hypoplasia is extreme, discoloration affects both the enamel rods and the interprismatic substance\textsuperscript{51}. Mottled enamel is a type of enamel hypoplasia which can be caused by an excess of ingested fluoride\textsuperscript{48}.

The surface of mottled enamel readily becomes discoloured when the teeth erupt.

Enamel Hypoplasia might also be due to local infection or trauma. Although there are surprisingly few reports on the
effects of abscessed primary teeth upon the permanent dentition, the direct effects of apical inflammation on the primary teeth have been studied from two standpoints: Hypoplasia \(^{70-72}\) and pre-eruptive caries \(^{73}\). Turner (1912) \(^{70}\) first described defects of the enamel of two bicuspids and traced them to an apical infection of the nearest primary molar. Enamel hypoplasia due to local infection is sometimes called "Turner's Hypoplasia". The involved teeth, usually occurring singly, are often referred to as "Turner's teeth". There might be any degree of enamel hypoplasia in these teeth and is seen as a defect ranging from a mild brownish discolouration of the enamel to a severe pitting and irregularity of the tooth crown.

Morningstar (1937) \(^{71}\) studied the mandible of an 8 year old girl at autopsy; he examined a cystic formation between the roots of an abscessed second primary molar where the entire region was filled with granulation tissue. He found that the tooth germ of the bicuspids was affected by the inflamed tissue. The area of ameloblasts nearest the inflammatory cells was entirely obliterated. He concluded that hypoplastic defects can result from periapically involved primary teeth. Bauer (1946) \(^{72}\) also used jaws obtained at autopsy; from these he was able to show that some areas of missing enamel epithelium were the direct result of infiltration from abscessed deciduous teeth. He concluded that all periapically involved teeth should be removed. Muhler (1957) \(^{73}\) presented two clinical cases as evidence that there might be relatively large numbers of teeth, usually bicuspids, which are affected by dental caries before they enter the oral
cavity. In both instances periapical inflammation of the
deciduous teeth had persisted for several months, and the
succeeding permanent teeth were found to be affected by
apparent dental caries before they erupted. These lesions
were diagnosed by radiographic examination of the unerupted
tooth "in situ".
B. INTRINSIC PIGMENTATION
Certain conditions arising from the pulp can cause the whole tooth to appear discoloured. Factors giving rise to these conditions include blood-borne pigments, blood decomposition within the pulp, and drugs which are used in root canal therapy.

1. BLOOD-BORNE PIGMENTATION

Some blood-borne pigments are capable of localizing within the pulp to cause the whole crown to appear discoloured. Erythroblastosis 64 is a form of jaundice arising clinically after birth which may bring about a diffusion of colour in the developing teeth so that the deciduous dentition appears greenish or bluish. Fortunately this condition is rare, as blood transfusions are now capable of preventing this disease. Typhus cholera and the acute exanthemata are occasionally held responsible for pink colouration of the teeth 66. In these diseases, pigments may circulate in the blood and when carried to the capillaries in the pulp, will sometimes, albeit rarely, cause pink colouration of the teeth. A pink post-mortem discoloration of the teeth in cases of strangulation, drowning, and carbon monoxide poisoning has been reported 67. Blood-borne discoloration of teeth following internal administration of various drugs has not been recorded in recent literature 34.

2. BLOOD DECOMPOSITION WITHIN THE PULP

Decomposition of erythroblasts within the pulp is the most frequent intrinsic cause of tooth discoloration 34. It is
usually caused by conditions which bring about rapid hyperesthesia of the pulp, resulting in pulpitis. This occurs frequently following traumatic injuries, dental caries, or pulp treatment during operative dentistry. This pigmentation is due to hemoglobin or its various derivatives, hematoxin (reddish brown) and hemosiderin (yellowish brown).

3. DRUG USE IN ROOT CANAL THERAPY

Certain drugs and metals used in root canal therapy may account for discoloured teeth. Ammoniacal silver nitrate forms a silver precipitate especially when reduced with eugenol. This black pigment can readily penetrate the dentinal tubules. Iodine and certain essential oils (eugenol, oil of cloves) also can penetrate the dentinal tubules from the pulpal wall and discolour a tooth permanently.

Successful root canal treatment of an anterior tooth becomes somewhat incongruous if the tooth becomes badly discoloured, therefore an appraisal of any drug used in endodontics should consider its chromatic effect on tooth structure.
C. EXTRINSIC STAINS
Discolouration of tooth surfaces that takes place after eruption is referred to as extrinsic or exogenous. Vallotton (1945) summarized many of the studies concerned with deposits most usually found on the teeth. Discolouration and deposits associated with defects such as enamel hypoplasia, exposed dentin, caries, or any roughness of the enamel surface, cannot normally be removed by abrasives. On the other hand, that which occurs on normal intact enamel is usually referred to as stain and can be removed by abrasives such as dentifrices. The amount of stain retained on sound enamel will vary with oral hygiene and the type and amount of foods eaten. Different types of extrinsic stain and deposits found on sound enamel are discussed here. Salivary calculus deposition will not be taken into consideration in the review.

1. ENAMEL CUTICLE, when present on a tooth surface, is often permeable to discolouring agents located in the oral environment. Primary enamel cuticle is a thin continuous membrane covering the surface of enamel before a tooth erupts. During the emergence of the tooth, the reduced enamel epithelium covering the crown produces a keratinous layer on the surface of the primary cuticle. This horny integument is the secondary enamel cuticle, and at least some of it persists for a varying period of time after a tooth appears in the oral cavity.
2. THE BACTERIAL (DENTAL) PLAQUE is part of the oral environment. As soon as the teeth appear in the oral cavity, the exposed surfaces of their enamel (with or without cuticle) become coated with a slimy substance that also covers the surfaces of the tongue and mucous membranes. This substance is a thin "bacterial plaque" which can be removed but will form again in a few hours. The bacterial plaque becomes thicker with a collection of amorphous debris and a few disquamated epithelial cells and is called "materia alba" on account of its supposedly white colour. The presence of materia alba can indicate poor toothbrush habits and a lack of fibrous (detergent acting) foods. Because the term "materia alba" so poorly describes this deposit, Arnim uses the term "microcosm".

3. GREEN STAIN is a deposit varying in colour from dark green to light yellowish green which can occur on the tooth enamel at any age but is most common in children. It is seen unusually on the gingival third of the labial surfaces of maxillary anteriors. It is another enigma of our profession that although it has been reported in the earliest dental literature, the actual cause is still uncertain. It has often been reported to be the result of the action of chromogenic bacteria on the enamel cuticle, but the bacteria are still unidentified. As it sometimes reoccurs after removal it is not a cuticle. However, it is possible that in these cases the cuticle may not be removed completely. Sometimes the enamel is found to be
demineralized under the green stain, but at least one authority does not accept the general conception that caries tends to develop beneath these green stains.

1. ORANGE STAIN sometimes seen on teeth is also thought to be due to pigment-producing organisms \(^4^8\). It is easily removed with a dentifrice and may or may not recur. Its actual cause and significance, if any, is unknown.

5. TOBACCO STAIN is a yellowish brown to black deposit arising from the tars and resins of tobacco. It is superficial but might become a nidus for calculus formation \(^4^8\). Shafer \(^4^8\) states that the amount and intensity of the stain will vary with the amount and kind of tobacco used. Stones \(^3^1^4\) claims that the amount of staining varies not so much with the amount of tobacco smoked as with the individual.

6. BROWN AND BLACK STRUCTURELESS DEPOSITS develop on the teeth of certain individuals. Stones \(^3^1^4\) describes these deposits as thin black lines approximately 1 mm. from the gingivae which tend to recur after removal. It is seen in non-smokers, especially females and young children. Pickerill \(^8^1^i\) described this plaque in detail as "a thin dark brown stained line about the necks of the teeth. The stain varies from a light brown to a very dark brown colour and is from 0.5 mm. to 1 mm. in width. It occurs at any age from infants upwards." Manly \(^8^5\) called it a "brown
pellicle" occurring especially on the labial surfaces of anterior teeth of some people not using dentifrices. He noted that the colour varies from gray to brown and found it to be a structureless bacteria-free pellicle giving a positive reaction to protein tests. Bibby suggests that the pigment is produced by chromobacteria or mesenteric bacteria but he found little evidence of such bacteria in smear tests. Shafer points out that this occurs close to the orifices of the salivary gland ducts. This deposit was also reported to be more common among people with a post-nasal drip and among mouth breathers. Although the aetiology remains unknown, most authorities note that this deposit is associated with caries-immunity.

