EFFECT OF A STABLE 30 PER CENT STANNOUS FLUORIDE SOLUTION ON RECURRENT CARIES AROUND AMALGAM RESTORATIONS

by

William Everett Alexander

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INTRODUCTION

Recent surveys in the United States indicate that the dental health problem is still acute.[1,2] It is estimated that the population of 180 million people in 1960 had accumulated at least 700 million unfilled cavities.[3] A survey by the American Dental Association in 1965 reported that approximately 67 per cent of the children age five to nine needed restorations.[4] The average child entering school has three decayed teeth, and by age 15 has 11 decayed, missing, or filled teeth.[5]

A 1959 survey by the Dental Division of the Indiana State Board of Health of grade school children in Indiana disclosed that less than half of their decayed teeth had been restored.[6] Although the majority of teeth affected by dental caries remain untreated, the importance of the problem cannot be appreciated until one considers that not all of those teeth which are restored will remain free from recurrent caries.

How frequently do we encounter recurrent caries at the margin of a restoration? Healey and Phillips[10] reported the incidence of recurring carious lesions around defective dental restorations as 53.5 per cent.

It is increasingly apparent to the dental profession that any real success in the elimination of dental caries must begin with practical caries-preventive measures capable of reaching the masses of population. Investigators[106-125, 145-168] have found that the use of fluorides is probably the most effective preventive measure for the partial elimination of dental caries today. It has been demonstrated that an optimal level of fluoride in communal water supplies will result in a significant reduction of dental caries.[107-113] There is considerable evidence available to show that the topical application of fluoride will provide a significant reduction of dental caries in human teeth.[114-125, 145-168] This form of dental treatment has become a routine preventive measure in most dental offices and clinics throughout the country.

It now becomes possible to consider the practical application of a fluoride solution for the use in cavity preparation to reduce the recurrence of dental caries around the margins of restorations. This thesis is an attempt to study the effect of a stable 30 per cent stannous fluoride solution on recurrent caries around amalgam restorations.

REVIEW OF THE LITERATURE

Clinical Studies and Observations

The International Dental Federation's Special Commission on Oral and Dental Statistics[7] defines recurrent caries (secondary caries) as a "positively diagnosed carious lesion occurring at the margins of an existing restoration."

Jørgensen and Wakumoto[8,9] studied the relationship between the size of marginal defects and the incidence of recurrent (secondary) caries in 134 occlusal amalgams which had been in the mouth from one to nine years. The magnitude that a marginal defect must have in order to produce recurrent caries was approximately 50 microns. They also observed that the presence of marginal excess tended to increase recurrent caries; most frequently in fissures and grooves.

Broadhurst[11] states that the percentage of recurrent caries around a restored margin will vary with: (1) length of time of restoration exposure, (2) the surface restored, and (3) the caries activity. Carious lesions occurring around the margins of restorations could conceivably arise in the following ways: (1) caries not removed during cavity preparation;

(2) primary caries which starts separate from the filling, but in its course of extension, reaches the margin of the restoration; (3) caries resulting from an obvious cause, such as a fracture of the restorative material or enamel margin; and (4) caries occurring at an unaffected enamel margin.

Wedelstaedt[12] lists six considerations which may lead to the recurrence of decay around interproximal restorations. They are: (1) a poor marginal seal; (2) an overhang at the gingival margin; (3) a rough margin; (4) a margin which has been trimmed too much; (5) areas which accumulate and retain particles of food; and (6) poor contour of the interproximal space.

Amalgam failures are usually due to recurrent caries around the fillings, overhanging gingival margins, protruding margins on axial surfaces, restoration fractures, lack of properly carved occlusal and proximal surfaces and discoloration.[13]

A large majority of these amalgam failures are due to one or more of the following controllable causes: (1) faulty cavity design and preparation; (2) improper use of a matrix; and (3) mismanagement of the amalgam.[14]

Healey and Phillips[10] studied accumulated data on 1521 defective amalgam restorations for the purpose of determining their causes of failure. Clinical observations preliminary to the actual collection of data revealed that failure of amalgam restorations was generally due to: (1) recurrent caries, (2) fracture, (3) dimensional change, and (4) pulp and/or periodontal involvement.

The data on the four types of failures and the causative factors for each type showed that the most common cause of failure was recerrent caries. Actual existence of recurrent caries was found in 813 restorations or 53.5 per cent of the total number of failures observed. Main factors contributing to the failures were judged to be improper cavity preparation, which was the causative factor in 56 per cent of all failures, and faulty manipulation of the material or its contamination at the time of insertion in 40 per cent of the failures. The most common of all cavity preparation failures was found where there was inadequate extension of the proximal surface.

It is apparent from Healey and Phillips' study that the clinical success of amalgam restorations is dependent upon many factors, most of which can be controlled by the dentist. Careful cavity preparation, proper manipulation and restoration of normal anatomical contour can reduce to a minimum clinical failure of amalgam. This study verifies the opinions of Richardson,[15] Wiggins,[16] and others[13,14, 17-19] regarding importance of proper cavity preparation and manipulation of the material in the ultimate clinical success of the amalgam restoration.

In regard to recurrent caries around amalgam restorations, Crawford[13] theorizes that lack of extension for prevention and improper condensation are more often the causes of failure than the lack of inherent physical properties of the material. Amalgam cannot and should not be expected to prevent caries if margins are placed in susceptible areas.

According to Deschenes[17] and Tocchini,[20] the most common defects of cavity preparation include partial removal of carious material, lack of extension for prevention, inadequate retentive form of the cavity, insufficient provision for bulk of material, and improper preparation of the cavo-surface margin. Faulty manipulation of the filling material includes insufficient or excessive mixing of alloy and mercury, lack of condensation, contamination, a rough finished surface of the restoration, and faulty occlusion.

Easton[14] examined 415 amalgam restorations at the University of Iowa dental clinic for the purpose of determining and classifying the possible causes of failure. All of the restorations had been marked for replacement because of clinical evidence of recurrent caries. A disregard for the basic principle of extension for prevention was in evidence in 81 per cent of the restorations. In 69 per cent of the cavities the recurrent caries was limited to the peripheral walls. In 74 per cent of the restorations the failure was limited to one or both proximal surfaces. In only eight per cent was the failure limited to the occlusal surface, while in 18 per cent the occlusal and proximal surfaces were involved. Eighty-one per cent presented a decidedly incorrect proximal contour and a faulty contact. An excess of amalgam at the gingival margin was easily detectable in 84 per cent of the restorations. In 23 per cent of the restorations, a definite U-shaped fracture of the amalgam was found at the buccal and lingual margins of the proximal surfaces.

More than four-fifths of the amalgam restorations examined in Easton's survey were faulty on the proximal surfaces.

Of those defects which may be associated with improper cavity preparation, the most frequent is inadequate extension; thus caries recurrence seems inevitable, particularly in mouths with a high dental caries index.[18]

In a clinical study involving 377 Class II amalgam restorations, MacRae _et al_[21] found proximal margin defects to occur more frequently than any other type of defect. These defects were judged more often to be due to amalgam rather than enamel breakdown. The next most frequent defect found was the gingival margin overhang. In deciduous first molars, marginal defects occurred more often on the buccal than on the lingual surface in mandibular teeth and more often in mandibular teeth than maxillary teeth. In deciduous second molars, marginal defects occurred more often on the buccal than lingual surface in mandibular teeth but not in maxillary teeth.

According to Staples,[22] the majority of cavity preparations are not carried to the extent of the decay;

hence, they should be extended until there is no suspicion of diseased tissue. Extension for prevention is necessary until the cavity is thoroughly cleansed of every vestige of decay; then the cavity should be filled in order to preserve the tooth.

Davis[23] believes that the danger of secondary caries increases in each mouth proportionately as the aggregate length of cavity outline is increased. He states that placing the cavity outline in areas not susceptible to primary caries will materially decrease the liability to recurrent decay, even though the aggregate cavity outline in the mouth is thereby greatly lengthened.

According to Gail,[24] the frequency with which caries develops along the interproximal margins of obviously underextended restorations explains the necessity of extending interproximal margins into self-cleansing areas of the tooth in order to prevent recurrent decay.

Moss[25] observed 540 amalgam restorations judged as failures due to recurrent caries. Of these, 520 were attributed to faulty cavity preparation, while only 12 failed because of the material. He concluded that most amalgam failures were due to short-comings of the operator, not the material, and too little time spent in preparing a cavity suitable for receiving and retaining an amalgam. He recommended that a greater effort be made by most operators to become familiar with the management, manipulation, and preparation for amalgam restorations.

Volker, Belkakis and Melillo[26] examined 175 defective amalgam restorations for the presence of caries on the margin, on the floor, and on the approximating surface. The following table shows the incidence of caries around amalgam restorations.

Incidence of Caries Around
175 Inadequate Amalgam Restorations

Site	Per Cent
Margin	82
Floor	75
Margin & Floor	65
Approximating Surface	68

Incidence of Caries Around

66 Inadequate Occlusal Amalgam Restorations

Site	Per Cent
Margin	72
Floor	54
Margin & Floor	42

Ottolengui,[27] using extracted teeth, conducted a study to investigate "what dentists are doing, rather than what they might do." Fillings were not judged as failures because a ditch appeared around the margins or because they were so poor that in the opinion of the investigator failure would ensue. If, however, the ditch showed unmistakable evidence of recurrent caries within its walls, such fillings were marked as failures. He concluded that the highest percentage of failure with the proximal-occlusal amalgam restoration occurs on the proximal surfaces, with the greatest amount of failure at the gingival margin. Ottolengui was impressed by the low percentage of recurrent caries on the occlusal surfaces even with small fillings and minimal extension.

Broadhurst[11] examined a total of 4242 restored surfaces in a survey of 459 students age 12 and 13 years, and found 936 surfaces or 22.1 per cent afflicted with recurrent caries. Of 1364 restored occlusal surfaces in first permanent molars, 307 or 22.5 per cent evidenced recurrent caries, whereas, 181 or 29.6 per cent of 611 proximal surfaces presented with recurrent decay around the margins.

Laswell[28] found the overall prevalence of secondary caries (recurrent caries) around amalgam restorations in the permanent molar teeth of 1134 Navy recruits (ages 17 to 20) to be 9.2 per cent. The frequency of recurrent caries around the occlusal restorations of molar teeth ranged from 8.2 per cent in the mandibular second molar to 12.2 per cent in the maxillary second molar. He concluded that the susceptibility of the occlusal surface of posterior teeth generally follows the susceptibility of the teeth for primary caries (i.e. the greater the probability of occurrence of a primary lesion, the greater the probability of occurrence of a secondary lesion). Although the proximal surfaces are less than half as likely to have initial decay as the occlusal surface (41 per cent versus 85 per cent), they were equally susceptible to recurrence of decay (recurrent caries).

