6/0

A MICROGRAPHIC STUDY, IN VITRO, OF THE MARGINS OF CERTAIN RESTORATIVE MATERIALS AFFECTED BY MULTIPLE PROPHYLAXIS TREATMENTS

A Thesis

Presented to

the Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Murray Arthur May

Department of Dental Materials

August 1967

ACKNOWLEDGEMENTS

The author wishes to express his sincere thanks to the many people who provided guidance and encouragement during the course of this study and in particular to Dr. Zack Kasloff who acted as supervisor and contributed his effort and time in reviewing this manuscript.

Appreciation is extended to Mrs. Carol Newey and Miss Pat Maltby for typing this manuscript; to Mr. Brian McCann for constructing the oral appliances; to Mr. Leslie Allen and Mr. William Bergman for valuable technical assistance and Messrs. Alex Domokos and Douglas Lane for their photographic and art contributions.

It is fitting that I record here the moral assistance and encouragement afforded to me by my wife Leona, and for the unselfish attitude displayed by her throughout the duration of this study.

ABSTRACT

The purpose of this study was to determine in vitro, what changes, if any, occurred at the cavo-surface margins of six commonly used restorative materials, by the abrasive influences of two prophylaxis polishing compounds. Ten polishing procedures were applied to represent the equivalent of semi-annual prophylaxis treatments routinely performed over a period of five years. Removable appliances were constructed to store the specimen teeth in the oral environment. Each of a group of three teeth were filled with three restorative materials. One tooth was polished with flour of pumice and the second with zirconium silicate. The third specimen was not polished and served as a control. Four appliances were made to provide a total of seventy-two restorations for the experiment. Silver plated models made from rubber base impressions of a series of tooth specimens, served to provide the areas for micrographic measurement. Six incremental reductions on each restorative margin were made, and an average of these served as the basis for evaluation. Comparisons were made between measurements taken prior to and subsequent to the institution of polishing procedures. A statistical analysis was made to determine whether changes observed were significant. In general, when all of the filling materials used in this study were considered as a group, flour of pumice appeared to affect the margins to a greater degree than zirconium silicate. With the exception of silicate cement, the margins of metallic restorative materials resisted abrasion to a greater extent than those of non-metallic materials. Methyl methacrylate resin was the most vulnerable material. The margins of the composite resin materials were more resistant to the abrasive action of flour of pumice than were those of methyl methacrylate resin. It is possible that when noticeable improvement in marginal adaptation was evident, mineralization of plaque material may have filled the space at the interface. It is suggested that further studies along similar lines be undertaken to include other restorative materials and additional prophylaxis compounds. The results of this experiment indicate that care should be taken to protect the vulnerable margin areas of restorations when prophylaxis polishing procedures are performed.

TABLE OF CONTENTS

PAGE

LIST OF FIGURES

FIGURE PAGE

LIST OF TABLES

TABLE PAGE

INTRODUCTION

Dental procedures most commonly practiced are concerned with restoring teeth which have been attacked by dental caries. To be effective, such procedures must be supported by sound preventive measures in an effort to eliminate or reduce recurrence of the disease.

The ideal restorative material should be biologically acceptable, possess aesthetic and physical properties identical to those of tooth structure and be capable of forming a permanent seal. It is evident that to date no such material is available. The lack of a perfect seal is probably the most important factor associated with leakage at the margin between filling and cavity wall, permitting fluid exchange and bacterial invasion.

A prophylactic procedure commonly performed in the dental office consists of scaling teeth and polishing them with some form of abrasive agent. The effects of polishing on the surface characteristics of tooth structure and restorative materials have been investigated previously. Very little is known, however, about the effects of such procedures on the margin area.

REVIEW OF THE LITERATURE

I. INTEGRITY OF CAVO-SURFACE MARGINS

Recurrent caries at the interface between a restoration and tooth structure may be associated with an initial marginal defect or one that has occurred subsequent to placement of the restoration. Factors such as oral hygiene and size of the defect would have an influence on caries activity. Hine[1] suggested that faulty cavo-surface margins are conducive to the retention of food debris and bacterial plaque. Shafer, Hine and Levy[2] stated that recurrent caries is the type of activity occurring in the immediate vicinity of a restoration, probably caused by inadequate extension for prevention, favouring retention of debris. They also considered poor adaptation of the filling material as a contributing factor.

Phillips[3] reported that critical examination of old amalgam restorations revealed margins with a perceptible groove or "ditch". Baumgartner, Bustard and Feierabend[4] pointed out that although caries may not be present in such a groove, dentists often prescribed replacement of the faulty restoration as a prophylactic measure. They also suggested that the location of such a defect was important because occurrence in a self-cleansing area could be relatively uneventful, whereas defects in interproximal and gingival areas might lead to rapid production of caries.

The role that bacteria play in production of recurrent caries by way of patent margins has been investigated by many workers.[5,6] Fisher[6] found that in a large proportion of cases organisms remained viable for long periods of time in carious dentine insulated by metallic restorations. He postulated that the supply of nutrient material for the residual organisms could be made available by way of the dentinal tubules from the pulp or by leakage of substrate from the oral cavity along the interface between the restoration and the cavity wall.

Phillips et al.[7] questioned whether leakage via the filling margin was the source of nutrient for persistent organisms (e.g. lactobacillus) because their findings indicated a decrease in leakage with the age of the restoration. Fisher[6], however, found viable organisms under amalgams that had been in position for 14 months. He further stated that although fermentable organisms remained alive under fillings, there was no evidence to indicate that these organisms were actively involved in extending the carious process.

A considerable amount of research has shown that silicate cement, as a restorative material is capable of resisting caries attack.[8,9] Volker, Bekaris and Melillo[8] demonstrated that the fluoride flux incorporated into the material was responsible for this cariostatic property.

Clinical symptoms of extreme sensitivity in teeth can occur following the insertion of restorations in deep seated cavities. This sensitivity could be due to mechanical or thermal injury associated with cavity preparation, pulpal irritation caused by certain restorative materials or by leakage occurring around all freshly placed restorations.[10] The larger the restoration, the greater is the linear extent of cavo-surface margin permitting penetration of oral fluids and microorganisms. A hyperaemic pulp may be produced by the ingress of this bacteria-containing fluid, causing sensitivity and pain to the patient. Resolution of the pulpal damage is dependent on factors such as proximity of the pulp to the leakage products, age and the general health of the patient.[2] It is possible to produce irreversible changes in the pulp and subsequent necrosis as a result of irritation from leakage products. Fisher[6] pointed out that the leakage pathway could be modified by sclerosis, dead tract and secondary dentine formation.