7. METALLIC STAINS tend to form on the labial surface of the anterior teeth of some industrial workers by inhalation of certain metallic dusts or fumes. Like all extrinsic stains they are essentially superficial and can be quite easily removed with a dentifrice unless of course they are found in enamel defects or exposed dentine. Miller (1934) has related different coloured stains with various metals: Greenish stain on the teeth of copper alloy workers is believed to be due to the formation of a carbonate or sub-acetate of copper. It is also reported to occur in some musicians using brass instruments. Nickel workers also may show a characteristic green stain on their teeth. It is said to be induced by the action of the saliva on the inhaled nickel. Black or
greenish stain is frequently seen in steel workers who inhale iron dust, or from the fumes while processing steel with hydrochloric acid. Orange or chestnut discolouration is sometimes seen in cadmium workers. This pigmentation, usually deposited on the necks of the teeth, is claimed to be a "danger sign" of toxic absorption of cadmium.

8. CERTAIN DRUGS AND MOUTHWASHES cause stained tooth surfaces, especially in enamel defects, on exposed dentine, and on unclean surfaces. Fifty years ago almost all dentifrices containing colouring matter were shown capable of penetrating hypoplastic enamel and exposed dentine. More recently mercurial compounds used in mouthwashes have stained teeth black or dirty green because of their tendency to form coloured sulphides.
D. DISCOLOURATION ASSOCIATED WITH THE DISEASE OF DENTAL CARIES
No attempt will be made to summarize our comprehensive knowledge of the epidemiology of dental caries, or to consider the complex problem of the etiology of this disease. As the effective prevention of a disease must be based on some comprehension of its onset, the primary attack of caries on the enamel has thus become the subject of intensive study. This review will consider the discolourations associated with the formation of carious lesions, particularly initial carious lesions.

1. WHITE OPAQUE AREAS OF INITIAL CARIOUS LESIONS

Early carious lesions of the smooth surfaces of the teeth can be seen as white opaque areas in the enamel surfaces. These areas of white opacity are the first indications seen macroscopically of smooth surface caries. They appear as white spots usually just below the contact point in early proximal caries, and as white lines along the gingival margins of the teeth in early labial and buccal lesions. The unnatural opaqueness is caused by the interference with refraction of light rays by the irregular dissolution of minerals of the enamel.

Demineralization of enamel structure gives rise to these white opaque areas. This demineralization described by Coolidge and Brightman (1957) as a "leaching ionic pattern" is affected by the carrying away, in solution, of inorganic ions. Humery (1926) showed that a zone of hypercalcification develops deep to a carious lesion. He figured this to be a defence reaction.
of the enamel against the advance of caries*. At this early stage of caries there is no apparent loss of continuity of the enamel surface, that is, an area of decalcification appears within the enamel while the surface remains intact. This phenomenon was first described by Applebaum (1932)* when he took radiographs with soft x-rays of ground sections of carious enamel. Later Darling (1956) showed the presence of a hypercalcified layer of enamel overlying the carious lesion, between the caries and the enamel surface.

Although no break in the enamel surface has been demonstrated in these cases of early caries, it must be assumed that demineralizing agents do penetrate the enamel surface through one or more points of entry without apparent damage to the outer layer. The precise nature of the points of entry by which the demineralizing agents pass through the outer surface is not yet known, probably because they are small enough to remain undetected in the thickness of a ground section of tooth structure. It is oftentimes alleged that the small organic parts of the enamel, the tufts and lamellae, not only provide paths for demineralizing agents but also provide a substrate for invading proteolytic bacteria. Nevertheless, these pathways can also be regarded as normal structures which may prove to have physiological functions not yet understood. No correlation can be shown to exist between the occurrence of enamel lamellae and the incidence

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*A reaction of similar nature takes place within the dentine*.
of smooth-surface caries. In fact, it has been suggested by Sognnaes that lamellae actually become involved in a defence mechanism against caries.

As enamel demineralization progresses, the surfaces of the white chalky zones of initial caries become slightly roughened, denoting one or more breaks in the enamel. Caviaration of the surface is then demonstrable and the whitish areas become pigmented. The amount of pigmentation often depends on the rate of progress of the disease.

2. YELLOW-BROWN PIGMENTATION OF DENTAL CARIES.

Pigmentation has been described as "the only singular characteristic common to all types of dental caries". The colouration usually appears yellow-brown but may vary in hue from pale yellow to black. As there is so little organic matrix in enamel, demineralization will remove the whole substance, forming a cavity. The shape of the enamel lesion varies according to its location of the tooth. A striking feature of histological examinations of carious enamel is the brown pigmentation of the enamel rod sheaths.

When the caries reaches the dentine, its appearance is considerably different in that the greater amount of organic matrix, although softened, is sufficient to hold the form of the dentine and delay cavitation. The degree of pigmentation in dentine depends to a great extent upon the rate of progress of the disease. Light yellow colouration as a rule
indicates acute dental caries. The dentine in these cases can be removed in large leathery masses and is sometimes called "caries humida". This acute form of the disease or "rapid caries" is more common in children and often progresses so fast that there is a lack of secondary dentine formation. The pulp is exposed before we realize it. Dark pigmentation is usually associated with the chronic dental caries which is more common in adults. The slower progress of the lesion induces minimal softening of the dentine and allows secondary dentine formation.

3. THE NATURE AND THE SOURCE OF CARIES PIGMENTATION.

A survey of dental literature has shown a diversity of opinion regarding the cause and nature of pigmentation associated with dental caries.

The belief is held by many that the pigmentation associated with caries is caused by bacterial action. Miller (1890) stated that pigmentation is due to the action of microorganisms upon the organic matter of the tooth and that incidentally it was of no importance in the carious process. Bibby (1931) asserted that the colouration is due to the presence of chromobacteria or the mesenteric bacteria although he found little evidence of such bacteria in carious lesions. Gottlieb (1957) believes an unknown group of microorganisms invades the tooth and produces the pigment. He agrees it is not the bacillus acidophilus as no one has reported that these
organisms are capable of producing a pigment. Crawford (1949) indicates that staphylococcus aureus may be involved in the production of the pigment. Hurst et al (1948) showed that bacteria resembling Actinomyces bovis and Actinomyces israelii produced a brown discolouration in experimentally induced caries in the extracted molar teeth of Syrian hamsters.

It is alleged by others that the discolouration of carious lesions is caused by non-bacterial pigments. Black (1899) declared that the pigmentation is due to the formation of heavy metal sulphides by the action of hydrogen sulphide upon certain metallic elements introduced into the mouth. Colyer and Sprawson (1953) considered that discolouration of carious teeth is merely an incidental phenomenon of the disease produced solely by outside agents and that chromogenic bacteria are not responsible.

Not only is the origin of caries pigmentation disputed, but there is no agreement about its chemical composition. Attempts to isolate the pigment and identify it by qualitative analysis have been made by Deakin (1941) and later by Vollenron (1945). These workers failed to identify the pigment but they showed it to be a melanin-like substance similar to that found in wool and hair. Later Brussel and Bemel (1954) determined that the brown spots of early enamel caries had a higher nitrogen content than normal enamel, indicating a greater percentage of protein present. Ockerse and Wasserstein (1955) made spectroscopic examinations of caries and their studies suggest that the amount of manganese compounds present in the lesion is responsible for the degree of pigmentation.
After Weisberger (1946) proposed that glucose provides the substrate to produce the pigment, Dreizen and his associates (1949) showed that the intermediate carbohydrate breakdown products, methyl glyoxal and acetyl carbinol, when acting on tooth substance will yield the same yellow-brown pigment found in caries. They interpreted these findings to mean that the pigment found in caries is a direct result of the products of carbohydrate metabolism acting on tooth structure. But this work by Dreizen et al. was severely criticized by Hutton and Nuckols (1950). They pointed out that there is a large amount of evidence to show that methyl glyoxal and acetyl carbinol are not the usual intermediate compounds of carbohydrate metabolism. Furthermore, they declared that it was impossible to state that complex organic compounds such as pigments are identical, even if superficially similar, on the basis of chemical composition alone.