Kantorowicz[29] noted that only one quarter of all cervical amalgam restorations seen were adequate, and that most of the remainder required replacement if the strict criteria of satisfactory restorations from the standpoint of being smooth, well condensed, and free from marginal caries, were maintained. Approximately 50 per cent of the Class V amalgams observed showed marginal failure while about 6.59 per cent of the restorations had recurrent caries around the margins.

Recently at the Emory University School of Dentistry, a study was conducted on patients to evaluate how effectively silver amalgam restorations and gold inlays prevent recurrent caries at their margins. Only the mesio-occlusal surface of permanent first molars and the disto-occlusal surface of second bicuspids were examined. Of 531 amalgam restorations, 33 or 6.2 per cent failed because of recurrent decay, whereas only 26 or 3.9 per cent of 666 gold inlays showed evidence of recurrent caries.[30]

A commonly-observed flaw at the occlusal margins is the ditching that develops slowly as the filling is subjected to masticatory stress. These frail margins of amalgam crumble because of certain intrinsic weaknesses and because the strictest care has not been to the finishing of the cavity margins.[18]

Horwitz[31-33] used the television microscope instrumentation to study cavity margin deterioration in 51 mesio-occlusal silver amalgam alloy restorations which were placed in maxillary second deciduous molars. The mesio-buccal proximal margins of the restorations were observed by the television microscope and the marginal deterioration was electronically measured at intervals ranging between one week and one year. The results showed that the gingival area of the proximal margin deteriorated at a faster rate during the first three months postoperatively than the occlusal area. The average gingival marginal deterioration ranged from 49 microns at one week to 54.8 microns at one year. The occlusal area of the proximal margin deteriorated at a faster rate during the last nine months than the gingival area. The average occlusal marginal deterioration ranged from 5.4 microns at one week to 77.7 microns at one year. The initial gingival deterioration was attributed to marginal alloy flash, while repeated masticatory stresses were believed to be the major causative factors for the occlusal deterioration during the last nine months.

Gainsford[34] states that recurrent caries may result under the shelter of marginal excess or in the crevices resulting from marginal fracture and spurlike overhangs in marginal areas of the tooth surface.

According to Phillips,[35] the overhanging margins of a restoration produced by the expansion of amalgam usually will lead to marginal fractures in areas of stress with a resultant recurrence of caries.

McDonald and Phillips[36] observed 60 contracting amalgam restorations which were placed in the mouths of children for the purpose of determining the clinical significance of contraction. After a three-year period, there was no clinical evidence of open margins or recurrent caries in the restorations which contracted up to 31 microns.

Two investigators[18,27] suggested that excessive polishing of amalgam restorations may produce temperatures above 65° C (140° F) causing mercury to be released from the amalgam, thus creating weakened or defective regions. If these regions occur at the margins of restorations, they may ultimately invite caries recurrence.

In 1925, Ottolengui[27] examined 1000 amalgam restorations, 95 per cent of which were not polished. Of the 10 per cent which were polished, none showed a recurrence of decay, as far as he could determine without removing the restorations from the teeth.

Microleakage

The possibility that fluid interchange at cavity margins may be a factor involved in recurrent dental decay has received attention. It seems possible that secondary or recurrent caries may be initiated by one or both of two processes. The first is the actual penetration of microorganisms between the tooth and the restorative material and second, the penetration of oral fluids containing acids and enzymes between the tooth and restoration. Both of these processes would require a space or opening between the tooth and margin of the restoration.[37]

Hermetic sealing of the margins is a primary requisite for a successful dental restoration. Fluid exchange at the margins of restorations has received relatively little attention in dental research, yet this factor influences the life of the restoration and may be an explanation for the recurrence of caries at the margins of some restorations.[36]

The integrity of the margins of dental restorations has been studied by a variety of technics.[37-48, 52-64] These have included the adaptation of materials to extracted teeth by the measurement of the resistance to tensile stress and to air pressure,[57,58] the percolation by moisture at the marginal areas during temperature change[56] and by marginal penetration of various dyes,[38,52,53] bacteria[37,54,55] and radioactive isotopes[39-48] around restorations.

Armstrong and Simon,[39] using extracted teeth, reported that all six of the filling materials they used including amalgam, gold inlay, gold foil, zinc phosphate cement, silicate cement and acrylic resin showed varying amounts of marginal penetration by ^{45}Ca after 48 hours' immersion in a solution of this isotope.

Crawford and Larson[40] used ^{45}Ca to determine whether solutions could penetrate around fillings after they had been in service in the oral cavity. They concluded that all cavity margins exhibit leakage when isotopes are used as the testing agent.

Wainwright *et al*[41] reported that freshly inserted amalgam restorations *in vitro* demonstrate marginal leakage when subjected to ^{131}I-labeled human serum albumin and ^{131}NaI (isotopes).

Going et al[42] investigated the marginal penetration of dental restorations by various radioactive isotopes. All restorations showed some degree of marginal penetration to one or more of tracers. Silver amalgam restorations immersed in ^{35}S labeled sulfate, ^{45}Ca, and ^{86}Rb solutions showed penetration of the isotopes around the margins, through the dentin to the pulp chamber.

In vitro studies by Swartz and Phillips[43] have evaluated the adaptation (marginal leakage) of various restorative materials using a radioisotope technique. The relative sealing abilities were determined on the basis of the marginal permeability to ^{45}Ca. The margins of the 24-hour-old amalgam restorations were readily penetrated, but leakage diminished with aging of the restoration.

^{45}Ca has been used to study the marginal adaptation of amalgam restorations *in vivo* by a radioautographic technique.[44] Initially, the margins of the amalgam restorations were readily penetrated by the isotope, but leakage appeared to diminish as the restoration aged and was partly or completely prevented when a cavity varnish was used.

Baumgartner et al,[45] using radioisotopes (^{131}I), examined 47 teeth extracted after more than five years *in vivo* and found that most showed marginal leakage. They concluded that clinically it was not possible to predict those restorations which would exhibit marginal leakage purely on the condition of the margin unless secondary (recurrent) caries was observed.

Going and Massler[46] studied the influence of cavity liners under amalgam restorations *in vitro* on penetration by radioactive isotopes. They found that films formed by a copal resin varnish and a polystyreneethylcellulose liner decreased the penetration of radioisotopes through the margins of amalgam restorations and completely blocked the penetration of isotopes into the dentine.

Brannstrom and Soremark[47] investigated the penetration of ^{22}Na ions around amalgam restorations *in vivo* with and without cavity varnish. Autoradiograms showed penetration around the amalgam and into the dentine to the pulp under all fillings without a cavity varnish. The cavity varnish prevented, or greatly reduced, the penetration.

Stowell and Wainwright[48] studied the influence of saliva on marginal penetration of radioactive inorganic ^{131}I along the margins of Class V amalgam fillings placed *in vitro*. After two weeks or more, they observed a marked reduction in penetration of the isotope in the teeth maintained in saliva. It was suggested that saliva may deposit in the previously patent margins of such fillings, thereby preventing entry of such ions as iodide. It has also been thought that corrosion products form that may seal and prevent leakage as well as block or slow recurrent caries.[49-51] From this, Stowell and Wainwright concluded that the first one or two weeks following placement of an amalgam restoration might be considered the danger period when penetration into the underlying tooth structure is more likely to occur.

Dyes

Massler and Ostrowsky[52] tested the sealing qualities of various filling materials *in vitro* in glass cavities with the use of dyes (gentian violet and methylene blue). They found that even under ideal conditions, marginal leakage occurred within 24 hours when zinc oxyphosphate cement and acrylic resin were used as filling materials. The margins of inlays cemented with zinc oxyphosphate cement remained intact under these conditions for 90 to 120 days. Zinc oxide-eugenol and amalgam showed the most effective marginal sealing qualities.

Going et al[38] used crystal violet dye and radioactive sodium to test the marginal integrity of various filling materials in common clinical use. Both old and fresh restorations were studied. All restorations showed some degree of penetration by ^{131}I. With silver amalgam, zinc oxide-eugenol cement, and temporary stopping, the isotope penetrated into the underlying dentin. Copper amalgam and red copper cement provided good marginal sealing. Old silver amalgam and silicate cement restorations appeared to show less penetration at their margins than did fresh restorations.

Kakar and Subramanian[53] made an effort to quantitate the amount of leakage demonstrated by penetration dye using various restorative materials. Materials were tested in glass tubes partially filled with plaster of Paris, in cavities in extracted teeth at body temperature, and in cavities in extracted teeth at alternate temperatures of 4° and 60° C. The restorative materials tested were: gold foil, silver amalgam, gutta percha and zinc oxide and eugenol, zinc oxyphosphate and silicate cements. Amalgam and zinc oxide-eugenol cement provided the best protection against marginal penetration of the dyes.

These results confirm Grossman's[54] report that the commonly-used filling materials exhibit marginal leakage in a relatively short period of time and that zinc oxide-eugenol and amalgam are the most effective sealing agents.

Bacteria

In 1929, Fraser[55] studied marginal permeability to see if bacteria were able to pass through the filling material or around its margins. She placed restorative materials in glass ampules and noted turbidity in previously sterile broth if bacteria passed between the material and the glass wall. By this method, she found amalgam and copper cements impermeable to bacteria. Gutta-percha also remained sterile, but temporary stopping allowed bacteria to pass between the filling and cavity walls.

Mortensen et al[37] investigated the penetration of microorganisms between the margins of amalgam restorations.

They concluded that approximately 55 per cent of the amalgam restorations placed in intact teeth permitted bacteria to pass between the margin of the restoration and the cavity wall.

Nelsen _et al_[56] used an ingenious method to demonstrate the role of thermal expansion in causing fluid exchange through the margins of dental restorations. Extracted teeth were filled with self-curing acrylic resins, chilled in ice water for 30 seconds, wiped dry and viewed under a binocular microscope while the tooth was warmed with the fingers. Small droplets of fluid exuded from the margins of the restoration as the tooth warmed. They concluded that this marginal percolation was caused by differences in the thermal expansion of the fluid occupying the crevice between the tooth and the restoration. They also found that amalgam, gold inlay, silicate cement, gold foil and zinc oxide-eugenol cement restorations in extracted teeth leaked when they were subjected to cooling and warming.

Fiasconaro and Sherman[58] employed air pressure to determine the sealing qualities of gold foil, inlay, amalgam, silicate cement, zinc oxyphosphate cement and acrylic. They sealed a tube into the pulp chamber, immersed the tooth under water and determined the amount of air pressure necessary to break the seal as evidenced by the appearance of an air bubble at the cavo-surface margin of the filling. They found that acrylics leaked at six to eight pounds pressure, silicates leaked at 38 pounds, inlays at about 45-50 pounds, while amalgam, gold foil and zinc oxyphosphate cement did not leak at their maximal limit of 50 pounds of pressure per square inch.

An in vitro cariogenic technic which may link the development of recurrent caries with microleakage, has been used to study in vitro carious lesions around amalgam restorations.[59] Twenty-eight extracted teeth were restored with amalgam (occlusal surface) and exposed to the effects of bacterial growth for either 12 or 16 weeks. The technique used provided an effective means of producing carious lesions around restorations. The results demonstrated that amalgam restorations with a cavity liner were less susceptible to the production of carious lesions than unlined amalgam restorations.