Waerhaug[11] suggested that a rough surface might predispose to the retention of plaque and bacteria in the subgingival space. He further reasoned that cavo-surface discrepancies could be caused by lack of adaptation of the restorative material, food abrasion, tooth brush trauma or prophylaxis procedures leading to chronic gingivitis. Zander[12] used monkeys to study the effect of silicate and amalgam restorations that had been extended subgingivally on the buccal surfaces of teeth. On histological examination a discrepancy of 0.2 mm. was revealed as a gingival shortage or overhang. This suggested that such a discrepancy could encourage added plaque retention and bacterial stagnation leading to gingival inflammation. Another investigation by Waerhaug and Zander[13] found evidence of chronic periodontal inflammation associated with self-curing acrylic resin restorations placed below the gingival margin. Trott[14] stated that under normal clinical conditions it would be difficult to finish margins flush with the tooth in order to avoid creating a site for plaque formation and bacterial stagnation.

It has become evident in recent years that many failures associated with presently used restorative materials occur at cavo-surface margins.[15] Such failures may be due to faulty cavity preparation resulting in fracture of unsupported and weak enamel subsequent to the placement of the restoration. The cavo-surface margin which clinically appears to be intact may present a different picture when viewed at high power magnification.[16] Faulty manipulation of materials may also cause marginal defects.[17] Bjorndal and Sahs[16] reported on a visual assessment of marginal adaptation of gold inlays and amalgams viewed microscopically at 60X.

A higher percentage of defects were found at the margins of gold inlays than amalgams. Other investigations concerning marginal integrity have utilized penetrant dyes or radioactive tracers to study leakage patterns.[7,18,19,20,21,22,23]

Breakdown of cavo-surface margins may be due to inadequate physical properties of some of the presently used restorative materials compared to the properties of tooth structure.[24,25] The property of edge strength, commonly used to describe resistance of thin edges to fracture also implies resistance to bending. Continued bending leads to fatigue and fracture. In a recent report on edge strength gold foil was found to be four times more resistant than amalgam.[26]

Dimensional change has a direct influence on marginal adaptation.[27] The type of material and its inherent physical and chemical properties influences the amount and direction of dimensional change. MacDonald and Phillips[28] measured setting expansion and contraction of amalgam restorations and found no evidence of open margins or recurrence of decay around amalgam restorations when the value was in a range of 31 ± 3 microns. Wing and Lyell,[29] reporting on a study of marginal seal of amalgam restorations, found the measured space between tooth and material to be greatest at the cavo-surface margin. They suggested that high concentration of mercury at the margin was responsible, and that unrestricted expansion of amalgam could take place at the cavo-surface region.

Physical characteristics of the tooth being restored may also have a bearing on the cavo-surface margin. Such factors as enamel hardness, degree of enamel calcification and induced cracks could all influence the integrity at the cavo-surface junction. Kasloff, Swartz and Phillips,[30] using a fluorescent penetrant dye, observed the presence of developmental or induced cracks in human teeth. They revealed that such defects could be produced by various types of rotational cutting instruments under certain conditions. They also suggested that such instrumentation during cavity preparation might lead to cavo-surface breakdown of tooth structure at the cavity margin subsequent to placement of restorations.

Chemical and physical changes associated with the oral environment may affect the marginal integrity of restorative materials. Chemical changes occurring in the mouth caused by the close association of plaque and tooth substance and influences by the alkalinity or acidity of certain ingested foods and beverages cause wide pH variations in saliva.[31] Phillips[32] stated that this constantly altering pH may contribute to the disintegration and solubility of certain materials that otherwise have highly desirable properties.

Phillips[32] also stressed the fact that the warm and moist conditions in the oral cavity are ideally suited for corrosion to take place, and that this process may become so severe with amalgam that an actual disintegration of the restoration results. Jorgensen[15] demonstrated that corrosion products in nearly all cases occurred in greatest amounts at the margins. Corrosion also results from the galvanic action occurring between dissimilar metals used as restorative materials.[25]

There are many forces occurring in the oral cavity which could contribute to a breakdown of the margins between restorations and teeth as well as their surface characteristics.

The type of food ingested and habits of the patient may produce compressive and tensile forces and dimensional changes. Abrasion resulting from poor brushing techniques, coarse food, bruxism, traumatic occlusion and the thermal cycling effect of hot and cold foods are additional factors that play an important role.[32] Effects of polishing agents used in routine prophylaxis procedures also abrade tooth structure and restorations.[33,34]

II. MICROLEAKAGE ASSOCIATED WITH CAVO-SURFACE MARGINS

Microleakage has been shown to occur in varying degrees with all freshly placed dental restorations.[7,10,35] Phillips[36] has shown that microleakage is related to subsequent failures of margins and the production of secondary caries. He also believes that other biologic sequelae can be associated with the leakage pattern.

Many techniques have been employed to assess the adaptation of restorative materials. The most common methods have been the application of penetrant dyes,[19,37] radioactive isotopes[7,18,20,21,35] and bacteria.[38] Most of these studies compared the leakage pattern of different restorative materials, influenced by such factors as thermal cycling, manipulative techniques and the length of time the restorative material had been in service.

In an in vivo study reported by Phillips et al.[7] using Ca^{45} it was found, that initially, the margins of amalgam restorations leaked considerably but that the leakage pattern diminished with time. They also indicated that the application of a cavity varnish prior to the insertion of amalgam improved its initial sealing ability. They found the microleakage pattern of silicate restorations to be variable. Some silicate specimens exhibited gross penetration of the margins whereas less ingress was noted with others. Leakage occurred with zinc phosphate cement but this diminished around older restorations. The resin materials produced a relatively good seal of the cavity over the period of time involved in the experiment. A subsequent in vitro study by Swartz and Phillips[35] substantiated the previous findings. They also stated that differences in technique exist between operators and therefore suggested that proper evaluation was only possible if many operators were involved in such an investigation.

A recent study by Going and Sawinski[39] investigated the microleakage pattern of a new anterior resin restorative material. It was found that the initial sealing qualities of this material was as good or better than other autocuring restorative resins. It was superior to the initial seal of silver amalgam and silicate cement but somewhat less effective than gold foil. Langeland et al.[40] have also reported that the marginal adaptation of this new restorative resin seemed to be good. They carried out marginal leakage studies after various restorations had been subjected to thermal cycling procedures and found that silicates and gold foil showed no obvious changes in leakage patterns; composite resin restorations showed a slight increase whereas the leakage around acrylic resin restorations was greatly increased. Jorgensen[15] believes that good adaptability provides more support to the filling margin which is essential to its durability. Hatt[41] and Jorgensen[42] corroborated the findings of Swartz and Phillips[35] agreeing that amalgam does not seal the cavity at the tooth-restoration interface and that leakage can be demonstrated immediately after placement.

Menegale, Swartz and Phillips[43] conducted a study of the adaptation of restorative materials in relation to roughness of the cavity wall. It was found that the 'Cavitron', an ultrasonic device, produced cavity walls of a smoother texture compared to those produced by burs at low or ultra high speeds. They used the radioactive isotope technique for assessing the adaptation of several restorative materials over a specified period of time. Examination of the data revealed that with a given material, leakage was always less when the material was inserted into cavities prepared with rough walls than in those with smooth walls. They also observed that the amount of leakage changed with time and this was in general agreement with the results of other workers.[7,35,44] They also found that regardless of the change in the leakage pattern with time, at any given interval leakage was less with rough walled cavities than with those having smooth walls.