Alas, it seems that until a complete understanding of the carious process is recognized, any pronouncement we may make about cause and effect relationships in this disease will be open to much criticism. As long as many aspects of the etiology of dental caries remain obscure, efforts at prevention can never be completely successful. Teeth do acquire arrestment of caries, however, and this phenomenon is usually associated with increased pigmentation.
E. DISCOLOURATION ASSOCIATED WITH THE
CONTROL OF DENTAL CARIES
Many factors have been shown to be responsible for the rate of progress of tooth decay. Without attempting to review any of these factors, we will discuss the changes in tooth colouration so often noted when the disease is slowed down or halted by the natural defence mechanism, by dental restorations, and by caries-immunizing agents. Retardation in the progress of caries has many times been associated with an increased intensity of pigmentation of the lesion. Furthermore, pigmented areas of enamel have been shown to be highly resistant to demineralisation.

1. THE NATURAL DEFENCE MECHANISM.

A natural defence mechanism is known to develop when caries attacks a tooth, and it is especially evident in chronic dental caries. This mechanism manifests itself in various ways in the enamel, the dentine, and the pulp.

Hypercalcification of the enamel interprismatic substance around a carious lesion has been noted. If an early carious process is retarded or arrested in the enamel, the initial white spots become pigmented. This condition develops, for instance, after an approximating tooth has been extracted thereby exposing a carious sone on the surface of its neighbor. This pigmentation can also occur without any apparent break in the enamel surface.

The defence mechanism is more evident in dentine. Hypercalcification of similar nature takes place in the dentine.
When the caries progresses slowly enough, the dentinal tubules usually become sclerosed and deeply pigmented. This sclerosis and pigmentation of the dentinal tubules is sometimes referred to as "eburnation". Not only has the progress of caries been known to slow down, it has also been observed to become static. Reports of arrested caries are confusing on account of the lack of agreement (which would be expected) on the clinical diagnosis of arrested caries.

Many factors have been associated with the natural mechanism involved in the defence of a tooth against caries. However, the cause and effect relationships of these factors remain far from being completely understood. The mechanism of decay resistance remains one of the unanswered questions in the study of dental caries.

2. DENTAL RESTORATIONS.

Preventive dentistry procedures for the control of dental caries are being adopted by public health departments and by private practitioners and research is being maintained for the development and improvement of caries-immunizing agents. Meanwhile operative treatment, involving the removal of tooth decay and the placement of restorations continues to account for most of the dentists' time.

Dental treatment is responsible for numerous types of tooth discolouration. In the first place, the fracture of enamel rods and the exposure of dentinal tubules during cavity preparation
tend to make a tooth more susceptible to the penetration of many chromatic elements present in the oral environment. Tooth discolourations are also associated with various filling materials, especially metallic restorations.

In an early report on this subject, Bodecker (1914) said that tooth discolourations from metallic fillings were due to the action of the saliva on the metals to form "undesirably coloured sulphur combinations". Since then various explanations to account for discolourations of tooth structure associated with metallic restorations, and the tarnishing and corrosion of the restorations themselves, have been proposed by several authorities 113-115.

The following factors associated with different restorative materials are considered responsible for discolourations, and are summarized as follows 116. In silver amalgam fillings: the amount of mercury remaining in the amalgam; the role of polishing of the surface of the filling; the water contamination of the filling during triturating and insertion; the presence or absence of zinc in the alloy; and, possible galvanic action, when a different metal is in close proximity to the amalgam filling. In gold inlays: the percentage of copper is the suspected originating factor of tarnish 116. Silicate and acrylic discolourations: besides being related to operative procedures and the length of time the restoration has been in service, have been associated with certain peculiar attributes of the patient, for instance the composition of his saliva and whether he is a mouth-breather 117.
Other factors suspected of causing discoloration in restored teeth are oral hygiene, the nature of the diet, and the saliva, especially the sulfur content of the saliva. The roles of most of these factors however, are not substantiated by scientific work. It can be concluded that all discolorations associated with the use of any restorative material can be minimized by "sound dental operative procedure which assures the good marginal adaptation of a filling".

In reviewing the role of restorative dentistry in the control of caries we must consider prophylactic odontotony. For years this was judged the most effective preventive dentistry procedure to offer our patients. Since the procedure of prophylactic odontotony was advocated over 30 years ago, it has gained widespread acceptance all over the world. Such approval is based on observations that the great majority of molar fissures sooner or later become carious. The obvious objection to the routine practice of prophylactic odontotony as it was first recommended is, of course, that not all molars become carious even when they have deep fissures. Another drawback presents itself when a prophylactic odontotony is performed on a caries susceptible tooth. Only one section of the tooth is preserved, providing no protection to all the other surfaces nor indeed to all the other teeth that are prone to decay in a caries-susceptible mouth.

Phillips and Swartz (1957) reported that certain restorative materials will decrease the solubility of adjacent enamel.
This decrease in enamel-solubility was considered to be due to the fluoride content of the filling material. This investigation explained that the fluoride content of silicate materials might account for the decreased incidence of recurrent caries around silicate restorations. It should therefore be expected that filling materials of the future will be developed with special attributes to prevent recurrent caries.

3. THE USE OF SILVER NITRATE.

For more than one hundred years dental investigators have claimed that the application of silver nitrate will decrease dental caries. Although it is agreed that its effectiveness is due to its ready penetration and deposition into enamel lesions, researchers are still not in agreement regarding the mechanisms responsible for this precipitation. However, it is generally believed that the silver nitrate ions form a silver proteinate when they precipitate in the faulty enamel and dentinal tubules. This black deposit then acts as an impermeable barrier to mouth fluids and acid inducing conditions.

The use of silver nitrate as a topically applied agent for caries-immunization was probably the first effective preventive dentistry measure employed in this manner. Its application as a prophylactic against dental caries was reported as far back as 1846. Ammoniacal silver nitrate used as a control for caries has been studied by Prime (1937). He reported that
the action of silver nitrate has two clinical effects: (1) It
discloses initial caries in the enamel surfaces which cannot be
seen clinically; and (2) it arrests initial caries of the prox-
imal surfaces of the maxillary six anterior teeth. The same
worker tried for five years to immunize pits and fissures with
this silver nitrate solution but failed. Furthermore, he dis-
covered that when a lesion became large enough to be readily
seen radiographically, the caries arrestment is not effective.
This lack of effectiveness on pits and fissures was also dem-
onstrated by Klein and Knutson (1942) who found no decrease
in caries in first permanent molars treated with silver nitrate.

Caries arrestment resulting from the use of silver nitrate
was investigated by McDonald. The progress of proximal caries
in 72 molar teeth treated with one application of silver nitrate
was compared with similar caries in 92 molars left untreated.
The progress of decay was determined by comparing the size of
the lesions radiographically. After one year 75% of the treated
lesions became arrested while 54% of the lesions left untreated
showed no increase in size. It may be judged from this study
that silver nitrate, although exhibiting some propensity to arrest
caries, is not sufficiently effective for use as a topically ap-
plied agent when compared with the action of some other substances.

It also seems that the black staining effect of ammoniacal
silver nitrate, together with its tendency to irritate epithelial
tissue, prevented its general acceptance. Nevertheless, a log-
ical approach in the prevention of dental caries was introduced,
and the possibility of discovering other more effective substance was recognized.

4. **PIGMENTATION ASSOCIATED WITH THE USE OF STANNOUS FLUORIDE.**

Tin is the factor held responsible for any pigmentation attributable to stannous fluoride therapy. According to the qualitative analysis of tooth pigments made by Vallotton (1965) and later confirmed by Shay, Hadden, and Richmond (1955), the only two elements always found in brown pigment and never found in green pigment are tin and chlorine. Although classified as a trace element, tin is by no means a foreign substance to the human organism. Its common occurrence in foods makes the average adult intake of tin about 17 mg per day. Approximately 0.5 ppm is found in the long bones, and smaller amounts in other tissues. The enamel contains varying amounts of tin. Normal enamel was found to contain about 15 ppm tin and as much as 64.0 ppm tin has been found incorporated in the outer enamel layer of teeth after they had been exposed to stannous fluoride "in vitro" under conditions to simulate as much as possible the conditions existing under topical application in the mouth.