The possibility of recurrence of decay due to bacteria left under restorations cannot be overlooked. If the bacteria do not remain viable under the restoration, then recurrence of decay is not possible.[60]

Besic[61] investigated the fate of bacteria sealed in dental cavities. Small amounts of carious dentin were allowed to remain in the cavities and were sealed first with a cotton pellet and gutta percha and then covered with zinc oxyphosphate cement. Subsequent cultures showed that the carious process in dentin definitely stops or gradually ceases as soon as the lesion is closed from the oral environment even when the organisms remain alive. The bacteria have a tendency to die out, but in 30 per cent of the cases, positive cultures persisted after being sealed for more than one year.

Noonan[62,63] evaluated 93 Class I cavities bacteriologically before and after the placement of silver amalgam restorations in primary teeth. Of those teeth in which the caries had been completely removed or which were caries-free, 93 per cent were negative on initial culture and none of a group tested became contaminated after a 15-minute exposure to normal mouth conditions. However, at later time intervals, 93 per cent of the disks were found to be contaminated. Of the teeth with caries incompletely removed, 31 per cent of the disks were found to be contaminated on initial culture and 100 per cent were contaminated at later time intervals (two to 60 days after restorations were placed).

Harrison[64] studied the ability of a commercial varnish to prevent the penetration of bacteria around restorations of silver amalgam in the mouth. An aseptic technic was used to place occlusal restorations in 20 mandibular primary molars of 10 patients. A series of five cultures were made and after one week, all teeth in both the group with the cavity varnish and the group that was not lined with varnish, produced positive cultures. These results demonstrate that the margins of silver amalgam restorations are readily penetrated by bacteria.

Research to date seems to indicate that marginal leakage of some degree, occurs with all restorative materials.[40,51] Thus, the old idea of a hermetic seal appears to have been dispelled.[39,51,60] In view of the existing knowledge, there seems to be no alternative but the realization that leakage, minute or gross, is an everyday phenomenon that occurs around dental restorations and is probably the cause of a high percentage of the failures (recurrent caries) previously blamed on other factors.[39,51]

If any significance is to be placed in the marginal phenomena exhibited by restorations, then a closer examination of the enamel-amalgam relationship and influencing factors becomes important.[11]

It has been suggested that surface irregularities may affect the adaptation of the filling material to the cavity walls as well as the strength of the enamel cavo-surface margins.[65]

Good adaptability of the amalgam to the cavity walls increases retention of the amalgam in the cavity and improves the resistance of the margins to mechanical and electrochemical attack.[66]

The surface roughness of the enamel wall produced by various instruments has been thoroughly studied.[65,68]

The irregularity of the cut tooth surfaces resulting from preparation of cavities would appear to have a two-fold significance. First these irregularities should have some effect on the adaptation of the filling material to the cavity walls, and second, they may tend to undermine or weaken groups of enamel rods at the cavo-surface margins, thus resulting in a failure of the tooth structure surrounding the restoration.[65]

The influence of cavity-wall texture on the adaptation of restorative materials has been investigated by determining the relative amounts of ^{45}Ca that penetrated margins of restorations. The experiments demonstrated that rough-surface cavity walls markedly improved the resistance of mat gold, cohesive gold-foil, amalgam and silicate restorations to marginal leakage.[67]

Fanibunda[68] studied the effects of various instruments on the enamel. He divided the instruments according to their macroscopic mechanism of action as grinding and cutting instruments. The edge and surface produced by a grinding instrument was found to depend on the surface of the instrument; the orientation of the blade of a cutting instrument in relation to the direction of enamel prisms played an important role in deciding the type of edge and surface produced on the enamel.

The adaptation of silver amalgam to cavity wall surfaces produced with different cutting instruments has been studied with ^{45}Ca.[69] The most desirable surface appeared to be the one produced by the chisel while the least desirable surface resulted with the cross cut carbide bur.

Stephan[70] recommended the use of stones and finishing burs in preference to hoes and chisels for finishing the enamel margin. Street's[71] experiments demonstrated that chisels produce a very rough enamel surface and that a smooth surface is produced by fine sandpaper disks.

Peyton and Mortell[72] found that in general the hand instruments do not seem to present a superior surface to that resulting from rotary instruments.

Black,[73] Davis,[23] Gabel[74] and McGehee _et al_[75] recommended the use of chisels, hoes, and gingival margin trimmers for planing and bevelling the enamel margins.

The use of various types of rotaty dental instruments and, to some extent, the manner of their use result in differences in surface irregularities during the preparation of cavities.[76]

Lammie[77] used a profilometer or surface analyzer to measure the surface roughness of tooth surfaces resulting from cuts made with various rotary dental instruments. He found that relatively smooth surfaces were produced when cylindrical abrasive instruments were used, with the smoothest surface being obtained with a carborundum stone. In general, a rough surface was produced by the various tungsten carbide burs.

Cantwell et al[78] using a metallic shadow casting technic, showed that the air-turbine handpieces can provide an acceptable finish to a cavity preparation when they are used at the stallout zone. The stall-out zone is that condition in which the air pressure to the air-turbine handpiece is reduced to the point at which a very small amount of operating force will stall the bur. They recommended that the enamel margins be as smooth as possible in order to minimize the presence of unsupported enamel rods which are likely to fracture and leave a marginal discrepancy between the restoration and the tooth structure. An irregular and rough cavo-surface angle may contain impregnated debris which would detract from optimum marginal integrity.

Kramer[79,80] studied sections of teeth in which cavities had been prepared using turbine handpieces. It was noted that some of the teeth showed changes in the dentine adjacent to the cavity. These changes were of two main types designated as burning and darkening. It was concluded that the changes described were due to heat generated during cavity preparation. A suggestion that heating may cause increased fragility of enamel at the margin of the cavity merits further investigation.

On the basis of specifications established by the research commission of the Bureau of Standards, very few dental alloys are now available; hence the observed amalgam failures other than those due to faulty cavity preparations, must be attributed to improper manipulation of an acceptable material.[10,81,82] The success of the amalgam restoration is dependent upon control of, and attention to, many variables. *In vitro* experiments have shown that manipulative variables and percentages of mercury influence the marginal adaptation of amalgam.[83]

Hatt[84] assessed the relationship of the amalgam restoration to the cavity wall as influenced by (1) the amount of mercury expelled immediately after trituration and prior to condensation, (2) the condensation method, and (3) the condensation pressure. He stated that the quality of this relationship determines in large measure whether caries will recur in the restored tooth.

Wilson and Ryge[86] evaluated the relative importance of differences among six dental amalgam alloys as compared with differences in manipulative technics in terms of clinical success of 1425 restorations. The results showed that non-zinc alloys produced amalgam restorations with a higher incidence of marginal deterioration than did alloys containing zinc. Coarse-cut alloys tended to produce restorations with poorer surface characteristics than did fine-cut alloys.

Nadal[86,87] investigated the clinical manifestations of variations of mercury content of amalgam restorations. Two hundred fifty-seven amalgam restorations were placed in standardized cavity preparations _in vivo_ by three different technics which produced amalgam restorations of low, average, and high mercury content, as well as different physical properties. The restorations were examined 24 hours after insertion and at three-month intervals over a one-year period. Marginal deterioration was noted to some degree in restorations placed by all three technics, but both the number and severity of marginal failures increased as the residual mercury content of the restorations increased. Surface roughness and general degradation also increased in both incidence and degree in the groups of restorations containing a high mercury content. By reducing the size of the cavity there was a decrease in the incidence and degree of marginal breakdown.

Using an Talysurf surface analyzer, Hatt[84] found that as long as the amount of mercury expelled from the amalgam was within the range of 20 to 30 per cent of the original quantity of mercury, this variable had a relatively insignificant effect upon the relationship of amalgam to the cavity wall.

Fischer _et al_[88] observed corrosion of amalgam fillings containing a 50 per cent silver alloy one year after insertion. The deformation in the border regions appeared to be greater in amalgam fillings in which a 67 per cent silver alloy had been used.

The proportioning of silver amalgam is more consistently possible with pellets and dispensers than by any method of expressing mercury,[89,90] while controlled and automatically timed mechanical amalgamation operating on the principle of the mortar and pestle assures uniform mixes of amalgam.[91]

Phillips _et al_[92] investigated the effects of trituration time on 130 amalgam restorations which were placed in the teeth of both adults and children. The restorations were placed in a high caries experience group with poor oral hygiene, on the premise that small discrepancies in the restorations would develop more readily into flagrant flaws. Small dimensional changes due to variations in the trituration time could not be detected clinically; however, the over-amalgamated restorations tended to produce smoother and brighter surfaces, whereas the under-amalgamated surfaces, in general, developed excessive tarnish.

Wolcott <u>et</u> <u>al</u>[93] studied the strength, dimensional change and adaptation of amalgam alloys using the Eames technique (mercury-alloy ratio of 1:1[89,90]). Variables in the preparation of specimens included trituration time and expression of mercury. On the basis of adaptation studies, it was concluded that the slight increase in contraction which results from trituration up to 30 seconds could not be detected clinically.

Jørgensen[94] found that amalgam margins, carefully condensed by traditional technique or by the Eames' technique were, in all cases, very porous. With a modified technique (so-called wet technique) it was almost possible to completely eliminate the porosity, to improve the adaptability to the cavity walls, and to reduce the mercury content of the condensed amalgam to a relatively low and constant level.

Sweeney[91] found that a definite opening of the margins could eventually be detected in nearly all hand packed amalgam restorations. By control of the amalgam manipulation with mechanical aids and improved condenser points, these marginal discrepancies were reduced.

Wing and Lyell[95] studied the size of spaces occurring between amalgam restorations and tooth structure in relation to manipulation of amalgam. Using a reflected light microscope and a filar eyepiece, they showed that spaces existed between amalgam restorations and tooth structure. These spaces were most effectively reduced by good condensation of amalgam but were never completely eliminated.

Kato *et al*[96] using an aerosol-propelled red dye, studied the effect of burnishing on the marginal seal of amalgam restorations *in vitro*. All unburnished specimens showed slight to considerable leakage of the dye, while those burnished immediately after condensation and carving (burnished twice) showed no leakage. Those restorations burnished only after carving showed slightly less leakage than those burnished only after condensation.

Swartz and Phillips[97] studied the marginal adaptation of dental materials placed in extracted teeth by measuring the amount of isotope (^{45}Ca) which penetrated the margins of restorations. The adaptation of amalgam restorations was not appreciably altered by expansion or contraction of the alloy during setting, since the leakage patterns of grossly expanding and contracting alloys were comparable.

Other investigators[36] have shown that the contraction which may result from slight over-trituration of an alloy or the careful use of mechanical amalgamators or automatic condensers will not be clinically observable.