Materials capable of sealing the space between restoration and tooth have been investigated.[23,45,46] These studies have shown that a filling-in of this space produces a reduction in leakage. It is entirely possible but not yet clearly demonstrated that muco-proteins from saliva can be deposited in the patent margins at the cavo-surface junction.[47] There are many reports in the literature describing various organic deposits and films that are laid down on the enamel surfaces of teeth in the oral cavity.[48,49,50,51] There is evidence that this exogenic film on teeth is constantly renewed in the oral cavity when lost or abraded.[49] The presence of such organic films on enamel surfaces becomes of particular interest when compounds are applied topically to the tooth surface.

Schroeder, Lenz and Muhlemann[51] demonstrated that mineralization of structureless organic deposits on the enamel can occur in the oral cavity. Manly[48] reported the presence of proteinaceous deposits, referred to as brown pellicle, capable of being laid down in a reticulated fashion, particularly in inaccessible areas and on silicate fillings. Von der Fehr and Steinnes[52] also reported on organic films on surfaces exposed to the oral environment. They stated that these organic films, referred to as cuticles or pellicles, are either products of the saliva or of the microorganisms of the mouth. It was found that pellicles could form on abraded enamel surfaces within 15 minutes and that these deposits appeared to be highly resistant to mechanical abrasion.

The report of Stowell et al.[53] supports the theory of the effect of salivary deposits on the leakage pattern between restorations and teeth. They conducted their studies using radioactive iodine as the tracer. It would appear from the extensive amount of research that has been carried out on the formation of organic films and deposits on teeth, that some of this film or deposit could become mineralized and help seal the cavo-surface interface.

It has been demonstrated that copal resin varnish effectively seals the restored cavity at the margin from the penetration of ionic and molecular tracers.[23] The advent of copal varnish liners has reduced the problem of the immediate marginal leakage associated with all freshly placed restorations. The varnish protects the pulp from the irritating effects of the imbibed leakage products and also helps to seal the cavo-surface interface, diminishing fluid exchange to a great extent.

Wing and Lyell[29] agreed with the ability of copal resin varnish to reduce microleakage but were not convinced that it produced a bond between amalgam and tooth structure. Some doubt, however, has been cast on the efficacy of cavity varnish. Brannstrom and Soremark[54] demonstrated that varnish significantly reduced marginal leakage, but when subjected to variations of temperature, leakage was increased. They concluded that any seal that had been formed was broken down by temperature changes.

III. ABRASION AND POLISHING AND THEIR EFFECT ON MARGINS AND SURFACES OF RESTORATIONS

While many studies have investigated the cleaning and abrasive properties of various toothpastes, little attention had been paid to the abrasive materials used for dental prophylaxis purposes until Stookey, Hudson and Muhler[55] published the results of their studies concerning the polishing properties of zirconium silicate on enamel. Their studies showed that the degree of polish produced by zirconium silicate on enamel was dependent upon the length of time of application and the number of small particles present in the paste. They found that a mixture of zirconium silicate and water changed its consistency rapidly due to evaporation of water. This resulted in a change of particle distribution which in turn altered the polishing ability of the material. The difference in abrasive and polishing characteristics between zirconium silicate and other commonly used abrasive materials demonstrated that zirconium silicate provided both excellent cleaning and polishing properties. Zirconium silicate was found to be unique in that its abrasive effect was quickly altered due to the fracture of particles into smaller fragments. This finer material then acted as a polishing agent.

Swartz and Phillips[56] demonstrated that bacteria accumulated to a greater degree, per unit of time, on a rough abraded surface than upon a highly polished one. They found that bacteria were retained in greater numbers by rough surfaces even after vigorous brushing. Waerhaug[11] observed that a rough surface on dental restorations appeared to facilitate the retention of bacterial plaque.

Shell, Hollenback and Villanyi[34] suggested that a knowledge of the rate of wear of filling materials would provide a measure of their useful life expectancy in the mouth. They determined the amount of wear on metallic and non-metallic filling materials produced by a very fine prophylaxis polishing compound and a fluoride-containing dentrifice. A comparison of the non-metallic filling materials revealed that cements and silicates showed a considerable variation in wear. A composite resin material resisted wear to a greater degree than did the other non-metallic materials. An earlier study by Shell and Hollenback[33] revealed that enamel was not consistent in its wear pattern. In some cases, enamel wore more rapidly than gold foil, when polishing agents were applied. Jorgensen[45] found, that amalgam margins were very susceptible to fracture during polishing, due to either the rotation of the polishing bur, or the excessive temperature produced at the cavo-surface margin, or both. It can be postulated that marginal failure could occur as a result of injudicious polishing procedures during routine prophylaxis.

IV. METHODS OF MEASURING SURFACE AND MARGIN ABRASION

The most widely used technique consists of recording the loss of volume of restorative material resulting from the abrasive process.[34,57] It is often combined with photographing silhouettes of cross sections of the specimens and comparing surface contour changes.

Manly, Wiren and Manly[58] used an angular positioned transducer to record multiple magnified contours of teeth at several different locations. Subsequent to abrasive procedures a repeated recording was made and the results were compared by superimposition.

The technique of interference microscopy was used by Ashmore[59] in 1966 and he checked his results with a profilometer. The profilometer is a very refined and sophisticated apparatus for recording minute changes in surface detail.[60] Bjorn and Lindhe[61] also made use of the profilometer in their toothbrushing study which they conducted in 1966.

Charbeneau[62] studied the surfaces of amalgam restorations with a profilometer that produced profile graphs indicating the fineness of surface polish obtainable with various polishing agents.

Hatt[41] studied the effects of different techniques of condensation on marginal adaptation of amalgam. The degree of adaptation was measured with a profilometer. Measurements of this nature could vary quite widely depending on the regularity of the cavity wall and specific locations on the cavo-surface at which readings were made. Results therefore, might not be significant unless multiple measurements were made at various sites and then averaged. The technique used in this study illustrated the practical value of the profilometer in measuring extremely fine spaces between cavity walls and restorations.

A technique for measuring the thickness of copal varnish liners was described by Dolven.[46] A line was scratched on a polished gold surface and was filled with acridine orange-stained copalite so that its width could be measured with a calibrated microscope. This measurement served as a yard-stick to assess the width of the copalite liner at the marginal interface.

STATEMENT OF THE PROBLEM

It has been suggested that physical, chemical and mechanical factors present in the oral cavity can influence the integrity of the margin area between restorative materials and tooth structure.

Alteration of this relationship, resulting from loss of tooth structure, filling material, or both, could create an environment more favorable for food and plaque retention. Such a condition could lead to failure of the restoration and subsequent caries invasion. Abrasives, commonly used in prophylaxis polishing procedures, could contribute to the production of such an effect.

It was considered desirable therefore, to determine, in vitro, what influence certain abrasive compounds might have on the margin areas of restorative materials when routine prophylaxis polishing procedures are performed over a period equivalent to five years.