Dental publications were reviewed to find any mention of tooth pigmentation attributable to tin before the advent of stannous fluoride. By way of historical interest, if only to show the amazing profusion of our dental literature, one case of tooth discoloration which might have been associated with the action of tin was reported in 1870. An investigation was made in the case...
of a young man whose teeth repeatedly and mysteriously became
darkly stained. An intensive search which involved detailed
scientific detective work finally traced this discoloration to
"boarding house tea". It was assumed that this exposure could
explain many tooth discolorations of unknown etiology. It
appears that the place where this young man had his meals was
guilty of a common boarding-house practice of saving the un-
consumed tea of each meal, instead of throwing it out. In
this instance the unused tea was kept in a tinned vessel which
was re-heated at each meal with the addition of more tea. In
time the tin began to wear off the inside of the container and
surfaces of iron were left exposed. The incessant infusion
and re-heating of this brew acted chemically on the iron, mak-
ing a tannate or gallate of iron. The boarders were veritably
regaling themselves in inki!

In a review of the different metallic deposits found on
the teeth of various metal workers, Miller (1894) reported
that he was able to observe nothing characteristic on the
teeth of tinsmiths (or "whitesmiths"). Recently letters of
inquiry were sent to two American companies engaged in
manufacturing processes involving the use of tin. The research
directors of the companies were asked whether they had any
knowledge of tooth discoloration of workers that might have
resulted from inhalation of dust containing tin or tin com-
ponents. Their answers to this inquiry indicated that although
they actually had never considered the problem, they were
unaware of any tooth discolouration attributed to working with tin.

Although Brudevold (1956) indicated that there might be some discolouration or staining of enamel during the topical application of stannous fluoride, no actual evidence has shown discolouration of intact enamel from exposure to stannous fluoride. However, the staining potential of stannous fluoride on enamel was investigated a few years ago. Although this investigation was rather unresolved, it is the only instance of staining of intact enamel by stannous fluoride found in the journals and is therefore reviewed here. The study reported that enamel staining occurred when stannous fluoride and hydrogen sulphide were applied to teeth. The 12 teeth used in this study were selected from among patients who presented themselves for extraction. Their teeth were first painted with a 0.1 per cent solution of stannous fluoride and a saturated hydrogen sulphide solution was applied to them. As a result the enamel became light tan and the calculus and cementum became dark tan to brown. The conclusion made in this study, namely that the teeth might develop permanent dark stains from the use of the stannous fluoride dentifrice seems incongruous for three reasons: (1) The condition of the teeth on which the study was based was not mentioned, except that they all required to be extracted; (2) it seems that no comparisons were made with control teeth. It is not known, for instance, whether similar teeth not treated with stannous
fluoride would become stained after extraction when painted with a saturated solution of hydrogen sulphide; and (3) the action of the saturated solution of hydrogen sulphide used in this study (which would be expected to have a concentration of about 30 per cent) could not be compared with the relatively low concentration of hydrogen sulphide normally present in the saliva (about 0.01 per cent).

It has been suggested that any discoloration from stannous fluoride would be due to a reaction of tin with sulphides which might be present in the mouth. Accordingly, Hine, Swartz, and Phillips (1957) investigated the staining properties of topically applied solutions of stannous fluoride on resin and silicate restorations in the presence of sulphide solutions "in vitro". This study reported that no permanent discolouration of well adapted silicate or resin restorations resulted from exposure to 8 per cent stannous fluoride solutions followed by sulphide solutions, the concentration of which approximated the amount normally found in saliva. A dark brown precipitate was observed around the margins of poorly adapted restorations and the amount of this discolouring precipitate was related to the adaptation of the filling material.

When stannous fluoride was first used for the prevention of caries in clinical tests over 10 years ago, discolouration of certain areas of some teeth was observed following treatment. Since then, a characteristic pigmentation of carious and pre-caries lesions has been associated with exposure to
stannous fluoride. Muhler made a comparative study of the pigmentation associated with caries exposed to stannous fluoride and the naturally occurring pigmentation of untreated "normal" caries. This study showed that there is a greater incidence of pigmentation in teeth treated with stannous fluoride and that the amount of pigmentation is associated with the number of carious lesions present at the time of the fluoride application. It was also shown that the only portion of the enamel which becomes pigmented is that which was previously damaged by a carious or pre-caries lesion and that non-caries enamel surfaces are not affected. The most susceptible tooth surfaces to pigmentation were found to be the following: The occlusal and buccal surfaces of the molars, the occlusal surfaces of the bicuspids and the labial surfaces of the anteriors. It was also noticed that untreated caries in many cases appeared with pigmentation similar to that of caries exposed to stannous fluoride. Later observations noted that neglected oral hygiene often increases the intensity of pigmentation of caries treated with stannous fluoride.
F. STANNOUS FLUORIDE THERAPY IN THE
CONTROL OF DENTAL CARIES
The use of topically applied fluorides in dentistry was an aftermath of the discovery that the natural fluoride content of communal drinking water was responsible for a decrease in dental caries. When it was found that this caries reduction was related to a decrease in the acid-solubility of enamel, new impetus was given the search for an immunizing agent which could be topically applied to the teeth. Hundreds of substances were investigated for their influence on the solubility of the enamel.

Sodium fluoride was at first recommended as a preventive measure to be applied to the teeth of persons not living in fluoridated areas. Later, stannous fluoride was found to be more effective than sodium fluoride, and its value was demonstrated in fluoridated areas. After a method was developed to incorporate stannous fluoride in a dentifrice, numerous experimental studies demonstrated that the anticariogenic action of the stannous ion was potentially effective in this form. When extensive clinical trials proved it significantly effective, the use of a dentifrice containing stannous fluoride became an approved method to prevent tooth decay.

1. CLINICAL RESULTS OF TOPICALLY APPLIED STANNOUS FLUORIDE

Health authorities of many nations already recognize stannous fluoride to be an effective therapeutic agent in preventing dental caries. Dental authorities recommend its use in clinics and private offices. Those most interested in the possi-
bilities of stannous fluoride are public health dentists and
these private practitioners who are particularly concerned
with caries prevention in children. All this approval is
based on several human clinical studies commenced several
15-17
years ago.

In 1955, Howell, Gish, Smiley and Muhler published the
first clinical study of the results of topically applied stan-
nous fluoride and showed it to be significantly more effective
than sodium fluoride. This study observed the caries incre-
ment of approximately 1,200 children divided into four groups.
Group I received four applications of a 2 per cent solution of
sodium fluoride. Group II had four applications of a 2 per cent
solution of stannous fluoride applied in the same manner as the
sodium fluoride of Group I. Group III received treatment similar
to Group II except that the teeth were kept moist with stannous
fluoride solution for four minutes. Group IV received no treat-
ment and served as a control. After two years all the children
were re-examined. The sodium fluoride group showed a 36.3 per
cent reduction in new DMFS when compared to the control. Group
II, receiving the 2 per cent solution of stannous fluoride, ex-
perienced a 56.8 per cent reduction in the increment of new
caries, while Group III, which received the 2 per cent stannous
fluoride solution by keeping the teeth wet for four minutes, ex-
perienced 65.5 per cent reduction.

Later investigations by Gish (1957), Howell (1957), and Muhler (1958), have resulted in the development of a
treatment technique using a single application of stannous fluoride in solution. A single application of freshly prepared stannous fluoride solution applied once each year is significantly more effective in reducing dental caries in children than a series of four applications of a 2 per cent sodium fluoride solution applied each year. The single topical fluoride treatment is recommended by some dental health authorities to be given once each year. Many dentists, in their practices, give this treatment twice a year and oftener to those patients whose teeth show a greater propensity to decay.

The anticariogenic action of a single stannous fluoride solution combined with the unsupervised use of a stannous fluoride-containing dentifrice was observed in a study by Muhler. In this study, 751 children were divided into three groups. One group, used for a control, received no stannous fluoride either in a topically applied solution of distilled water, or in their control dentifrice. Another group received a similarly applied distilled water topical application and were given a stannous fluoride dentifrice. The third group received a single topical application of an 8 per cent stannous fluoride solution plus a stannous fluoride dentifrice. The three groups were re-examined after 6-month and 12-month intervals. When the groups were examined at the 6-month interval and compared with the control group, it was found that the caries increment
of tooth surfaces of the group receiving the stannous fluoride
dentifrice was reduced by 22 per cent, while the group receiving
the fluoride dentifrice after the stannous fluoride treatment
was reduced by 65 per cent. At the 12-month interval, the caries
increment, according to the DFS index, showed a 23 per cent re-
duction in the stannous fluoride dentifrice group and a 58 per
cent reduction was observed in the group using the stannous fluo-
ride dentifrice after the topical stannous fluoride treatment.
The evidence of this study suggests that an optimal anticariogenic
action can be obtained from the combined use of topical stannous
fluoride and a stannous fluoride dentifrice.