It appears that a good clinical technique of mixing and condensation of amalgam will result in good adaptation to rather rough cavity wall irregularities.[76]

In addition to using dental restorative materials with optimal physical properties, the desirability of utilizing materials that possibly have an inhibitory action on the recurrence of caries is self evident.[26]

As early as 1890, Miller[98] studied the <u>bacteriostatic</u> properties of filling materials by dropping them on an inoculated gelatin plate. He found that not only freshly-mixed fillings, but pieces of old fillings often retarded bacterial growth. Of the materials tested, copper amalgam was the only one that retained this antiseptic property for an indefinite time after insertion.

Kinnear[99] studied the antibacterial properties exhibited by various dental materials against a mixed culture of streptococcus viridans and staphylococus aureus. He observed that silver cements and copper were the only filling materials used extensively by the dentist that gave appreciable antiseptic action.

In 1935, Sheppard[100] showed that most gold inlays and amalgam fillings were bactericidal toward pure cultures of streptococci and lactobacillus acidophilus and against mixtures of mouth bacteria.

McCue et al[101] studied the relatively efficiency of dental filling materials as bacteriostatic agents under controlled conditions as compared to standard test organisms. All of the dental filling materials employed in the experiments produced inhibition to the growth of micrococcus aureus and escherichia coli. The materials listed in order of decreasing ability as bacteriostatic agents *in vitro* are silicate, copper amalgam, gold goil, zinc phosphate cement, copper cement, acrylic, silver amalgam, and gold inlay. Other investigators obtained similar findings.[102,103]

Lind *et al*[104] studied contact caries in connection with silver amalgam, copper amalgam, and silicate restorations. Contact caries refers to the decay of a previously intact proximal surface which has been in contact with a restored proximal surface. Using this method, copper amalgam demonstrated a lower rate of contact caries and consequently a better cariostatic effect than silver amalgam. These findings were verified by the studies of Granarth and Hikansson-Holma.[105]

Fluoride

Prevalence of dental caries, the cost of dental care, and the declining ratio of dentists to population in the United States all emphasize the need for greater utilization by the profession of the various caries-preventive measures presently available.[106]

Epidemiological studies by Dean and his collaborators [107-111] confirm that the presence of approximately one part per million of fluoride in domestic water supplies is associated with a decreased incidence of dental caries.

Results of the Grand Rapids-Muskegon study, after 10 years of observation, showed a 54 per cent caries reduction in deciduous teeth of six-year-old children and a 60 per cent caries reduction in permanent teeth of children exposed to fluoridated water since birth.[112,113]

In 1942, Cheyne,[114] using potassium fluoride, and Bibby,[115] using the sodium salt (NaF), first showed that fluoride applied topically to the teeth would reduce dental decay.

Knutson and Armstrong,[116] using between seven and 15 topical applications of a two per cent sodium fluoride solution, found approximately 40 per cent fewer new carious teeth in the treated as compared to the untreated teeth, after one year. After two and three years, 41.3 per cent and 36.7 per cent less teeth, respectively, became carious in the fluoride treated group than in the teeth of the untreated group of children. The number of additional tooth surfaces which became decayed in teeth which were carious at the beginning of the study was 21.1 per cent and 23.9 per cent less in the treated than in the untreated carious teeth.[117,118]

Jordan _et al_[119] studied the effects of various numbers of topical applications of sodium fluoride on the deciduous teeth of children. Their findings indicate a reduction of dental caries corresponding to the increased number of applications of sodium fluoride and that more than three treatments were necessary to obtain maximum results of studies previously reported.

Galagan and Knutson,[120] using a two per cent sodium fluoride solution found the incidence of initial caries in permanent teeth which were non-carious at the time of treatment was 21.7, 40.7, and 41 per cent less in teeth treated with two, four, and six applications of fluoride solution, respectively, than in untreated teeth. The number of additional permanent tooth surfaces which became carious in teeth which were carious at the time of treatment ranged from 14 to 25 per cent less in fluoride-treated carious teeth given two, four, and six applications, respectively, than in untreated carious teeth.

Ast and Wittich,[121,122] using a half-mouth technique, studied the effects of four to six topical applications of a two per cent solution of sodium fluoride to the deciduous teeth of two-to-seven-year-old children. They found a 22 per cent reduction in the incidence of dental caries (defs) after a one and two-year period.

Jordan[123] studied the effects of topical applications of a two per cent sodium fluoride solution on deciduous molars and found a 33.6 per cent reduction in the caries incidence (defs) of the treated molars.

Sundvall-Hagland,[124] using four applications of two per cent sodium fluoride to half the dentition of 107 children, found a decrease in caries in the sodium fluoride treated group of 19 per cent, 14 per cent, and seven per cent after one, two, and three years, respectively. The reduction in the treated versus untreated groups was 34 per cent, 23 per cent, and 12 per cent for the one, two, and three-year periods.

The results of clinical studies demonstrated that four applications of a two per cent solution of sodium fluoride to the permanent teeth of children will affect approximately a 40 per cent reduction in the incidence of dental caries.[119,120,125]

In 1947, Muhler and Van Huysen,[126] using a volumetric method, reported that stannous fluoride possessed the greatest ability to reduce the solubility of powdered enamel in acetic acid among 13 different fluoride compounds (including sodium fluoride).

In 1952, Muhler and Day[127] found that the effectiveness of sodium fluoride and stannous fluoride in decreasing the solubility of powdered enamel is substantially independent of the pH at which the fluoride is applied to the enamel. The pH values ranged from 2.5 to 7.0. It was also shown that stannous fluoride is much more effective than sodium fluoride in preventing powdered enamel from dissolving in acid.

Other studies have demonstrated that stannous fluoride is more effective than sodium fluoride *in vitro* for decreasing the acid solubility of powdered enamel.[128,129]

Massler,[130] using freshly extracted teeth, tested 33 fluoride compounds for effectiveness in preventing acid etching. Sodium silicofluoride was the most effective. Among others which had more protection than sodium fluoride were lead fluoride, stannous chloride and stannous fluoride.

Brewer *et al*,[131] using a chemical microscopy technic, found that a two per cent solution of stannous fluoride significantly reduces the permeability of the enamel to sodium chloride, while a one per cent sodium fluoride solution is of little or no effect. In the same study using an electrical conductance technique, stannous fluoride was markedly superior to either sodium fluoride or sodium monofluorophosphate in decreasing the permeability of intact enamel surfaces.

Scott *et al*,[132] using an electron microscope, observed a much more marked resistance to acid etching in specimens treated with four-tenths per cent stannous fluoride than those treated with two-tenths per cent sodium fluoride.

Muhler[133] exposed areas of intact enamel to four decalcifications and measured the solubility (protection) by comparing the amount of phosphorus lost during each decalcification after the teeth were treated with various protective solutions. The results showed stannous fluoride and stannous chlorofluoride to be the most protective compounds.

Other *in vitro* studies, using intact teeth, have shown that stannous fluoride is more effective than sodium fluoride in reducing the acid solubility of enamel surfaces.[134-136]

In 1957, Walsh *et al*[137-139] concluded that the protection afforded enamel by sodium fluoride and stannous fluoride is a function of the pH at which the fluoride is applied, with the greatest effectiveness appearing at low pH levels and with stannous fluoride solutions.

Investigators studied the effects of various fluorides in the drinking water (and in the diet) of rats and hamsters which were fed a cariogenic diet. Results demonstrated that stannous fluoride is greatly superior to sodium fluoride in reducing the incidence and severity of carious lesions in rats and hamsters.[140-144]

The effectiveness of topical applications of stannous fluoride on the teeth of children has been thoroughly investigated.[146-154,156-166,168]

Howell _et al_[149] did repeated topical applications of two per cent sodium fluoride solution at pH 6.8 and a two per cent stannous fluoride solution at pH 2.9 on 620 school children. There was a decrease in total DMF surfaces of 36.3 per cent with sodium fluoride and 58.8 and 65.5 per cent reductions in the two stannous fluoride groups.

McDonald and Muhler[146] compared the effectiveness of stannous fluoride and sodium fluoride on primary teeth in three groups of children who received either four applications of a four per cent solution of stannous fluoride, four applications of a two per cent sodium fluoride solution, or no treatment. When the two treatment groups were compared to the third group, which received only a prophylaxis, it was found that the stannous fluoride group, after one year, experienced a 37 per cent reduction in the incidence of new carious surfaces, while the sodium fluoride group experienced a 12 per cent reduction.

Gish et al[148-152] studied groups of children during a five-year period in order to evaluate the effectiveness on permanent teeth of a single application (four minutes) each year of an eight per cent solution of stannous fluoride when compared to four applications each three years of a two per cent solution of sodium fluoride. The cumulative data showed a superiority for the children receiving stannous fluoride of 38, 32, 31, 28, and 35 per cent, respectively, through years one to five, in terms of increments in the DMF surface index. When the data was evaluated by the DMF tooth index, per cent reductions were 34, 29, 30, 26, and 30, respectively, at year one through five. Comparing individual groups for yearly increments, the stannous fluoride-treated groups show approximately a 35 per cent greater reduction than the sodium fluoride-treated group.

Salter et al[153] studied the anticariogenic effects of one and two applications of stannous fluoride on the deciduous and permanent teeth of children ages six and seven. They found that the topical application of an eight per cent stannous fluoride solution on two successive days produces no better results than the single application technique.

Muhler[154,155] has shown that a single application of stannous fluoride is an effective anticariogenic agent in children residing in an optimal fluoride area, as well as in adults.

Rothhaar[156,157] evaluated the single application procedure with an eight per cent solution of stannous fluoride as an anticariogenic technique in a private practice limited to pedodontics. All of the children received six applications spaced six months apart. After three years, the lowest caries activity group had 100 per cent reduction in the incidence of new carious surfaces whereas the highest caries activity group had a 60 per cent reduction in the incidence of new carious surfaces.

Jordan _et al_[158,159] applied a single application of eight per cent stannous fluoride solution to 234 seventh and eighth grade children; after one year, they found a 20 per cent reduction in the number of new carious teeth and a 14.4 per cent reduction in new carious surfaces when compared to an equal control group using distilled water. After two years, the results showed a reduction of 37.9 per cent and 38.9 per cent for DMF teeth and surfaces, respectively, in the stannous fluoride-treated group.

Compton _et al_[160] found that a single application of eight per cent stannous fluoride reduced the one-year caries increment of deciduous teeth in preschool children by 28 per cent.

Burgess _et al_[161] studied the effects of a single topical application of eight per cent stannous fluoride solution on the deciduous teeth of 122 children. The stannous fluoride children had average def surface increments which were 18.5 per cent lower after the first year and 29.2 per cent lower after the second year than those of the control group. The reduction of def surface increments due to stannous fluoride treatment was slightly greater for interproximal surfaces (32 per cent) than for occlusal surfaces (22 per cent).

Other studies demonstrated the effectiveness of a single four-minute application of stannous fluoride.[162-164]

In a non-fluoridated area, Mercer and Muhler[165,166] found no difference in the effectiveness of 30-second topical applications with 10 per cent stannous fluoride and four-minute applications of an eight per cent solution, each given semiannually. Both procedures produced marked reductions in dental caries increments compared with the control group.