METHODS AND MATERIALS

The experimental procedures that were adopted will be described under the following headings:

I. SELECTION OF TEETH.

II. CAVITY PREPARATION.

III. PLACEMENT OF RESTORATIONS.

IV. ENVIRONMENTAL CONDITIONS FOR THE STUDY.

V. PROPHYLAXIS PROCEDURES.

VI. THE METHOD OF RECORDING MARGIN AND SURFACE CHARACTERISTICS.

I. SELECTION OF TEETH

Random samples of vital human maxillary central incisors and molars were selected without regard to the history of the pre-existing environmental conditions such as sex, age-group and the influence of fluoride, either topically applied, naturally available or supplementally ingested. Care was taken to select teeth that did not exhibit evidence of dysplasia, pitting, gross staining or extensive caries. All of the teeth selected were examined carefully with binocular loupes in an attempt to obtain specimens of similar surface texture and contour. All specimen teeth were mechanically cleansed of tissue remnants and calcarious deposits, polished with levigated alumina for one minute with a wet cloth wheel and stored in tap water in a refrigerator at 40^{O}F until required.

It was not possible to select teeth with uniform physical characteristics of hardness and modulus of elasticity because of the inherent variation which has been shown to exist in enamel.[63,64]

II. CAVITY PREPARATION

It was possible to prepare three rectangular shaped cavities, each 2 mm. long, 1.5 mm. wide and 1 1/2 mm. deep, on the relatively flat surfaces of central incisors. Cavities were prepared using a number 2 round bur followed with a No. 701 tapering fissure bur in an air turbine handpiece. A water and air spray was used as a coolant. The enamel margins were refined using sharp hand instruments to ensure that no unsupported enamel was present. Binocular loupes of 2X magnification were used at all times during cavity preparation. Only those specimens which were free of enamel fracture from cavity preparation were selected. This was done to provide specimens which had cavity margins as regular as possible.

Reference grooves for purposes of recording were prepared on each tooth by placing cuts a short distance lateral to the vertical cavity margins which were to be evaluated. A prepared specimen tooth is illustrated in Fig. 1.

The roots of the specimen teeth were severed and the pulp chamber mechanically cleansed of all debris. This area

Figure 1 - A prepared specimen tooth

(a) Cavity preparation
(b) Reference grooves

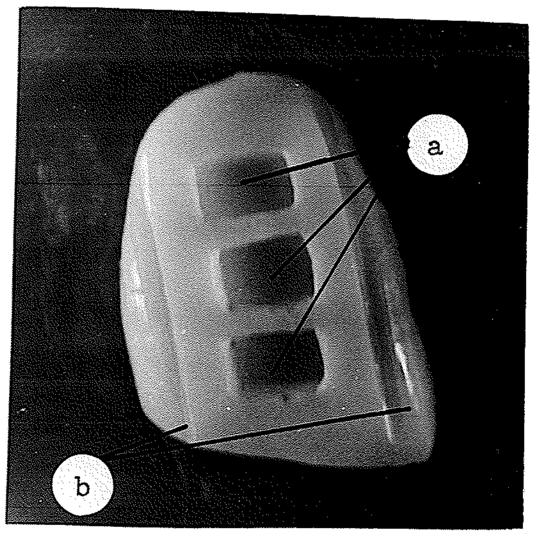


Fig. 1

served as the point of attachment for the serrated end of a J-shaped annealed piece of .020" diameter stainless steel wire held in place by self-curing acrylic as shown in Fig. 2.

Stone matrices were prepared to hold each group of specimen teeth in the same relation during the entire length of the study for purposes of evaluation. Custom made acrylic resin trays were constructed for each matrix to enable rubber base impressions to be made from the group of teeth. The flanges of these trays in contact with the matrix were made flat. The rubber base impressions were subsequently metallized with silver and reinforced with stone and these replications provided the samples for evaluation. The stone backing for the metal was poured and the relationship of the stone base to the surface of the metal was maintained in all models of the same series by the nature of the impression tray design. A stone matrix assembly holding a group of specimen teeth is illustrated in Fig. 3. A metallized replication reinforced with stone is illustrated in Fig. 4.

III. PLACEMENT OF THE RESTORATIONS

Restorative materials employed were restricted to those commonly used in Class III and Class V situations in order to eliminate the influence of mastication on abrasion and wear. This enabled the study to limit itself to the effect of prophylaxis procedures only. Uniformity of manipulation