The prodigious capacity of stannous fluoride to stop decay
which has already begun was shown in a study by McDonald. He
compared the rate of progress of caries treated once with an 8
per cent solution of stannous fluoride with caries left untreated.
Only proximal caries of first permanent molars adjacent to silver
amalgam restorations on the distal of second maxillary deciduous
molars were observed. Bite-wing radiographs taken at the beginning
of the study were compared with those taken 12 months later, in
order to determine whether the caries progressed. Evidence of 33
carious lesions used in the group treated with the stannous fluo-
ride showed that only 7 per cent increased in size and a few
actually seemed to disappear. Of the control group of 92 un-
treated carious lesions, 46% increased in size. This study also
indicated that one application of stannous fluoride seems to lose
its effectiveness after one year in regard to caries arrestment.
When the same teeth were examined after 24 months, it was found that 57 per cent of the caries in teeth treated with stannous fluoride increased in size; while 74 per cent of the caries in untreated teeth became larger. This loss of effectiveness was due to the fact that no further stannous fluoride was made available to the teeth after the initial treatment. It can therefore be recommended that stannous fluoride be made available to the teeth after an initial topical treatment. The anticariogenic action of stannous fluoride is otherwise gradually lost after the initial treatment.

2. THE ACTION OF STANNOUS FLUORIDE.

The ability of stannous fluoride to arrest initial carious lesions and its caries-immunity action on sound enamel make it an ideal agent in preventive dentistry. This two-fold action is based upon the reactivity of stannous fluoride with tooth substance and the subsequent reduction in acid-solubility. The two reactions responsible for this protection from decay have been postulated by Mahler and are accounted for as follows:

(i.) When enamel is exposed to the acidogenic action of initial caries, calcium is removed from the enamel crystal lattice. This action actually results in stannous fluoride having a greater affinity for the enamel. For this reason it readily forms a tin phosphate with the now calcium-deficient enamel. Although this tin phosphate is not yet identified, it is known to be light brown in colour and accounts for the
pigmentation observed in various lesions after exposure to stannous fluoride. This action is undoubtedly responsible for the lesions which seemed to disappear in McDonald's study already reviewed.

(ii.) The action of stannous fluoride on intact enamel is different. The tin of the stannous fluoride forms a tin oxide in the hydrous amorphous film which surrounds each enamel crystal. This tin oxide is a hydrous stannous oxide which is colourless. The incorporation of tin within this amorphous film of the enamel crystals can be defined as an adsorption rather than a chemical reaction. This "tin plating" or adsorption, which makes the enamel surface so highly insoluble to acid action accounts for the high degree of caries resistance in teeth which have been exposed to stannous fluoride.

3. LIMITATIONS OF TOPICALLY APPLIED STANNOUS FLUORIDE.

At the present time dentistry's foremost problem still appears to be dental caries. When we attempt to evaluate our progress against this disease, we become increasingly aware of the benefits not only of communal fluoridation, but also of topically applied anticariogenic agents, particularly stannous fluoride. As long as we remain members of a highly respected profession, we will continue to give ourselves and our methods the strictest self-scrutiny, therefore by appraising topically

See pages 37-41.
applied stannous fluoride, the following limitations are to be considered:

(a.) The rate at which communities are adopting fluoridation of their drinking water has failed to keep pace with the population growth and there are, indeed, a great many people who are not even supplied by a community water system. Just as we can realize that from a public health point of view many people will never really benefit from fluoridation, so also we can even more readily appreciate the fact that the treatments required for topical fluoride therapy could not possibly be provided to everyone with our present dental viewpoint. In the first place the cost would be high, and besides, there would not be nearly enough dental manpower available to undertake such an extensive and time-consuming treatment program.

(b.) For one reason or another, many dentists are dissuaded from providing their patients topical fluoride therapy. In the first place, any new idea is invariably met with opposition from a well-established group, and indeed it has been pointed out that such preventive treatment introduces a new concept to many private practitioners. A large number are conditioned to think in terms of "piece work" and become apprehensive about taking a fee for such an "intangible" service. Furthermore, it is entirely possible that the technique advocated for the application of stannous fluoride to the surfaces of teeth is not understood or appreciated by some dentists. Also, results of inadequate technique would not be evident as they would be in cases of fractured amalgams.
(c.) Stannous fluoride therapy gives no permanent protection to large number of teeth against caries. The reaction between stannous fluoride and the enamel being a surface reaction, the teeth gradually lose their immunity to decay if the treatments are not maintained. Studies "in vitro" of the uptake of tin by the enamel show that it is the outermost layer of enamel which adsorb the protective stannous ions, with little or no tin permeating into the deeper layers. Being purely a physical reaction, it does not form a permanent bond which would change the chemical structure of the enamel. Consequently the decay-resistant shield of the adsorbed stannous ions becomes worn off by the normal wear and tear of the oral environment and once again unfortified tooth structure becomes exposed to caries attack. This explains the loss of effectiveness in clinical studies after one year, both in the prevention and the arrestment of caries, in those studies where only one application was given.

(d.) Tooth pigmentation has become a deterrent in the use of stannous fluoride by some dentists who do not understand the caries arrestment value of SnF₂. It is occasionally cited as an undesirable effect brought about by exposure to stannous fluoride, even though no instance of discoloration of intact enamel by stannous fluoride therapy has been shown. Various discolorations of teeth can result from one or more of a wide variety of factors, and although the mechanism responsible for any one type of staining or pigmentation is never entirely known, observations of many cases have shown certain factors to be associated with particular
types of discoloration. Increased pigmentation of carious lesions has repeatedly been associated with retarded or inactive caries \cite{39}, \cite{42}, \cite{96}, \cite{100} and when stannous fluoride is applied to decayed teeth, the subsequent caries-arrestment can be associated with increased pigmentation of the carious lesions.

4. THE ACTION OF STANNOUS FLUORIDE IN A DENTIFRICE.

When it was discovered that the teeth acquired a definite immunity to caries when exposed to a solution of stannous fluoride, a method was developed to incorporate stannous fluoride into a compatible dentifrice.

A paste was developed that with normal use would permit the therapeutic action of stannous ions to be imparted to the teeth. It was soon learned from laboratory evidence\cite{39} and clinical tests that the anticariogenic action of topically applied stannous fluoride could be enhanced and prolonged by the daily use of this dentifrice\cite{248}. The fact that the surface protection of the teeth obtained from topical fluoride therapy lacks durability, makes the daily use of a dentifrice which is able to provide usable stannous ions, a prodigious remedy in the prevention of dental caries.

Further clinical studies by Mühler observed that the use of a stannous fluoride dentifrice will protect the teeth from decay when used by itself and without the benefit of topical fluoride therapy. The unsupervised use of this dentifrice under normal home conditions resulted in a 23 per cent reduction, while supervised brushing with this dentifrice was found to reduce caries
incidence by 57 per cent \textsuperscript{21, 22}.

\textsuperscript{20, 22} Other investigators have also established that the use of a stannous fluoride dentifrice can provide a significant degree of immunity to dental caries. The development of a dentifrice in which stannous fluoride is incorporated was recently (1959) judged one of the "highlights of research in preventive dentistry" \textsuperscript{149}. 
STATEMENT OF THE PROBLEM
Several studies have already been concerned with the occurrence of pigmentation in dental caries. 31, 131, 135, 136, 138 Although there seems to be no agreement about the mechanism of caries pigmentation, it has been observed that increased pigmentation of a carious lesion is usually associated with a retardation or arrestment in the progress of the disease. 89, 94, 96, 100

A previous study 31, in which 8 and 10 per cent solutions of stannous fluoride were applied to the teeth of children and adults, observed the occurrence of pigmentation. This study estimated the amount of tooth pigmentation present in each individual by the number of tooth surfaces which were judged to be pigmented. It was found that the incidence of pigmentation increased when teeth were treated with stannous fluoride.