In a clinical evaluation of Navy personnel, Scola[167] found that a 15-second, 10 per cent stannous fluoride topical application was as effective as a four-minute application in reducing dental caries.

A three-year study in an optimally-fluoridated community was initiated to determine the caries- inhibiting effect of both four-minute and 30-second topical applications of stannous fluoride applied annually to children whose teeth had matured on fluoridated water. The results showed that children who received two four-minute topical applications of stannous fluoride experienced a 20 per cent reduction in their incremental DMF tooth rate, as compared with children in the control group; on surfaces the reduction was 13 per cent. Children who received two 30-second applications of stannous fluoride had no reductions in DMF tooth and surface increments compared with children in the control group.[168]

Various investigators[169-173] demonstrated that topical application of a stannous fluoride solution has the ability to arrest dental caries. Pigmentation, a common characteristic of caries arrestment, has also been discussed in the literature.[169]

Mercer and Muhler[170] treated two groups of subjects with a prophylactic paste and topical applications in order to determine if stannous fluoride is associated with the arrestment of carious lesions. Lesions of comparable size were photographed before treatment and at six-month intervals throughout a two-year study period. No apparent increase in gross size of the lesions was noted in the subjects treated with stannous fluoride, while in every instance there were measurable increases in the size of the carious lesions in the control subjects.

Muhler *et al*[172] conducted a study to evaluate multiple stannous fluoride therapy on the subsequent rate of progression of incipient dental caries in young adults. The subjects received a prophylaxis with lava pumice-stannous fluoride prophylactic paste and a topical application of stannous fluoride every six months. In addition, they used a stannous fluoride-calcium pyrophosphate dentifrice to maintain the tin concentration in the incipient lesion induced by the topical stannous fluoride applications. The data obtained after 30 months showed that the multiple stannous fluoride therapy reduced the rate of caries progress by 80.3 per cent.

In a two-year study, McDonald[173] compared the effectiveness of an eight per cent stannous fluoride solution and ammoniacal silver nitrate in arresting caries. Patients who had bilateral superficial involvement of the distal surface of the second deciduous molars and the mesial surface of the first permanent molar were selected. Ninety-three per cent of the lesions treated with stannous fluoride appeared identical in size at the end of the first year. At the end of the second year, with no additional treatment, 43 per cent remained unchanged. Although not as effective as stannous fluoride, 75 per cent of the lesions treated with silver nitrate remained unchanged in size during the first year. At the end of the second, the protective effect of silver nitrate was identical to that of stannous fluoride. As a result of the findings in this study, it seems advantageous to recommend the routine application of stannous fluoride to teeth prior to the placement of restorations.

The effect of age on the ability of 10 per cent aqueous solutions of stannous fluoride to protect enamel surfaces from acid decalcification was evaluated *in vitro*. Solution ages ranged from fresh to 18 months. There was no significant loss of protective effectiveness associated with age of the stannous fluoride solutions.[174]

Shannon[175] tested a 20 per cent stannous fluoride solution over a period of eight weeks as a stock solution for the preparation of topical solutions and prophylaxis pastes. Performance was based upon the ability of the test preparation to prevent *in vitro* acid decalcification of enamel surfaces. The stock solution maintained its protective potency over the entire experimental period.

Shannon[176] used a total of 1100 extracted teeth in evaluating the effect of age on the performance of 20 per cent stock aqueous stannous fluoride as a component of solutions for topical application. There was no deleterious effect of age on the performance of the stock solution. On the contrary, there was a tendency toward greater effectiveness when the stock solution aged for 12 to 16 weeks. Protection was based on the amount of phosphorous withdrawn from the enamel surface by lactic acid, both before and after fluoride treatment.

At the present time, the topical application of fluoride must be regarded as the most important single caries-preventive treatment administered by the dentist.[175]

Nevertheless, recurrence of decay at the margins of restorations is one of the problems which confronts the dentist frequently.[101]

This knowledge has spurred attempts to incorporate the remarkable protective potency of fluoride into restorative procedures for the prevention of recurrent caries.

The silicate restoration is unique in its resistance to recurrent caries. It is probable that the lower incidence of recurrent caries generally found around the silicate restoration can be attributed, to a great extent, to the uptake of fluoride (from the silicate material) by the adjoining tooth material resulting in decreased enamel solubility and an increased resistance to acid attack.[51,177,178]

Innes and Youdelis[179] suggested that calcium fluoride incorporated into the amalgam restoration would provide some immunity to the recurrence of caries.

Rowe and Kramer[180] investigated the effect of a stannous fluoride (300 ppm fluoride) compound incorporated into silver amalgam alloy on the properties of dimensional change, delayed expansion, crushing strength, and corrosive damage. They concluded that a mixture of a stannous fluoride compound incorporated into an amalgam alloy does not seem detrimental to the workable properties of that restorative material.

Gursin[181,182] studied the effects of incorporating stannous fluoride into dental cement. His results showed that when zinc phosphate cement with a freshly prepared 30 per cent stannous fluoride solution incorporated into the cement liquid is applied to the enamel surface, the enamel becomes more resistant to the softening action of a weak acid. This reduction of solubility of the enamel produced by fluoride diminished over a period of prolonged exposure to a weak acid.

Troyer and Stookey[183] conducted an _in vitro_ study in order to determine if any difference occurred in leakage at the margins of cavity preparations which were restored with either $Zn_3(PO_4)_2$ cement or fluoride-containing $Zn_3(PO_4)_2$ cement. Class V preparations were made in cuspid and bicuspid teeth whose surfaces were intact and caries free. The teeth were divided into three groups and restored with (1) $Zn_3(PO_4)_2$ cement, (2) fluoride-containing $Zn_3\ (PO_4)_2$ cement, or (3) fluoride-containing $Zn_3\ (PO_4)_2$ cement preceded by a one-minute topical application of a 30 per cent stable stannous fluoride solution. Autoradiographs were made after the teeth were immersed in a ^{45}Ca tracer solution for two hours. The autoradiographs were examined, both visually and with the aid of a reflectometer.

Results showed that the restorations treated with the 30 per cent SnF_2 cavity liner followed by the fluoride-containing $Zn_3\ (PO_4)_2$ cement exhibited 74.5 per cent less marginal leakage than those treated with the $Zn_3\ (PO_4)_2$ cement.

The restorations treated with the 30 per cent stannous fluoride cavity liner followed by the fluoride-containing $Zn_3\ (PO_4)_2$ cement exhibited 61.5 per cent less marginal leakage than the group treated with the fluoride-containing $Zn_3\ (PO_4)_2$ cement.

Nishikawa[184] designed an experiment to determine the possible anticariogenic effect of applying stannous fluoride to the cavity wall prior to the insertion of the filling material for the prevention of recurrent caries around restorations. Occlusal cavities were prepared in a total of 64 caries-susceptible weanling rats. A freshly prepared solution of eight per cent stannous fluoride was then applied to the experimental animals for four minutes. Distilled water was used in the control group. The rats were fed a cariogenic diet for 30, 50, or 70 days after applying the fluoride and then sacrificed and examined grossly and histologically. The data indicated that the animals which received the stannous fluoride had a reduction in the incidence and severity of caries.

The degree of penetration of tin and fluorine through the dentin was also histochemically examined. The deposition of tin and fluorine was clearly demonstrated in the superficial layer of the cavities. Those layers in the cavity wall which were altered by the reaction of tooth structure and fluoride seemed to be more resistant to caries-producing agents and possessed the ability to protect against recurrent caries.

These results suggest the possible clinical application of stannous fluoride to the cavity walls prior to the placement of the restoration for the prevention of recurrent caries around the margins of restorations.

STATEMENT OF PROBLEM

Dental caries occurring adjacent to a restoration is a common finding of all dentists. It is inconvenient to both the patient and dentist in that it requires the removal of the restoration in most instances and the extension of the cavity preparation into sound tissue. Such procedures are not only time consuming, but costly to the patient.

Recently, dental research has developed a technique whereby stannous fluoride, a known anticariogenic agent [106,140-168] can be stabilized in concentrations of 30 per cent.[185] This development has made possible the practical application of stannous fluoride for use in cavity preparation to reduce enamel solubility. Following cavity preparation, only 15-second treatment time is required to obtain the benefits of stannous fluoride therapy.[165-167] As a result, the benefits may be obtained conveniently and easily, since the treatment solution is ready to use and can be applied to the walls immediately following the preparation of the cavity.

Reported in this thesis is a study of the effect of a stable 30 per cent stannous fluoride solution on recurrent caries around typical amalgam restorations.

EXPERIMENTAL PROCEDURES

Selection of the Study Sample

A procedure was designed to determine the effect of a stable 30 per cent stannous fluoride solution upon recurrent caries around amalgam restorations in children. In order to obtain the desired information, control and experimental groups were established. In the control group (I), cavity preparations were treated with a placebo solution (sodium chloride, glycerin, sorbitol and water) prior to the placement of amalgam restorations. In the experimental group (II), cavity preparations were treated with a stannous fluoride solution prior to the placing of amalgam restorations. The teeth of each child in the study were completely restored and examined after a one-year period at the Indiana University School of Dentistry. A program was offered on voluntary basis, and without cost.

The population studied consisted of school children, grades one through three, with active caries and with no previous fluoride experience from Noblesville, Indiana (Second Ward School and Third Ward School) and Mooresville, Indiana (Northwood School and Newby School); both communities were non-fluoridated areas.

Children were screened according to (1) past dental experience, (2) past fluoride experience (topical), and (3) fluoridation of community water (Figure 1).

The following method based on the caries susceptibility formula of Radike and Votaw[186] was used to assign children to the control and experimental groups:

1. When the initial examination of a child had been completed and recorded, the number of erupted permanent teeth including extractions were counted. The same number of permanent teeth were found in the left column (Figure 2) and the ratio opposite this number (parenthesis) was taken.
2. This ratio was multiplied by the number of surfaces decayed in permanent teeth. Extracted molars were counted as three surfaces. Teeth decayed down to the gum line were counted five for posteriors.
3. The product resulting from step two placed the child in the proper susceptibility class as follows:

Step 2 - product	Susceptibility Class
0 to 9	1
10 to 19	2
20 to 29	3
30 to 39	4
40 to 49	5
50 to 59	6
60 to 69	7
70 to 89	8
90 and higher	9

4. The child was assigned to treatment I (control) or II (experimental) on a tally sheet so that the number of children in each susceptibility class in either group I or group II differed by no more than one. When the numbers of assigned children in any susceptibility class were unequal between the two groups, the next child in that class was assigned to the group with the lesser number. When the numbers were equal, a coin was flipped to determine the next assignment.

Clinical Operative Procedures

Caries diagnosis was made for each subject following (1) a clinical examination using a mouth mirror, explorer, proper lighting and air to dry the teeth, and (2) examination of bite-wing radiographs.