Figure 2 - Attachment wires on lingual surfaces of specimen teeth

(a) .020" stainless steel wire
(b) Self-curing acrylic attachment

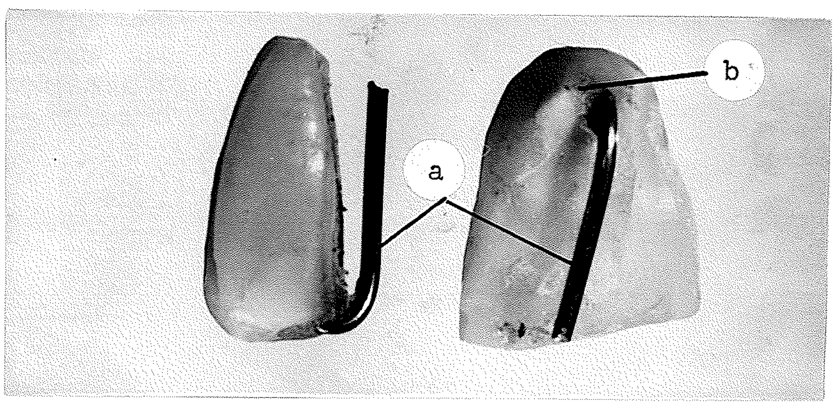


Fig. 2

Figure 3 - A stone matrix assembly

(a) Brass form
(b) Black coloured stone matrix
(c) Specimen teeth

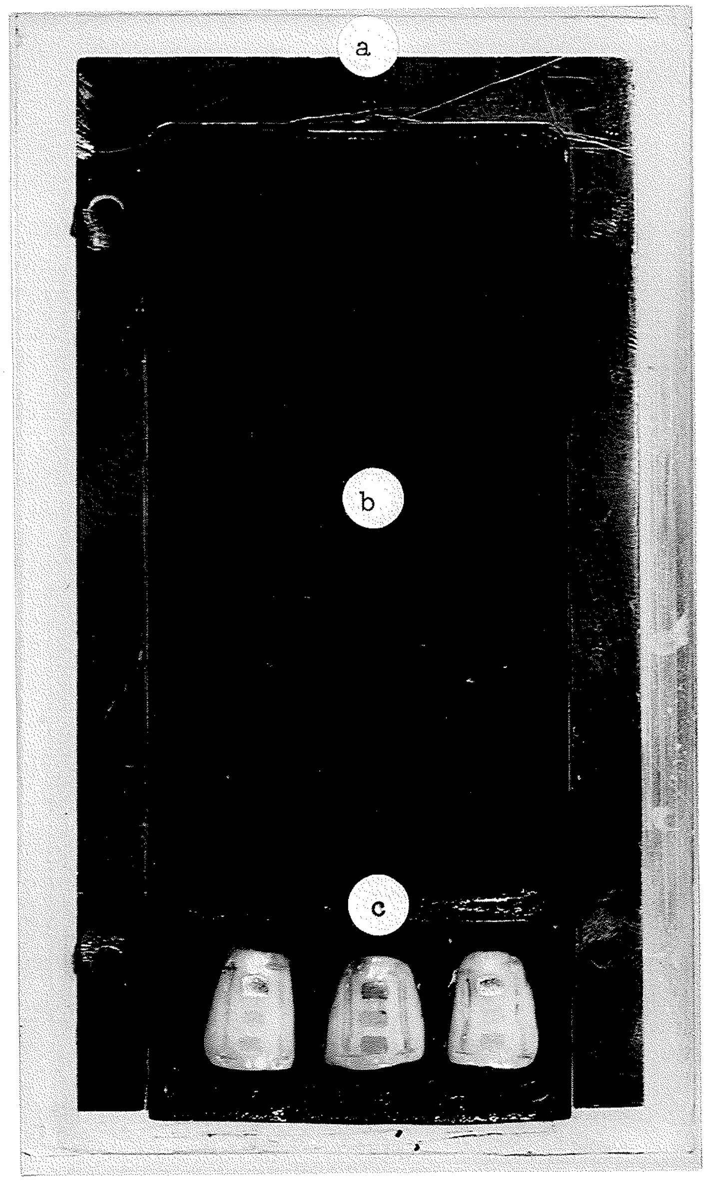


Fig. 3

Figure 4 - A metallized silver replication

(a) Electroformed silver
(b) Stone reinforcement

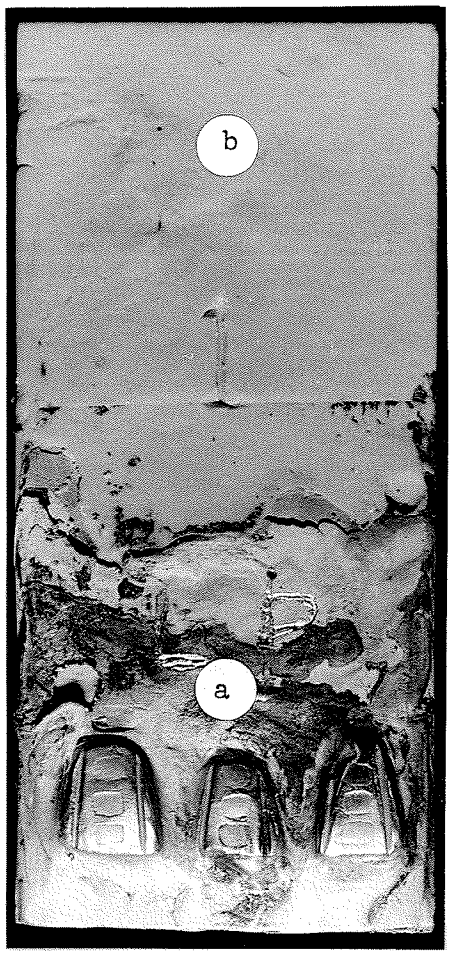


Fig. 4

and insertion of restorative materials were controlled by having these procedures performed by one operator. Two classifications of materials were employed.

(1) Metallic--Silver amalgam* and gold foil**

(2) Non-Metallic--Methyl Methacrylate resin≠

--Silicate cement+

--Two composite resin filling materials#

For the amalgam restorations the 1:1 ratio and technique suggested by Eames[65] was followed. Immediately after surface carving, the teeth were stored in an atmosphere of 100 per cent humidity at 37°C for 24 hours prior to polishing. This was done in conformity with sound principles of operative dentistry whereby polishing procedures are not performed immediately after insertion of amalgam. The polishing procedure consisted of dressing the surface initially with fine cuttle discs lubricated with vaseline. This was followed by the application of a mixture of water and flour of pumice in a rubber cup.

* T.C. fine cut pellets--L.D. Caulk Co., Milford, Delaware.
** Goldent, veneered with cohesive gold foil--Morgan Hastings Co., Philadelphia, PA.
≠ Bonfil--L.D. Caulk Co., Milford, Delaware.
\+ Syntrex--L.D. Caulk Co., Milford, Delaware.
\# 1. Addent--3M Co., St. Paul, Minn. 2. Dakor--L.D. Caulk Co., Milford, Delaware.

The final polish was achieved with a commercial polishing agent.*

Mechanical condensation was used for forming the gold foil restorations. The bulk of the cavity was filled with powdered foil and the balance of the restoration was completed with cohesive foil. These restorations were polished with lubricated fine cuttle discs, followed by an application of flour of pumice and water and finally with tin oxide and alcohol.

The silicate filling material was mixed according to American Dental Association specifications[24] and placed using accepted techniques for this material. The surface of the silicate was protected from dehydration and contamination with moisture by coating with vaseline and storing in an atmosphere of 100 per cent humidity at 37°C for 24 hours prior to finishing. Final finishing was accomplished by using lubricated fine cuttle discs and care was taken to avoid production of frictional heat.

The manufacturer's recommended technique for mixing methyl methacrylate resin was followed and the bulk pack technique was employed in placing these restorations. The manufacturers directions for manipulating composite resin materials was followed precisely with each of the two

* Amalgloss--L.D. Caulk Co., Milford, Delaware.

materials of this type. For the resin and composite resin materials, polishing procedures were carried out after polymerization was complete. These materials were finished and polished in accordance with the specific instruction of the manufacturer.

In all cases every effort was made to eliminate excess filling material so as to provide a distinct margin for evaluation.

IV. ENVIRONMENTAL CONDITIONS FOR THE STUDY

It was considered desirable to provide a storage medium for tooth specimens subjected to prophylaxis procedures comparable to the human oral environment.[66] It was decided therefore to store the prepared specimen teeth in the oral cavity by mounting them on a removable appliance which could be supported by natural teeth or a complete denture. Specific designs for such appliances were selected and are illustrated in Figs. 5 and 6.

A tooth-borne removable appliance was used in the maxilla and a complete denture for the mandibular region. Maxillary incisors were used exclusively in the upper appliance while buccal segments of maxillary molars were used in the lower denture.