Because the use of stannous fluoride to control dental caries is becoming more and more widespread, it was decided to further investigate the occurrence of pigmentation following stannous fluoride therapy. Careful observation will be made as to prevalence of occurrence, site of occurrence, frequency of occurrence, and factors responsible for enamel pigmentation following topical stannous fluoride (SnF₂) therapy. This investigation will also attempt to determine if the amount of pigmentation of the teeth is related to the caries increment and oral hygiene.
EXPERIMENTAL PROCEDURE
The subjects used in this investigation were a part of a three-way dental caries test conducted throughout a three-year period by Muhler*. Group I used a non-fluoride control dentifrice, and, in addition, received a topical application of distilled water each six months. Group II similarly received a topical application of distilled water each six months, and, in addition, used the stannous fluoride-containing dentifrice (Crest). Group III received a topical application of an 8 per cent aqueous solution of stannous fluoride each six months, and, in addition, used the stannous fluoride dentifrice. The subjects in Group III comprised the sample for this study. No control group was included (for comparative purposes) since the design of the investigation was to measure the most common places on the dentition where pigmentation occurs; to study its prevalence, to learn if pigmentation occurs around silicate, plastic, amalgam or gold restorations; to describe the color of such pigmentation; and to associate, if possible, the occurrence of these factors in relation to oral hygiene habits of the patients and to caries experience.

Group III was comprised of a total of 259 subjects at the initial examination; of these, 230 were examined 12 months later. From this group, a total of 105 subjects were available and examined for this study. Colour photographs were taken of representative cases in order to demonstrate the salient points to be subsequently emphasized by the data. Each subject was examined with a mirror and explorer and their caries experience, oral
hygiene, and pigmentation index were determined.

For the colour photography, a 35 mm. single lens reflex camera was arranged so that it would duplicate, with an equitable degree of accuracy, pictures taken of the same teeth before and after treatment (figures 1 and 2). It is realized that this apparatus will not allow exact duplication of the size and colour of enamel lesions at a later date on account of certain variable factors, such as the changes in shade of colour of film which occurs from time to time in the manufacture and processing of the film; and the lack of exact accuracy in the mechanism that would permit a slight variation of angles from which the pictures are taken.

The caries experience of each subject was measured by using the DMFT and DMFS indices at the initial examination, after a thorough prophylaxis was given and bite wing radiographs taken. Examination findings were recorded, surface by surface, on record forms at the time of the initial examination, and in the same manner, and by the same examiner, when they were assigned to this study. The age and sex distribution of the 105 subjects used for this study is shown in Table I, and the average DMF surfaces for these subjects is shown in Table II. The incidence of new dental caries of the group from which these 105 subjects were taken is found in Table III which demonstrates the effectiveness of a single topical application of stannous fluoride combined with the use of the stannous fluoride dentifrice when compared with a control group after 12 months.
Figure 1. This 35 mm. Exacta single lens reflex camera was used for the photographs. The camera is maintained on a separate table. The subject is seated at the table with his chin placed in the cup (1a) and his forehead stabilized by the frame (1b).
Figure 2. This is a slight modification of the camera shown in Figure 1. A Bellows (2) replaces the extension tubes and a small lamp (3a) with transformer (3b) is added for lighting the mouth while tooth is being brought into focus. The adjusting knob (4) will move the lens (5) while the object is seen through the viewfinder (6).
### TABLE I.
**AGE AND SEX DISTRIBUTION OF SUBJECTS**

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<td><strong>61</strong></td>
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### TABLE II.
**AVERAGE DMF TEETH AND SURFACES OF SUBJECTS**

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<th>Number of Subjects</th>
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<td>Average DMFS</td>
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TABLE III.
Reductions in the Incidence of New Dental Caries in a Group of Children Receiving a Topical Application of SnF₂ Each Six Months Plus the Daily Use of the SnF₂-Containing Dentifrice Throughout a Three-Year Period Compared with a Control Group.*

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* Data obtained from a study by Mahler138.

** The 105 subjects of this study were included in this group.
Oral hygiene was estimated by examining the entire mouth with the aid of good artificial light, dental explorers and mouth mirrors and by assigning the following values to the different grades of oral hygiene:

"very good" was given the value of 4
"good" was given the value of 3
"fair" was given the value of 2
"poor" was given the value of 1
"very poor" was given the value of 0.

In order to make the value of the oral hygiene more meaningful, the sum of all six estimates (made at 6-month treatment intervals) was used, and the average for each was computed.

The amount and type of pigmentation was estimated for every subject by examining each tooth with the aid of good artificial light and recording the findings on a chart for each individual (see figure 3 which shows a representative chart). Enamel defects which were observed to have discolouration which could not be readily removed with a scaler were considered to be pigmented. Light brown, dark brown, and black pigmentation were recognized and recorded for this study. Examples of these colour intensities of pigmentation are shown in figures 4, 5 and 6. Pigmentation of a surface as shown in figure 4 was considered black. Pigmentation rated as dark brown was comparable to the surfaces shown in figure 5, and pigmentation like that shown in figure 6 was considered light brown.

Areas of pigmentation observed in any tooth surface were drawn
Figure 3 (a).

This chart was designed to record all observations used in the study. One chart was completed for each subject.

Two separate full mouth diagrams showing the complete dentition (except the third molars) are printed on each chart. The upper diagram was used to record tooth pigmentation: All surface pigmentation which was observed in each subject was sketched on the corresponding tooth surface in the diagram. Care was taken to reproduce as closely as possible the size and shape of any pigmented area on each tooth surface. Three colours of ink were used to show the different pigmentation recognized in this study. Black pigmentation was sketched with black ink, dark brown pigmentation was reproduced with red ink, and green ink was used to duplicate all areas of light brown pigmentation.

The previous estimates of Oral Hygiene which were made at 6-month intervals for the three previous years were recorded besides the estimate of Oral Hygiene made for this study. The mean of the values of all the estimates was computed and this figure was used as the Oral Hygiene Rating of each subject.

The lower diagram was reserved for recording all caries, restorations, and missing teeth. Caries were recorded by outlining the defective tissue without filling in spaces. A line drawn mesio-distally through the occlusal or incisal diagram indicates a missing tooth. All restorations were outlined and filled in.
Figure 3 (b).

A typical chart is shown completed. Data used in this study was recorded in this way.

The previous estimates of Oral Hygiene were taken from the records of each patient as recorded each 6 months during the three year study. The Mean is computed on top right of chart. The DMFT and DMFS were also checked with the records of each patient as recorded during the three year study. Any unusual observation, such as an orthodontic appliance or a partial denture, or a pathological condition was remarked at the bottom right of chart.

All pigmented areas were drawn in the upper dentition diagram. The total number of pigmented surfaces is shown at right of chart beneath the total number of teeth and surfaces present in the mouth. The total pigmented surfaces are classified according to type.

All restorations and missing teeth are recorded in the lower dentition diagram. Note the association of pigmentation of maxillary centrals recorded in the upper diagram with the margins of silicate restorations sketched in the lower diagram.
**Date:** 8 Aug 60

**ORAL HYGIENE**

- **Very Poor:** 0
- **Poor:** 1
- **Fair:** 2
- **Good:** 3
- **Very Good:** 4

**PREVIOUS ESTIMATES**

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**DMFT:** 12  
**DMFS:** 26  

**TOTAL PERMANENT TEETH:** 27  
**NUMBER OF TEETH PIGMENTED:** 14  
**TOTAL SURFACES PIGMENTED:** 19  

**BLACK** | **DARK BROWN** | **LIGHT BROWN**  
---|---|---  
3 | 7 | 9

**REMARKS:**

- **11 occlusal margin fault**

**CODE:**

- **BLACK AREAS = BLACK PIGMENT**  
- **RED AREAS = DARK BROWN PIGMENT**  
- **GREEN AREAS = LIGHT BROWN PIGMENT**
Figure 4. The discolouration of the mesial caries of the upper left lateral seen in this illustration is an example of black pigmentation. The crown of the upper left cuspid, although not seen clearly in this photograph, is extensively broken down and is completely discoloured with intense black pigmentation. Light brown pigmentation can be seen on the labial surfaces of some lower anterior teeth of the same subject.
Figure 5. The labial surfaces of the upper right lateral and cuspid seen in this photograph are examples of what were rated dark brown pigmentation. This illustration also shows areas of light brown pigmentation of the enamel surfaces of other teeth.
Figure 6. The labial surface lesion of the upper left bicuspid seen in this photograph illustrates an example of light brown pigmentation.
by pen in the equivalent surface of the chart. Care was taken
to reproduce, as accurately as possible, by drawing with pens,
the areas of pigmented enamel on the appropriate surface of the
chart. The three different colour intensities of pigmentation
were differentiated by using three different coloured pens.