Cavity preparations in deciduous teeth followed the principles recommended by McDonald.[173] They were extended sufficiently to include all pits and fissures, and included areas that had carious involvement or those that would likely retain food and plaque material and were considered as potential carious involvement.

The isthmus was made as wide as possible buccolingually (average width of the isthmus should be approximately one-half the intercuspal dimension of the tooth). The depth of the occlusal portion of the preparation, including the isthmus, was carried approximately one-half millimeter pulpally from the dentino-enamel junction. A flat pulpal floor with rounded line angles was used. The axial pulpal line angle was beveled or grooved and rounded angles were used throughout the cavity preparation.

In the class II cavity preparation in deciduous teeth, the buccal and lingual extensions were carried to self-cleansing areas. The cavity design demonstrated a divergence of the buccal and lingual walls toward the cervical area of the preparation. This divergent pattern in the proximal step was necessary because of the broad flat contact areas of the deciduous molars and because of the distinct buccal bulge in the gingival third. In cases where proximal marginal enamel was undermined or poorly supported, capping of one or both cusps was done to prevent marginal deterioration that often occurs at these points.

The principles as recommended by McDonald[173] were followed in the class III and the modified class III cavity preparations in deciduous teeth.

Cavity preparations in permanent teeth were done according to the principles of G. V. Black.[73]

The brass matrix technique, described by McDonald,[173] was used. The band material was fitted, contoured, and properly adapted with the use of a wedge shaped toothpick.

The trituration and condensation techniques were standardized. Fine-cut alloy pellets (Caulk) were mixed with mercury (1:1 ratio) and triturated for 17 seconds. No attempt was made to express mercury in a squeeze cloth.

The amalgam was condensed with hand condensers and carved immediately. The restorations were polished after a 24-hour period.

Method of Usage of Stable 30 per cent SnF_2 Solution As a Cavity Liner[187]

The stannous fluoride treatment solution was designed for application to the prepared cavity walls immediately following the removal of the carious tooth structure and debris and the preparation of the walls of the cavity to provide retention for the restoration. When a base was employed, the stannous fluoride treatment solution was applied following application of the base.

Studies conducted using the stable 30 per cent stannous fluoride solution followed by the insertion of amalgams, gold inlays, resins, silicates and gold foil restorations for periods ranging up to 30 days have shown that the direct application of the 30 per cent stannous fluoride treatment solution to freshly cut dentin has no adverse response on the dental pulp of dogs.[188]

A typical restorative procedure utilizing the stable 30 per cent stannous fluoride treatment (or the placebo treatment) was as follows:

1. Administration of local anesthesia and placing of rubber dam.

2. Excavation of carious tooth substances and preparation of cavity walls for the restoration.
3. Application of the stable stannous fluoride treatment solution (or the placebo treatment solution) to the walls of the preparation by dipping a cotton pledget into the stannous fluoride solution and painting the walls of the cavity. The cavity walls were kept moist with the stannous fluoride solution (or the placebo solution) for 15 seconds. Following the treatment application, any excess solution was removed by drying with air. Care was taken so that the treatment solution would not come into contact with the oral soft tissues. The normal restorative procedures were then resumed.
4. Restoration of the tooth with amalgam.

Recurrent Caries Examination

Recurrent caries examinations followed the method described by Broadhurst.[11] The examinations were carried out by the author after one year with the aid of a mouth mirror, explorer, magnifying loops (five diopter), air, adequate lighting and bite-wing radiographs.

Each accessible margin of every restored surface was examined in the following manner: Where the margin was visible, areas were tested with a sharp explorer, when not visible, the explorer was drawn along the margin, from margin to restoration and from margin to enamel. Bite-wing radiographs taken immediately following restoration of the teeth and after a one-year period were used to diagnose recurrent caries at the gingival of proximal restorations.

The margin was judged fractured or caries recurrent if the explorer gained entry between the tooth and restoration to at least the depth of enamel, with the knowledge that this condition was not present at the time of restoration.

Recurrent caries was recorded if a positively diagnosed carious lesion (color and consistency of active caries) occurred at the margin of a restoration. A roughened white chalky spot at the margin of a restoration was diagnosed as early decalcification of enamel.

The following factors were recorded in the recurrent caries examination.

1. Tooth.
2. Surface of tooth restored.
3. Type of restoration - distinction between smooth surface restoration and one replacing a fissure or groove.
4. The number and description of the susceptible margins of the restoration.
5. Position of each margin in relation to tooth contour, gingiva, and proximal contact (i.e., the extension of the restoration).
6. The condition of the surface of the restoration.
7. The condition of the margins of the restoration.
8. The condition of the enamel margin.
9. The contour of the restoration and tooth contact of the proximal restoration.
10. The position and description of the recurrent caries.

A simple chart was devised allotting each tooth a square with a central division to record the data for each restored surface of the tooth. Pertinent data was recorded in the following scheme.

<u>Left division</u>	<u>Right division</u>
Restored surface	Recurrent caries - margin and associated conditions
Marginal extension of the restoration	Condition of surface, restorative margin, enamel margin, contour and contact

DATA

A total of 290 teeth, 153 in Group I (control) and 137 in Group II (experimental) were restored and examined after a one-year period. Thirty-four children, 18 in Group I and 16 in Group II, comprised the sample. Of 304 restored surfaces in Group I, 4.60 per cent were associated with recurrent caries at the margins of restorations. Of 280 restored surfaces in Group II, 1.78 per cent were associated with recurrent caries at the margins of restorations. Table I presents the number of surfaces examined and the number and percentage exhibiting recurrent caries. Table II presents the number of susceptible margins examined and the percentage of recurrent caries. Table III is a summary of the one-year data.

First permanent molar teeth showed the greatest difference in the percentage of recurrent caries. Of 101 restored first permanent molar surfaces in Group I, 9.9 per cent were associated with recurrent caries. A total of 88 surfaces were restored in first permanent molar teeth in Group II, of which 3.4 per cent showed evidence of recurrent caries. No other permanent teeth in either groups I or II showed evidence of recurrent caries.

The restoration of the occlusal surface of first permanent molar teeth proved to be the least successful of the operative procedures. A total of 70 occlusal surfaces were restored in first permanent molars in Group I, of which 14.28 per cent were associated with recurrent caries at the margins of restorations. Of 61 restored occlusal surfaces in first permanent molars in Group II, 4.91 per cent showed evidence of recurrent caries. No other surface in first permanent molar teeth in either Group I or Group II showed evidence of recurrent caries at the margins of restorations.

All recurrent caries in first permanent molar teeth occurred as fissure caries in the occlusal surface. The distribution of recurrent caries at the margins of restorations as well as the associated conditions are presented in Table IV. Inadequate extension in occlusal fissures and grooves was associated with 76.9 per cent of the recurrent carious lesions in permanent molar teeth. Fracture of the amalgam or enamel margin was associated with 46.2 per cent of the recurrent caries around the margins of restorations. Fracture of the amalgam margin was twice as prevalent as fracture of the enamel margin.

Deterioration of the amalgam margin was associated with 92.3 per cent of the recurrent lesions in permanent molar teeth while marginal excess in fissures and grooves due to improper finishing occurred with 30.8 per cent of the recurrent caries. Overextension in fissures and grooves was the least common of the associated conditions, occurring with only 15.4 per cent of the recurrent carious lesions.

Deciduous teeth showed a slight difference in the percentage of recurrent caries between the two groups. Of 192 surfaces restored in all deciduous teeth in Group I, 2.08 per cent were associated with recurrent caries at the margins of restorations. A total of 192 surfaces were restored in deciduous teeth in Group II, of which 1.04 per cent showed evidence of recurrent caries.

A total of 121 surfaces were restored in second deciduous molar teeth in Group I, of which 1.65 per cent were associated with recurrent caries at the margins of restorations. Of 114 restored second deciduous molar surfaces in Group II, there was no evidence of recurrent caries.

A total of 59 surfaces were restored in first deciduous molar teeth in Group I, of which 3.38 per cent were associated with recurrent caries at the margins of restorations. Of 74 restored first deciduous molar surfaces in Group II, 2.70 per cent showed evidence of recurrent caries.

There was no evidence of recurrent caries associated with restored surfaces in deciduous cuspids in either group.

The percentage of recurrent caries in the occlusal surface of deciduous teeth was less than that of the first permanent molar teeth. Of 97 restored occlusal surfaces in deciduous molar teeth in Group I, 4.12 per cent were associated with recurrent caries at the margins of restorations. A total of 93 occlusal surfaces were restored in deciduous molar teeth in Group II, of which 2.15 per cent showed evidence of recurrent caries.

Comparison of bite-wing radiographs taken immediately following restoration of the teeth and after a one-year period showed no evidence of recurrent caries at the gingival of proximal restorations in deciduous teeth in either group.

No other surface in deciduous teeth in either group showed evidence of recurrent caries around the margins of restorations.

The data for the occlusal surfaces in second deciduous molar teeth showed less recurrent caries than occlusal surfaces in first permanent molar teeth. A total of 64 occlusal surfaces were restored in second deciduous molar teeth in Group I, of which 3.12 per cent were associated with recurrent caries at the margins of restorations. Of 54 restored occlusal surfaces in second deciduous molars in Group II, there was no evidence of recurrent caries.

The occlusal surface of first deciduous molar teeth in Group II showed only a slight reduction in recurrent caries as compared to first permanent molar teeth and second deciduous molar teeth. Of 33 restored occlusal surfaces in first deciduous molar teeth in Group I, 6.06 per cent were associated with recurrent caries at the margins of restorations while 5.12 per cent of 39 restored occlusal surfaces in first deciduous molar teeth in Group II showed evidence of recurrent caries.

The pattern of recurrent caries in deciduous teeth was quite different from the recurrent caries in first permanent teeth. One-third of the recurrent carious lesions in deciduous teeth occurred as fissure caries in occlusal surfaces while the other two-thirds occurred as smooth surface caries (occlusal surface). Inadequate extension in fissures and grooves was the major contributing factor associated with recurrent fissure caries, occurring in 100 per cent of the cases. Deterioration of the amalgam margin was associated with 50 per cent of the recurrent fissure caries.

Overextension of the cavity preparation was the major contributing factor in 75 per cent of the recurrent caries of smooth surfaces. Fracture of the amalgam margin was the major contributing factor associated with the remaining 25 per cent of the recurrent smooth surface caries.

Marginal fractures were associated with all recurrent carious lesions of smooth surfaces. Fracture of the amalgam margin was associated with 50 per cent of the lesions while fracture of the enamel margin was present with 75 per cent of the recurrent caries at the margins of restorations. Deterioration of the amalgam margin was associated with 100 per cent of the recurrent carious lesions of smooth surfaces.

The percentage of recurrent caries according to susceptible margins is presented in the following data. A total of 1125 susceptible margins in Group I were examined in permanent and deciduous teeth, of which 1.24 per cent were associated with recurrent caries around the margins of restorations. Of 977 susceptible margins examined in permanent and deciduous teeth in Group II, 0.51 per cent were associated with recurrent carious lesions. These data show that children receiving the stable stannous fluoride treatment solution prior to the placement of amalgam restorations experienced a 58.9 per cent reduction in recurrent caries in the mixed dentition when compared to the control children receiving the placebo treatment solution.