The attachment of the specimen teeth was effected by the stainless steel wire attached to the specimen tooth

Figure 5 - Maxillary appliance with a group of specimen teeth attached

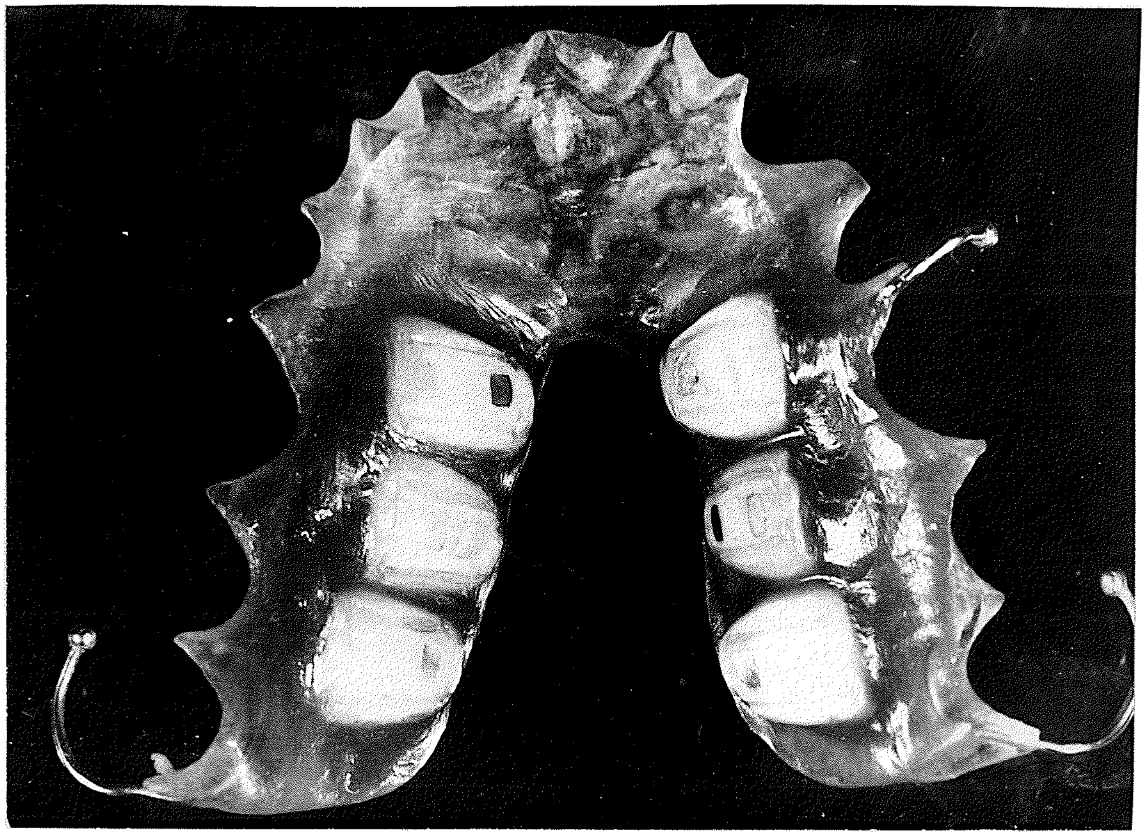


Fig. 5

Figure 6 - Mandibular appliance with a group of specimen teeth attached

Fig. 6

fitting into .025" diameter stainless steel tubing previously secured to the resin base of the appliance with self-curing resin. Base-plate wax was then applied to the surrounding area of the teeth merely to stabilize them and to prevent accumulation of debris. This provided a simple method for removal and replacement on the appliance when prophylaxis treatments were undertaken.

Every precaution was made to prevent dehydration by storing the specimens in a moist environment and by maintaining them at 37°C, except during the filling and polishing procedures.

The subjects were instructed to wear the appliances continuously except during meal times and when required for prophylaxis treatment procedures. The appliances were kept in a vessel of water during the course of a meal.

V. PROPHYLAXIS PROCEDURES

The specimen teeth were arranged on each appliance as illustrated in Table I. Each restoration was subjected to the equivalent of 5 years of semi-annual prophylaxis treatments by applying a polishing compound for a period of 30 seconds at 4 day intervals, ten times.

The polishing apparatus used in the experimental procedures is illustrated in Fig. 7. The dental engine was controlled by a rheostat which provided an average speed of

TABLE I

LOCATION AND ARRANGEMENT OF SPECIMEN TEETH ON AN APPLIANCE

	RIGHT SIDE			LEFT SIDE		
SPECIMEN POSITION	CAVITY LOCATION	RESTORATIVE MATERIAL	POLISHING COMPOUND	CAVITY LOCATION	RESTORATIVE MATERIAL	POLISHING COMPOUND
Posterior	Cervical	Amalgam	Zirconium Silicate*	Cervical	Gold Foil	Zirconium Silicate
	Middle	Composite Resin No. 1	"	Middle	Resin Filling Material	"
	Incisal	Composite Resin No. 2	"	Incisal	Silicate Cement	"
Centre (control)	Cervical	Amalgam	Nil	Cervical	Gold Foil	Nil
	Middle	Composite Resin No. 1	"	Middle	Resin Filling Material	"
	Incisal	Composite Resin No. 2	"	Incisal	Silicate Cement	"
Anterior	Cervical	Amalgam	Flour of Pumice**	Cervical	Gold Foil	Flour of Pumice
	Middle	Composite Resin No. 1	"	Middle	Resin Filling Material	"
	Incisal	Composite Resin No. 2	"	Incisal	Silicate Cement	"

*Zircate--L.D. Caulk Co., Milford, Delaware.
**Denco--The Dental Company of Canada Ltd., Toronto, Ontario.

Figure 7 - Apparatus for controlled prophylaxis procedures

(a) Cord-driven straight handpiece operated by dental engine
(b) Turntable and specimen assembly