The pigmentation rate per tooth was estimated by calculating
the percentage of teeth affected by pigmentation. This calculation
was made by dividing the number of pigmented teeth (the numerators)
by the total number of teeth examined (the denominator) and mul-
tiplying by 100. For example, if a total of 30 pigmented teeth
was found in 10 subjects each having a full complement of teeth
(28), the pigmentation rate per tooth would be: 30 divided by
the total number of teeth (28 times 10) or 107 or 10.7%. The pig-
mentation rate per surface was estimated in the same manner but
in this calculation the total number of pigmented surfaces was
divided by the total number of tooth surfaces. The number of
tooth surfaces per each anterior tooth was 4, consisting of the
labial, the lingual, the mesial and the distal. Each bicuspid
and molar was considered to have 5 surfaces: occlusal, buccal,
lingual, mesial and distal. Pigmentation of an interproximal
surface was counted when it extended onto the labial or lingual
surface of an anterior tooth or onto the buccal, lingual or
occlusal surface of a bicuspid or molar.
DATA AND DISCUSSION
The group of subjects used in this investigation had been receiving topical applications of an 8 per cent aqueous solution of stannous fluoride each six months and had been using the stannous fluoride containing-dentifrice throughout a three-year period previous to the examination for this study. The amount of caries prevention in this group compared to a control group is shown in Table III on page 53. The dental caries increments in terms of DMFS and DMFT indices are shown to be significantly less in the stannous fluoride treatment group used in this study.

Based on the DMFS index, there was a difference of 63 per cent in favour of this group. The caries increment based on the DMFT index was 57 per cent less than the control group. These differences of 63 per cent and 57 per cent are both highly significant at the 0.001 level of confidence.

Table IV shows a composite of the data obtained in this study. A total of 105 children were used in the sample. This table includes the subject number, the number of pigmented teeth present, the number of pigmented surfaces, the total number of permanent teeth present, the pigmentation color index of the pigmented surfaces, the mean oral hygiene, the caries incidence expressed in terms of the DMF surface index, and the age of each subject.

It can be seen from the data that when there were relatively few pigmented tooth surfaces observed in an individual, this was most often associated with a low incidence of DMF surfaces. Subjects with a large number of pigmented teeth and surfaces
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<td>DMFS &amp; Age Rating</td>
<td>Sex</td>
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<td>73</td>
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<td>14</td>
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<td>20</td>
<td>14F</td>
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<td>74</td>
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<td>16</td>
<td>22</td>
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<td>75</td>
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<td>26</td>
<td>4 5 6</td>
<td>2.0</td>
<td>22</td>
<td>14M</td>
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</table>
usually had large DMFS values. It is also noted that there seems to be a corresponding increase in the number of DMF surfaces as the number of pigmented tooth surfaces increases.

Black pigmentation is definitely associated with poor oral hygiene. No surface of black pigmentation was observed in subjects with an oral hygiene rating greater than 3.0. Of the 34 patients with black pigmentation, 23 had an oral hygiene of 2.5 or less and 12 had a rating of 2 or less.

Dark brown pigmentation seems to show the best correlation with the number of DMF surfaces. When dark brown pigmentation was estimated on many tooth surfaces, it was observed that the pigmented areas which at first glance appeared black, were, upon closer visual examination, actually dark brown. This difference was noted when the teeth were examined carefully under good artificial illumination and after being dried with compressed air.

The occurrence of light brown pigmentation was far greater than dark brown or black pigmentation. During the examination of the subjects the estimation of light brown pigmentation in deep pits and fissures presented the most difficulty. Deep pits and fissures are almost invariably light brown in colour and it was often most difficult to decide whether to rate this discolouration as light brown pigmentation or to ignore it as extrinsic stain. The deep pits and fissures often made it too difficult to scrape (and thereby test) the discolouration with even a sharp explorer. Each such doubtful case was classified as pigmentation. There seemed to be no relationship between the amount of pigmentation and age or sex differences.
The relationship between the number of DMF surfaces and the incidence of pigmented tooth surfaces is shown in Table V. The pigmentation rate per tooth is given based on the percentage of the total number of teeth affected. The number of pigmented surfaces per subject increases with the number of DMF surfaces as does the pigmentation rate per tooth. The rate of total pigmentation in the subjects examined showed a pronounced rise when the DMF became greater than 5 surfaces. After the DMFS index reached the value of 10, the pigmentation rate increased in a fairly regular trend as the DMFS increased. The occurrence of dark brown and black pigmentation seems to give a clearer picture of the rate of pigmentation in relation to the DMFS increase. Accordingly, Table VI reveals the rate of dark brown and black pigmentation per tooth and per surface in relation to the DMFS index. This table demonstrates a pronounced rise in the amount of pigmentation per tooth when the DMFS reaches 6, and an even greater increase when the DMF reaches 16 surfaces. The pigmentation rate per surface shows a more regular rise with increased caries experience.

The number of pigmented tooth surfaces in relation to oral hygiene is shown in Table VII. There is a relatively low incidence of pigmentation per tooth in subjects with good oral hygiene. The amount of pigmentation as shown by the number of surfaces becomes very pronounced as the oral hygiene is neglected. Because the majority of the subjects had an oral hygiene rating which was confined to the same range, the values of the relatively few
subjects with higher or lower ratings than average can not be considered significant. However, the occurrence of black pigmented surfaces is seen to increase sharply with poor oral hygiene. This was especially evident on the buccal and labial surfaces which are more accessible to a tooth brush. Table VIII displays the incidence of black pigmentation in relation to the oral hygiene. Of the 105 subjects examined there were 34 having one or more surfaces affected with black pigmentation. Of the total 34 patients having black pigmentation on one or more tooth surfaces only 7 had an oral hygiene which was considered good. Thus it can be considered that black pigmentation of tooth surfaces tends to be confined to subjects who do not have good oral hygiene.

The distribution of pigmentation as it occurs on the various tooth surfaces of the subjects examined is shown on Table IX.

The molars were the most frequently affected teeth and accounted for almost one-half of the total number of pigmented surfaces found in the mouth. The pigmentation rate per tooth of the molars was estimated at 59.6 per cent and this unexpectedly high figure can be explained as follows: Pigmentation in the pits and fissures of the molars and bicuspids presented the greatest difficulty in diagnosis. This was because deep pits and fissures, which are normally discoloured, often made it impossible to differentiate between pigmentation and extrinsic stain. All such discolouration, usually light brown, was rated as pigmentation in this study. It was seen in Table VII that of the total 724
**TABLE V.**

The Incidence of Pigmentation in the Teeth of Children After Three Years of SnF$_2$ Therapy in Relation to Their DMF Surfaces As Evidenced by Their Pigmentation Rate Per Tooth.

<table>
<thead>
<tr>
<th>TOTAL DMFS NO. OF SUBJECTS</th>
<th>TOTAL PERMANENT TEETH</th>
<th>NO. OF PIGMENTED TEETH</th>
<th>NO. OF PIGMENTED SURFACES</th>
<th>PIGMENTATION RATE (%) PER TOOTH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>870</td>
<td>153</td>
<td>14 39 110 163</td>
<td>17.6</td>
</tr>
<tr>
<td>0 to 5</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 &quot; 10</td>
<td>19</td>
<td>449</td>
<td>118</td>
<td>26.3</td>
</tr>
<tr>
<td>11 &quot; 15</td>
<td>20</td>
<td>504</td>
<td>153</td>
<td>30.4</td>
</tr>
<tr>
<td>16 &quot; 20</td>
<td>12</td>
<td>308</td>
<td>107</td>
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<tr>
<td>21 &amp; over 15</td>
<td>15</td>
<td>373</td>
<td>165</td>
<td>44.2</td>
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<td>TOTALS</td>
<td>105</td>
<td>2504</td>
<td>696 82 279 133 794</td>
<td>27.8</td>
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</table>
### Table VI.

The Incidence of Dark Brown and Black Pigmentation in the Teeth of Children After Three Years of SnF₂ Therapy in Relation to Their DMF Surfaces As Evidenced by Their Pigmentation Rates Per Surface.