A total of 466 susceptible margins in Group I permanent teeth were examined; 2.14 per cent showed evidence of recurrent caries around the margins of restorations. Of 355 susceptible margins examined in permanent teeth in Group II, 0.84 per cent were associated with recurrent carious lesions. Thus, children receiving the stannous fluoride treatment solution experienced a 60.7 per cent reduction in recurrent caries in permanent teeth when compared to the control children.

Of 659 susceptible margins examined in deciduous teeth in Group I, 0.60 per cent showed evidence of recurrent caries around the margins of restorations. A total of 622 susceptible margins in deciduous teeth were examined in Group II, of which 0.32 per cent were associated with recurrent carious lesions. These data show that children receiving the stannous fluoride treatment solution experienced 46.7 fewer recurrent carious lesions in deciduous teeth when compared to the control children.

From the data in Table I, the percentage of recurrent caries according to surfaces in Group I (4.6 per cent) and in Group II (1.78 per cent) were tested for significance of difference using the chi-square test with one degree of freedom. No difference was found between the two groups. (χ^2 = 3.68, .05<P<.10)

TABLES AND FIGURES

Figure 1. Form used to screen the study children.

Dental Program

Name of Child: Last First Middle

Address: Number Street City Phone No.

School: Grade Age Sex

City where child first resided. Birth date(Month, Day, and Year)

1. Has your child always lived in Noblesville? __Yes__No

2. If your child has not always lived in Noblesville, please name the other towns in which he lived and give the time he lived in each.

Name of Town & State	Length of Time Child Lived There From(Month & Year) To(Month & Year)

3. Does your child see a regular family dentist? __Yes__No

   If Yes, Name of dentist ______________________________

4. Has a dentist ever applied fluoride to your child's teeth?

   __Yes __No __Don't know

   If Yes, when ______
   year

5. Do you use the city (Noblesville) water supply or have your own well?

   __City Water __Own Well

____
Parent or Guardian's Signature

Figure 2. Susceptibility classification according to permanent teeth and surfaces involved.

CARIOUS SURFACES

No. of teeth	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
5 (1.25)	2	3	4	5	7	8	8	9	9	9	9	9	9								
6 (.92)	1	2	3	4	5	6	7	8	8	9	9	9									
7 (.79)	1	2	3	4	4	5	6	7	8	8	8	9									
8 (.83)	1	2	3	4	5	5	6	7	8	8	9										
9 (.72)	1	2	3	3	4	5	6	6	7	8	8	8	9								
10(.64)	1	2	2	3	4	4	5	6	6	7	8	8	8	8	9						
11(.59)	1	2	2	3	3	4	5	5	6	6	7	7	8	8	8	9					
12(.52)	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	8	8	9	9	9	9
13(.49)	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	8	9	9	9	9
14(.48)	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	8	8	9	9	9
15-23(.46)	1	1	2	2	3	3	4	4	5	5	6	6	6	7	7	8	8	8	8	9	9
24(.47)	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	8	8	8	9	9
25(.46)	1	1	2	2	3	3	4	4	5	5	6	6	6	7	7	8	8	8	8	9	9
26(.46)																					
27(.43)	1	1	2	2	3	3	4	4	4	5	5	6	6	7	7	8	8	8	8	8	9
28(.41)	1	1	2	2	3	3	3	4	4	5	5	5	6	6	7	7	7	8	8	8	8

Table I.

Percentage of Recurrent Caries According to Surfaces

Dentition and Surface	Group I Restored Surfaces	Group I Recurrent Caries	%	Group II Restored Surfaces	Group II Recurrent Caries	%
Permanent Teeth	112	10	8.92	88	3	3.40
First Molar	101	10	9.90	88	3	3.40
Occlusal	70	10	14.28	61	3	4.91
Mesial	2			4		
Buccal	18			13		
Lingual	11			10		
Second Bicuspid	5			0		
Occlusal	5					
First Bicuspid	6			0		
Occlusal	6					
Deciduous Teeth	192	4	2.08	192	2	1.04
Second Molar	121	2	1.65	114		
Occlusal	64	2	3.12	54		
Mesial	32			34		
Distal	8			13		
Buccal	8			7		
Lingual	9			6		
First Molar	59	2	3.38	74	2	2.71
Occlusal	33	2	6.06	39	2	5.12
Mesial	3			2		
Distal	23			33		
Cuspid	12			4		
Distal	6			2		
Lingual	6			2		
Total Surfaces	304	14	4.6	280	5	1.78

Table II.

Percentage of Recurrent Caries According to Susceptible Margins

Dentition and Surface	Group I Susceptible Margins	Group I Recurrent Caries	%	Group II Susceptible Margins	Group II Recurrent Caries	%
Permanent Teeth	466	10	2.14	355	3	0.84
First Molar	442	10	2.26	355	3	0.84
Occlusal	320	10	3.12	258	3	1.16
Mesial	6					
Buccal	51					
Lingual	65					
Second Bicuspid	20			0		
Occlusal	20					
First Bicuspid	24			0		
Occlusal	24					
Deciduous Teeth	659	4	0.60	622	2	0.32
Second Molar	419	2	0.47	384		
Occlusal	233	2	0.85	191		
Mesial	102			99		
Distal	30			42		
Buccal	28			24		
Lingual	26			28		
First Molar	184	2	1.08	226	2	0.88
Occlusal	97	2	2.06	121	2	1.65
Mesial	15			6		
Distal	72			99		
Cuspid	36			12		
Distal	18			6		
Lingual	18			6		
Total Susceptible Margins	1125	14	1.24	977	5	0.51

Table III.

Summary of one-year clinical data following use of 30% stable SnF_2 solution prior to the placing of amalgam restorations.

Dentition	Group	Treatment	Restored Surfaces	Susceptible Margins	% Recurrent Caries	% Reduc
Mixed	I	Placebo Sol.	304	1125	1.24	--
	II	30% SnF_2 Sol.	280	977	.51	58.8
Permanent	I	Placebo Sol.	112	466	2.14	--
	II	30% SnF_2 Sol.	88	355	.85	60.7
Deciduous	I	Placebo Sol.	192	659	.60	--
	II	30% SnF_2 Sol.	192	622	.32	46.6

Table IV.

Distribution of Recurrent Caries With Associated Conditions

Recurrent Caries and Associated Conditions	First Permanent Molar	Second Deciduous Molar	First Deciduous Molar
Occlusal Surface			
Carious Fissures	13	2	
Lack of Extension	10	2	
Overextension	(2)		
Marginal Excess	(4)		
Marginal Fractures			
Amalgam	2 (2)		
Enamel	1 (1)		
Marginal Deterioration	(12)	(1)	
Smooth Surface Caries			4
Overextension			3
Marginal Fractures			
Amalgam			1 (1)
Enamel			(3)
Marginal Deterioration			(4)

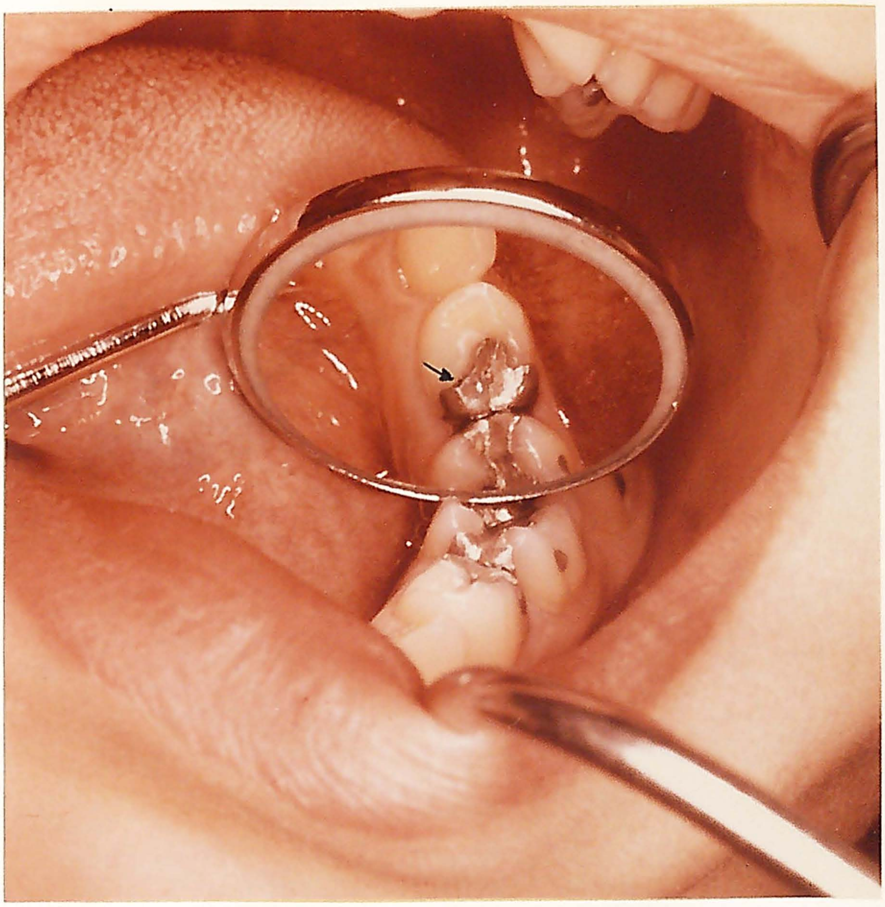
*Numbers without parenthesis - conditions judged to be the major contributing factor associated with the recurrent caries.

**Numbers in parenthesis - conditions associated with recurrent carious lesions.

Figure 3. Recurrent fissure caries associated with inadequate extension of the cavity preparation.

Figure 4. Recurrent fissure caries associated with inadequate extension of the cavity preparation and marginal excess of amalgam.

Figure 5. Recurrent caries associated with fracture of the enamel margin.



DISCUSSION

Previous clinical studies[106,114-125,145-168] have demonstrated the effectiveness of topical application of a stannous fluoride solution as an anticariogenic technique. Others[169-172] have shown that stannous fluoride is capable of arresting dental caries. Thus, it appears that topical application of stannous fluoride produces an enamel surface which is more resistant to caries attack than untreated enamel surfaces.

Recurrent caries at the margins of restorations may be due in part to factors which affect the solubility of the enamel margin. The tooth structure adjacent to the restoration can be viewed from the perspective of its relative susceptibility and the possibility that this may be altered by topical application of a stannous fluoride solution. With this in mind, it seems possible that routine topical application of a stable 30 per cent stannous fluoride solution to cavity preparations prior to the placement of amalgam restorations may aid in maintaining marginal integrity threatened by the pattern of caries attack.