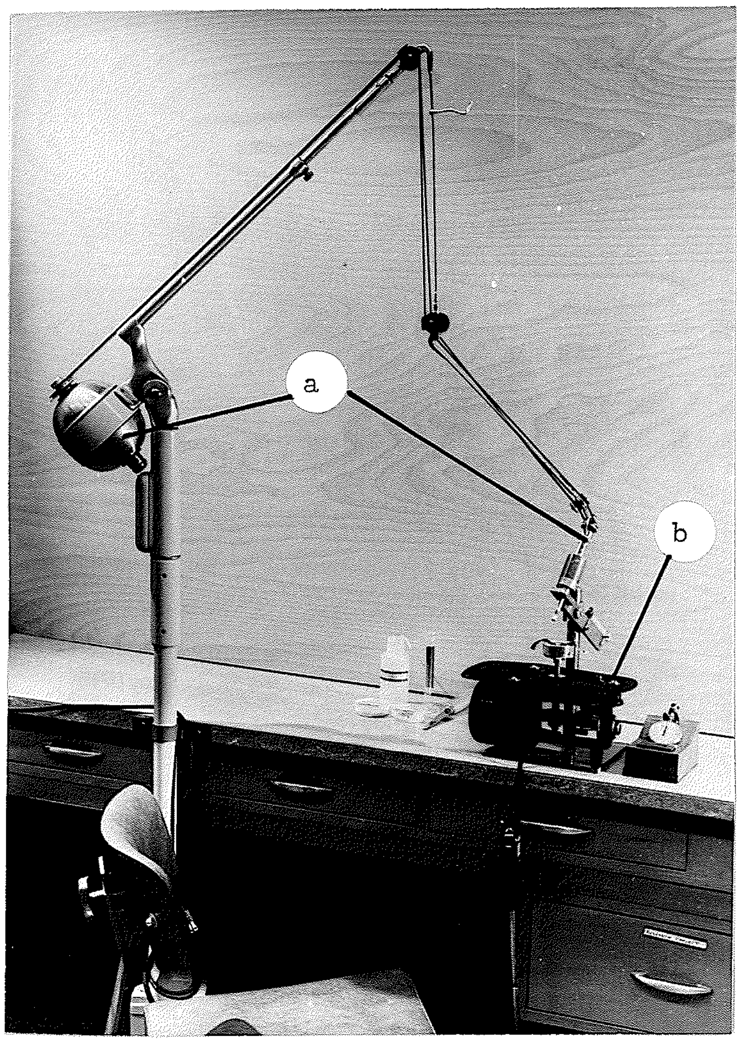


Fig. 7

1882 r.p.m. The cord-driven handpiece was stabilized in such a manner that a constant load of 150 grams could be maintained on the specimen being polished. This specific load was selected by determing the average load that was applied by several dental hygienists in executing prophylaxis procedures. The supporting arm carrying the handpiece was arranged so that the rubber cup, charged with the prophylaxis compound would be offset 1 mm. from the centre of the tooth being polished, to ensure that all restorations on each tooth received an equal amount of polish.

A controlled-speed motor-driven turntable served as the holder for specimens to be polished. A metal container, modified to provide a key for a stone matrix was constructed to fit the spindle of the turntable. This made it possible to construct individual stone matrices for each tooth which could be removed and returned to the polishing apparatus in the same relationship at all times. A narrow piece of linen strip was incorporated into the stone to facilitate its removal from the holder. The turntable, rotating at 125 r.p.m. was operated by an electrically driven motor. Figs. 8,9 and 10 illustrate this assembly. During the polishing procedure the simultaneous motion of the upper and lower portions of the assembly similated usual oral procedures whereby the rubber cup is kept in a constant movable state to avoid the development of undue amounts of frictional heat.

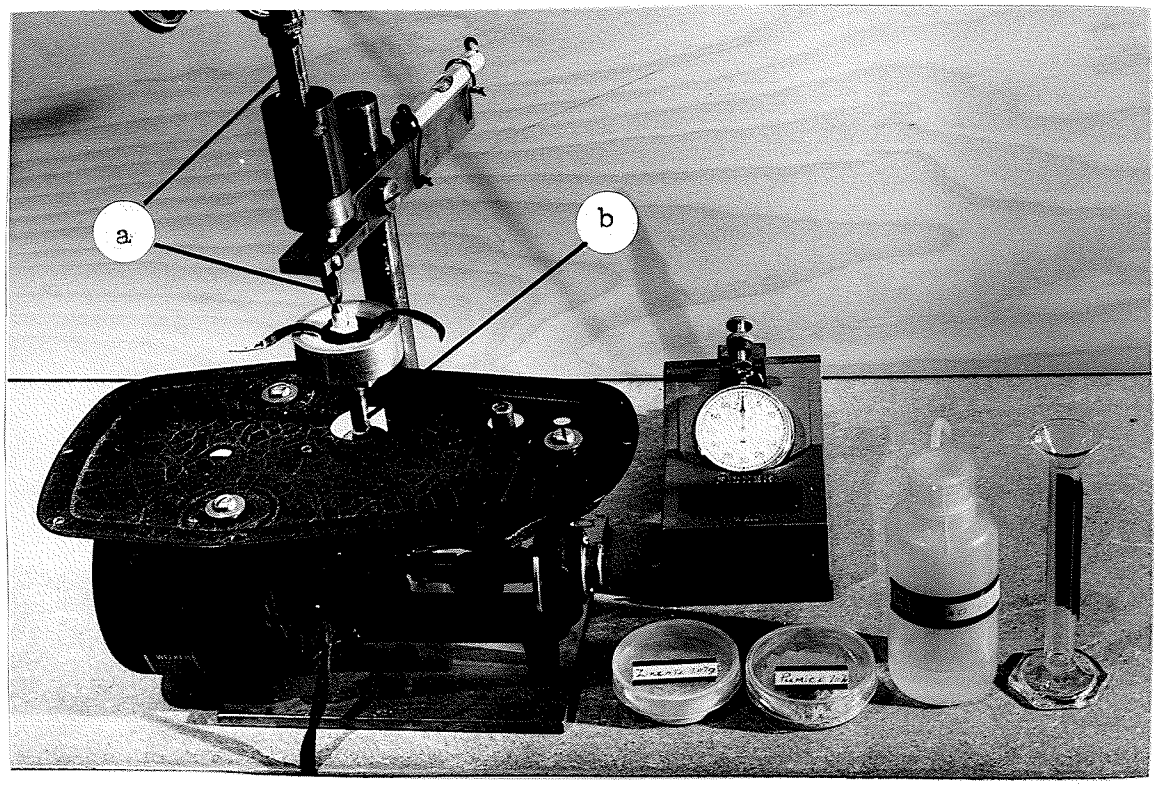


Fig. 8

Figure 9 - Top view of specimen holder with tooth fixed in stone matrix

(a) Modified specimen holder
(b) Stone matrix containing tape
(c) Surface of tooth to be polished

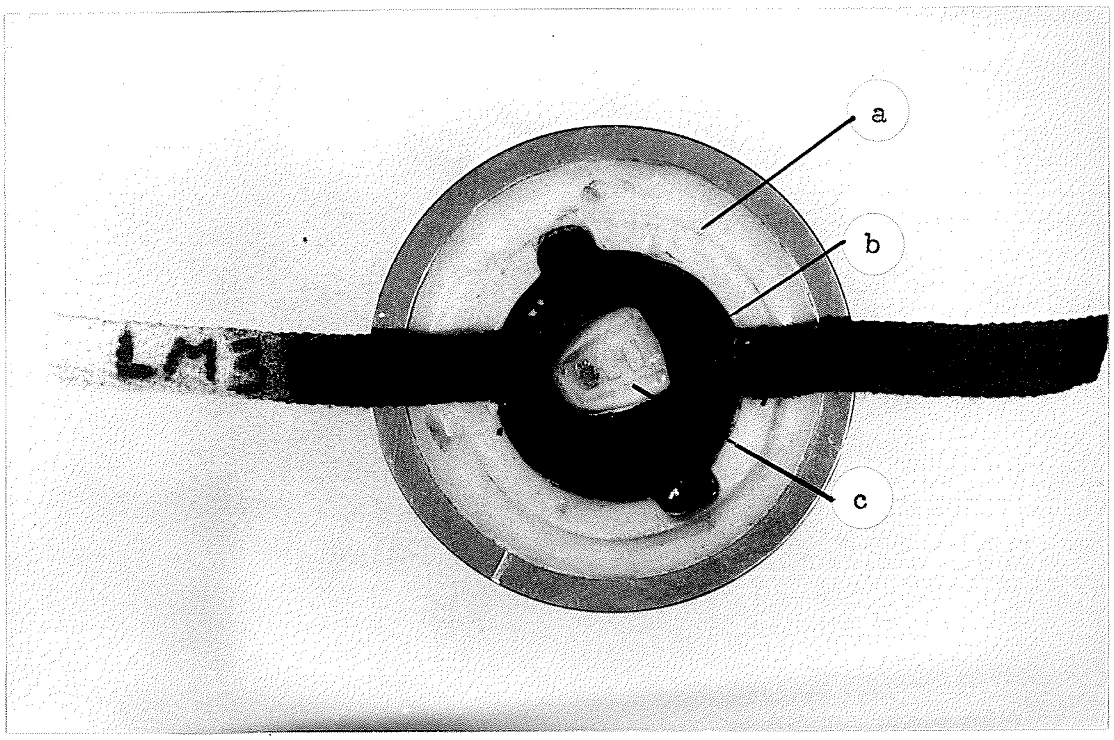


Fig. 9

Figure 10 - Close-up of relationship of rubber cup to specimen tooth during polishing