<table>
<thead>
<tr>
<th>DMFS</th>
<th>TOTAL NO. OF SUBJECTS</th>
<th>TOTAL PERMANENT TEETH</th>
<th>TOTAL NO. OF SURFACES WITH DARK BROWN AND BLACK DISCOLOURATION</th>
<th>PIGMENTATION RATE (%) PER SURFACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 5</td>
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<td>870</td>
<td>53</td>
<td>1.2</td>
</tr>
<tr>
<td>6 to 10</td>
<td>19</td>
<td>449</td>
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<td>504</td>
<td>79</td>
<td>3.1</td>
</tr>
<tr>
<td>16 to 20</td>
<td>12</td>
<td>308</td>
<td>81</td>
<td>5.2</td>
</tr>
<tr>
<td>21 &amp; over</td>
<td>15</td>
<td>373</td>
<td>95</td>
<td>5.1</td>
</tr>
<tr>
<td>TOTALS</td>
<td>105</td>
<td>2504</td>
<td>361</td>
<td>3.2</td>
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TABLE VII.

The Relationship of Oral Hygiene to the Incidence of Pigmented Tooth Surfaces of Children After Three Years of SnF₂ Therapy.

<table>
<thead>
<tr>
<th>ORAL HYGIENE RATING</th>
<th>TOTAL NO. OF SUBJECTS</th>
<th>TOTAL NO. OF PERMANENT TEETH</th>
<th>NO. OF PIGMENTED SURFACES</th>
<th>PIGMENTATION RATE (%)</th>
</tr>
</thead>
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<tr>
<td>0 to 0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.6 &quot; 1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 &quot; 1.5</td>
<td>2</td>
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<td>34</td>
<td>316</td>
</tr>
<tr>
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<td>375</td>
<td>140</td>
<td>22</td>
</tr>
<tr>
<td>2.1 &quot; 2.5</td>
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<td>548</td>
<td>200</td>
<td>31</td>
</tr>
<tr>
<td>2.6 &quot; 3.0</td>
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<td>1367</td>
<td>266</td>
<td>26</td>
</tr>
<tr>
<td>3.1 &quot; 3.5</td>
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<td>164</td>
<td>36</td>
<td>None</td>
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<tr>
<td>3.6 &quot; 4.0</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

| TOTALS               | 105                   | 2504                          | 696                       | 82                   | 279 | 433| 794 | 27.8 |
TABLE VIII.

The Incidence of Black Pigmentation on the Surfaces of Teeth in Relation to the Oral Hygiene of 105 Children After Three Years of SnF₂ Therapy.

<table>
<thead>
<tr>
<th>ORAL HYGIENE RATING</th>
<th>NO. OF SUBJECTS</th>
<th>NO. OF SURFACES WITH BLACK PIGMENTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 or less (poor)</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>2.1 to 2.9 (fair)</td>
<td>15</td>
<td>42</td>
</tr>
<tr>
<td>3 or more (good)</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>34</strong></td>
<td><strong>82</strong></td>
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TABLE IX.

Pigmentation As It Occurs on the Teeth of 105 Children After Three Years Treatment With SnF₂.

<table>
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<th></th>
<th>TOTAL PERMANENT TEETH</th>
<th>NO. OF PIGMENTED TEETH</th>
<th>NO. OF PIGMENTED SURFACES</th>
<th>PIGMENTATION RATE (%) PER TOOTH</th>
<th>PIGMENTATION RATE (%) PER SURFACE</th>
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<td>Anteriors</td>
<td>1196</td>
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<td>284</td>
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<td>729</td>
<td>108</td>
<td>126</td>
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<td>3.5</td>
</tr>
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<td>345</td>
<td>384</td>
<td>59.6</td>
<td>13.3</td>
</tr>
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<td>2504</td>
<td>696</td>
<td>794</td>
<td>27.3</td>
<td>7.0</td>
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TABLE X.

A Comparison of the Increase in Size of Lesions During the Three Year Period Which Were Present at the Initial Examination.

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<td>Percentage of lesions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>failing to increase in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>size during study**</td>
<td>24</td>
<td>62</td>
</tr>
<tr>
<td>Percentage which increased to size &quot;b&quot;</td>
<td>34</td>
<td>28</td>
</tr>
<tr>
<td>Percentage which increased to size &quot;c&quot;</td>
<td>42</td>
<td>10</td>
</tr>
</tbody>
</table>

* From A Study by Mahler using the same group of subjects.
** A lesion of size "a" is of such a size that it ranges from the smallest detectable incipient lesion to one representing less than 1/4 the size of a single tooth surface; one represented by size "b" is from 1/4 to 1/2 of a single tooth surface, and size "c" is a carious lesion greater in size than 1/2 of the tooth surface.
pigmented surfaces found in the 105 subjects examined, 133 or 54.5 per cent were classified as light brown pigmentation. Of the 510 pigmented surfaces found in the combined totals of the molar and bicuspid teeth, 347 were found to be on the occlusals. Furthermore, 220 of these 347 pigmented occlusal surfaces or 63.4 per cent were rated as light brown pigmentation. This proportion of light brown pigmentation was therefore much greater in these surfaces than that observed in the enamel faults of the other tooth surfaces, and accounted for a large proportion of the appraised pigmentation.

The labial surfaces of the anterior teeth (centrals, laterals and cuspids) were the next most frequently pigmented surfaces. Pigmentation of a mesial or distal surface of these teeth was evaluated when it extended onto the labial (or lingual) surface. Pigmentation associated with the margins of restorations was also included in the totals. Discolouration of deep lingual pits of the anterior teeth, especially the maxillary laterals, often presented the same difficulty of differentiation between pigmentation and extrinsic stain as did the pits and fissures of the molars and bicuspid.

Pigmented carious and pre-carious lesions of the buccal surfaces of the bicuspid appeared similar to most of the pigmented areas of the labial surfaces of the anteriors. Pigmentation of these areas, and the buccal surfaces of the molars, was often associated with what appeared to be enamel hypoplasia.
The amount of caries arrestment in the group of subjects observed in this study is shown in Table X. The areas of the carious lesions were estimated radiographically and clinically before and after the three-year treatment period to measure the rate of progress of the caries. The carious lesions of this group, who received a topical treatment of stannous fluoride each 6 months and in addition used the stannous fluoride-containing dentifrice throughout a three-year period, showed a marked tendency to become arrested. Of the lesions noted three years previously, 62 per cent failed to increase in size, while only 24 per cent of the lesions of the control group showed no size increase.
Pigmentation of teeth was investigated in a group of 105 children, ages 9 to 19 years. The subjects of this group had been given one application of an 8 per cent aqueous solution of stannous fluoride each 6 months throughout a three-year period, and, in addition, had been using the stannous fluoride dentifrice (Crest). The caries increment in this group when measured by the DMFS index was 63 per cent less than in a control group which received no stannous fluoride treatment and were not using the stannous fluoride dentifrice.

The amount of pigmentation was observed to be greater in the subjects with a high caries experience as measured by the DMFT and DMFS indices. Increased pigmentation even as a normally occurring phenomenon has often been associated with caries arrestment. This seems to be part of a natural resistance reaction against the carious process and naturally hyperpigmented areas of enamel have been shown to be highly resistant to demineralization. Poor oral hygiene was also found to be associated with increased pigmentation. Black pigmentation in particular was observed to be confined to subjects with a lower than average oral hygiene rating.

The surfaces most repeatedly affected by pigmentation were the occlusal surfaces of molars and bicuspids. The labial surfaces of the anteriors were the next most frequently pigmented. Light brown pigmentation accounted for more than half the total number of pigmented surfaces. When the pigmentation rate per tooth was estimated, it was found to increase with the caries experience as measured by the DMFS index.
CONCLUSIONS
CONCLUSIONS

1. It can be concluded from a review of the literature that increased pigmentation of a lesion in the surface of a tooth is associated with caries arrestment.

2. The amount of pigmented tooth lesions, in the children who received a single topical application of an aqueous solution of 8 per cent stannous fluoride each 6 months plus the daily use of the stannous fluoride-containing dentifrice throughout a three-year period, tends to increase according to their previous carious experience.

3. As 62 per cent of the carious lesions of the children of this study failed to increase in size (while 24 per cent of the carious lesions of the control group showed no size increase), the pigmentation observed in this study can be related to caries arrestment.

4. Poor oral hygiene is associated with increased pigmentation. Black pigmentation definitely tends to be confined to subjects whose oral hygiene is less than average. Dark brown pigmentation, on the other hand, does not tend to be confined to subjects with less than average oral hygiene. It can be concluded from this that black pigmentation is peculiar to carious lesions which do not receive the cleansing action of tooth brushing.

5. The most frequently pigmented surfaces are the occlusal of the molars and bicuspid and the labial surface of the anterior teeth.
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