Data in this study indicate that topical application of a stable 30 per cent stannous fluoride solution to cavity preparations prior to the insertion of amalgam seems definitely associated with a reduction in recurrent caries around the margins of restorations. This is demonstrated by a 58.9 per cent reduction in recurrent caries experienced by the children receiving the stannous fluoride treatment when compared to the control children. The children receiving the stannous fluoride treatment showed a 60.7 and 46.7 per cent reduction in recurrent caries in the permanent and deciduous teeth, respectively, when compared to the control group.

From the data in Table I, the percentages of recurrent caries according to surfaces in Group I (4.6 per cent) and in Group II (1.78 per cent) were tested for significance of difference using the chi-square test with one degree of freedom. The difference between the two groups approaches borderline significance ($\chi^2 = 3.68$, $.05 < P < .10$). Perhaps the difference may become statistically significant with increase in duration of the study.

The dental practitioner with preventive measures in mind recognizes that certain basic operative procedures are still among the very best assets in maintaining a dentition free from recurrent caries. Many investigators

[10-14,17-18,20,22-30,34-36,60] believe recurrent caries is related to violations of the fundamental principles of restorative dentistry.

Certain features of individual restorations were associated with the recurrent caries found around their margins. These were inadequate extension in fissures and grooves, overextension of cavity preparations associated with marginal fractures, marginal excess of amalgam, and deterioration of amalgam margins. Any of these conditions are capable of leading to food impaction and stagnation with a resultant recurrence of decay around the margins of restorations. It is important to note that these defects occurred more often without recurrent caries (in both the control and experimental group) than with recurrence of decay at the margins of restorations.

Inadequate extension in occlusal fissures and grooves was judged to be the major contributing factor associated with recurrent carious lesions in first permanent molar teeth. This point re-emphasizes the opinion of various investigators,[13-14,17-18,20,22] that cavity preparations should be extended to remove all evidence of fissures and grooves in order to prevent the recurrence of decay at the margins of restorations.

Fracture of the amalgam or enamel margin was the second most frequent major contributing factor associated with recurrent caries around the margins of first permanent molar restorations. This is in agreement with Gainsford[34] and Phillips[35] who state that recurrent caries is likely to appear in crevices resulting from marginal fractures.

Preparation of the cavo-surface margin cannot be overlooked when considering possible causes of marginal fractures. Healey and Phillips[10] believe marginal fracture of amalgam may be attributed to improper preparation of the cavo-surface area, resulting in inadequate provision for bulk of material. Other investigators[65] feel that irregularities in the prepared tooth surface may tend to undermine or weaken groups of enamel rods at the cavo-surface margins, thus resulting in a failure of the tooth structure surrounding the restoration.

The high percentage of deterioration suggests that marginal weakness may be an inherent defect in the amalgam restoration. The mechanism by which marginal breakdown occurred in this study was not clinically evident. Perhaps this type of defect is related to the so-called "edge strength" properties of the material. Sweeney[91] states that a definite marginal discrepancy can be detected in nearly all hand condensed amalgam restorations. Nadal[86-87] found that excessive amounts of residual mercury are related to marginal deterioration of amalgam restorations. Horwitz[31-33] used an intraoral television micromeasurement technique to show that cavity margin deterioration is a common feature associated with amalgam restorations.

Marginal excess associated with recurrent caries in fissures and grooves was attributed to improper finishing of the amalgam margin. Gainsford[34] is of the opinion that recurrent caries may result under the shelter of these marginal excesses.

Investigators,[189,190] have focused attention on the morphology of the fissure as a physical factor affecting caries. They believe the depth of the groove, as well as the steepness of the sides, may contribute to dental caries experience. Perhaps the high percentage of recurrent caries around occlusal restorations in first permanent molar teeth may be related to the surface morphology and therefore the ease or difficulty with which anatomical features can be removed and restored.

The low percentage of recurrent caries around restored occlusal surfaces in deciduous molar teeth may also be due in part to the morphology, i.e., shallow pits and grooves with few if any secondary fissures. Unlike recurrent caries in permanent molar teeth, inadequate extension in fissures and grooves was not judged to be the major contributing factor associated with recurrent caries around the margins of restored occlusal surfaces in deciduous teeth. This, too, might be attributed to the morphology of the occlusal surface.

More recurrent caries may have occurred around the margins of proximal surface restorations in deciduous teeth than were reported due to the inability to observe all margins of the restoration because of limited physical and visual access. Many of the proximal extensions were minimal in nature and their margins were not observed in their entirety.

The fact that no recurrent carious lesions were associated with restored buccal and lingual surfaces in either permanent or deciduous teeth may be attributed in part to the smooth surface morphology. Another point of interest was that the buccal and lingual surface restorations consistently showed less marginal deterioration than either occlusal or proximal restorations.

While microleakage seems to be an ever present factor to contend with, its clinical importance was not considered in this study. Microleakage, as well as adaptation of amalgam to cavity walls, has never been shown clinically to be related to recurrent caries. Further investigation is needed if any significance is to be placed on the marginal leakage phenomenal of restorations and its relation to recurrent caries.

The findings of this study indicate that recurrent caries around the margins of amalgam restorations depend on (1) the caries susceptibility of the adjacent tooth structure (enamel), (2) the extension of the cavity preparation, and (3) the condition of the amalgam-enamel margin.

In view of the findings of this study, the following is a summary of the measures recommended for the prevention of recurrent caries around the margins of amalgam restorations.

1. Caries should be intercepted as early as possible so that ideal restorations can be placed.

2. Cavity preparations should be extended to include all fissures and grooves.
3. The cavo-surface margin should be adequately prepared to prevent marginal fractures of enamel and amalgam.
4. A stannous fluoride solution should be routinely applied to cavity preparations prior to the insertion of the amalgam to reduce the susceptibility of the enamel to recurrent caries attack.
5. The amalgam should be properly condensed to provide marginal strength.
6. The amalgam surface should be carefully carved and finished to prevent any marginal excess.

The significance of this study lies in the fact that recurrent caries around the margins of restorations are as undesirable as primary caries. Routine application of stable 30 per cent stannous fluoride solution to cavity preparations prior to the placement of amalgam restorations now assures the dentist that he has provided an additional anticariogenic benefit.

SUMMARY AND CONCLUSIONS

This study was designed to evaluate the effectiveness of a stable 30 per cent stannous fluoride solution on recurrent caries around the margins of amalgam restorations. Thirty-four children, ages six to nine years, were selected for the study from two non-fluoridated communities. The children were divided into two groups according to caries susceptibility. The teeth of each child were completely restored and examined after a one-year period at the Indiana University School of Dentistry.

The application of the treatment solutions was done according to the double blind technique. Children in Group I received a 15-second topical application of a placebo solution to cavity preparations prior to the placement of amalgam restorations. Children in Group II received a 15-second topical application of the stable 30 per cent stannous fluoride solution to cavity preparations prior to the insertion of amalgam restorations.

A comprehensive coded system was used to record the description and position of existing conditions associated with recurrent carious lesions around the margins of restorations. The recurrent caries examinations were carried out by the author with the aid of a mouth mirror, explorer, air, magnifying loops (five diopter), adequate lighting and bite-wing radiographs.

The data obtained in this study showed that topical application of the stable 30 per cent stannous fluoride solution to cavity preparations prior to the placement of amalgam restorations was definitely associated with a reduction in recurrent caries around the margins of restorations. Children receiving the stannous fluoride treatment experienced a 58.9 per cent reduction in recurrent caries when compared to the control children. The children receiving the stannous fluoride treatment showed a 60.7 and 46.7 per cent reduction in recurrent carious lesions in permanent and deciduous teeth, respectively, when compared to the control group.

The reduction in recurrent caries around the margins of restorations was attributed in part to the anticariogenic effect of the stannous fluoride treatment. This anticariogenic effect was explained by the decreased solubility of marginal enamel following treatment with stannous fluoride.

The occlusal surface of first permanent molar teeth experienced the greatest number of recurrent carious lesions, all of which occurred as fissure caries.

Inadequate extension and marginal fractures were the major contributing factors associated with recurrent caries around the margins of restorations. The high number of recurrent caries was attributed in part to the complex morphology of this tooth (i.e., deep pits and grooves with steep walls) and the difficulty with which these anatomical features were removed and restored. Deterioration of the amalgam margin was associated with a large majority of the recurrent carious lesions.

The low number of recurrent carious lesions around restored occlusal surfaces in deciduous molar teeth was attributed in part to the relatively simple morphology (i.e., shallow pits and grooves with few if any secondary fissures) and the ease with which fissures and grooves were removed and restored. Fracture of the amalgam or enamel margin and marginal excess were the major contributing factors associated with recurrent caries in deciduous teeth. Deterioration of the amalgam margin was an associated condition in all cases of recurrent caries around the margins of restorations.

In view of the findings of this study, recurrent caries around the margins of amalgam restorations appeared to be related to (1) the caries susceptibility of the adjacent tooth structure, (2) the extension of the cavity preparation, and (3) the condition of the amalgam-enamel margin.

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CURRICULUM VITAE

William Everett Alexander

June 26, 1938	Born in Chico, California
1952 - 1956	Chico High School Chico, California
1956 - 1958	Sacramento Junior College Sacramento, California
1958 - 1961	A.B., University of California Berkeley, California
1961 - 1966	D.D.S., University of California School of Dentistry San Francisco, California
August 14, 1966	Married Barbara Ellen Grant
1966 - 1968	Graduate School Department of Pedodontics Indiana University School of Dentistry Indianapolis, Indiana

Professional Organizations

American Dental Association

American Society of Dentistry for Children

Xi Psi Phi Fraternity

ABSTRACT

EFFECT OF A STABLE 30 PER CENT STANNOUS FLUORIDE SOLUTION ON RECURRENT CARIES AROUND AMALGAM RESTORATIONS

by William Everett Alexander
Indiana University School of Dentistry
Indianapolis, Indiana

This was a study to evaluate the effectiveness of a stable 30 per cent stannous fluoride solution on recurrent caries around the margins of amalgam restorations. Two hundred ninety deciduous and permanent teeth were restored in 34 children, ages six to nine years. Cavity preparations were treated with either stable 30 per cent stannous fluoride solution or a placebo solution (double blind technique) prior to the placement of amalgam restorations. A comprehensive coded system was used to record the description and position of conditions associated with recurrent caries after a one-year period.

Children receiving the stannous fluoride treatment experienced a 58.9 per cent reduction in recurrent caries when compared to the control children. The children receiving the stannous fluoride treatment showed a 60.7 and 46.7 per cent reduction in recurrent carious lesions in permanent and deciduous teeth, respectively, when compared to the control children. The reduction in recurrent caries was attributed to the anticariogenic effect of the stannous fluoride treatment.

Conditions associated with recurrent caries were mainly inadequate extension in fissures and grooves,

overextension of the cavity preparation, marginal fractures of enamel and amalgam, marginal excess, and deterioration of the amalgam margin. Recurrent caries around the margins of restorations appeared to depend on (1) the caries susceptibility of the adjacent tooth structure, (2) the extension of the cavity preparation, and (3) the condition of the amalgam-enamel margin.