(a) Rubber cup charged with prophylaxis agent

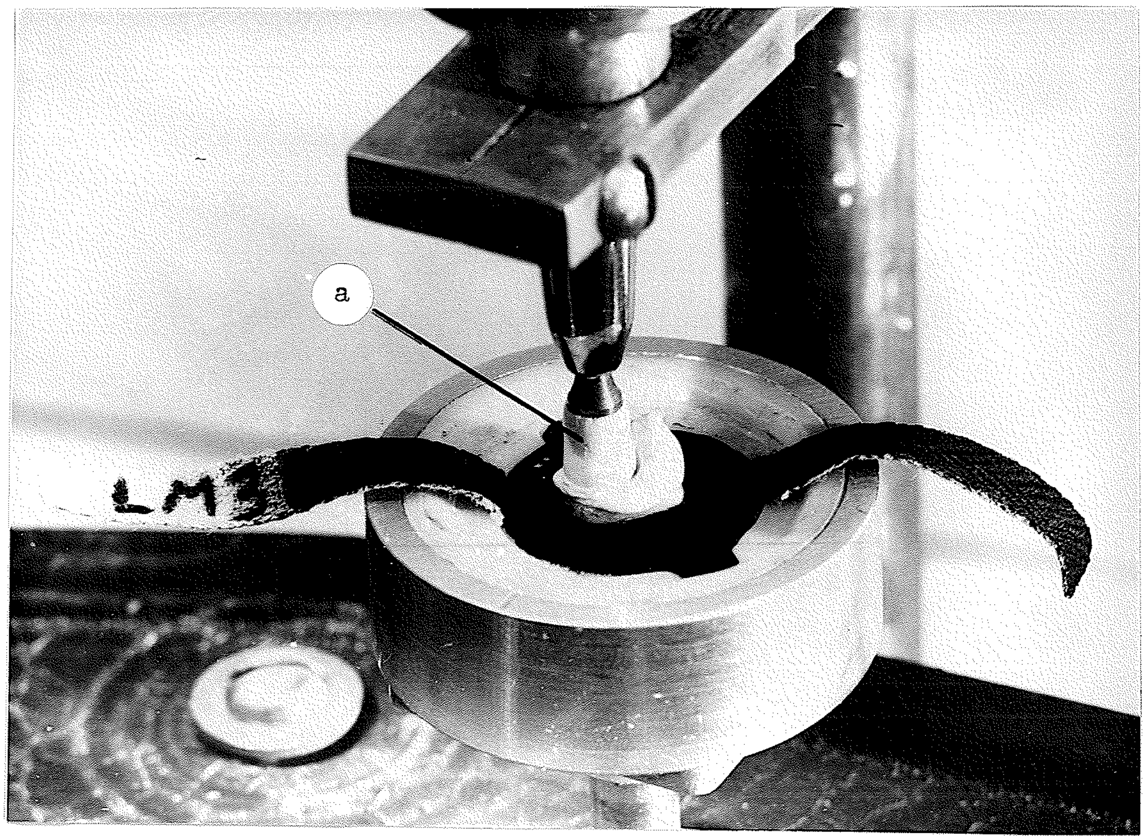


Fig. 10

The polishing materials selected for this study consisted of a commonly used material flour of pumice, and a more recently developed material, zirconium silicate. The mixture of flour of pumice and water was prepared to a putty like consistency using 7.07 grams of powder to 4.5 cc. of water. The mixture of zirconium silicate and water was prepared using the same weight of powder to 1.5 cc. These proportions were selected because they were found to be optimal in producing a putty like consistency as suggested by Pollard, Bergman and Kasloff.[67] A sufficient quantity was freshly prepared to carry out a prophylaxis procedure on the group of teeth for each appliance. A new Densco No. 7 webbed rubber cup was used with each of the compounds employed in polishing a group of samples on a given appliance.

Thirty seconds was selected as the length of time a polishing procedure was conducted. This interval served as a convenient standard for both materials, as suggested in two previous studies.[55,67]

VI. THE METHOD OF RECORDING MARGIN AND SURFACE CHARACTERISTICS

A metallized model was made from an impression taken prior to the institution of polishing procedures. This model represented the equivalent of newly placed polished restorations in the oral cavity. Two additional models were made for each group of specimens, representing the conditions present at the two and a half year period and at the end of five years of polishing. A total of twenty-four metallized dies were formed to provide the material for evaluation.

The models were coated with a transparent plastic material.* This was done to prevent the tendency of the fine layer of silver to lift away from the stone during grinding procedures.

The metallized models were reduced progressively by grinding from the incisal or occlusal to the cervical portions of the restorative materials. The reduction was made across the labial or buccal surfaces in a mesio-distal direction.

The first cut for each restorative material on a model was made by reducing the surface with a Norton A4884CR2 wheelstone to a point whereby the lower margins of the left and right replicated restorations were just encountered. This was done to provide a uniform starting point for all models of a group being reduced. A tube conducted a copious supply of water to the grinding wheel to provide more efficient cutting and a stream of air was directed to the surface of the model to permit clear vision while the reference cuts were being made.

* Wards Bioplastic--Natural Science Establishment In., Rochester, N.Y.

The assembly for forming this cut is illustrated in Fig. 11.

Additional sections were made by hand grinding on emery paper according to standard metallurgical procedures. The number and direction of the strokes in this procedure was carefully controlled. All models of the same series were prepared in the same plane by the use of a square block-support during the grinding procedures. Paraffin diluted with xylol was used as a lubricant. Progressive grits of polishing paper from 1/0 to 3/0 was used in the process. This hand grinding technique reduced the material approximately .01". Each cross sectional reduction was made on an unabraded surface of paper. A total of six incremental reductions were made for each restorative material. Fig. 12 illustrates such a prepared specimen.

Assessment of cavo-surface margin areas was made by positioning a specimen on a Zeiss metallographic microscope equipped with a plate camera as illustrated in Fig. 13. The photographic plate of the camera was substituted with a ground glass plate upon which a sheet of transparent graph paper was placed. This permitted tracings to be made which could subsequently be measured. The magnification factor was such that 12 squares on the graph paper was equivalent to 1/10 mm.

The first reference point during the tracing procedure was the junction of enamel and restorative material. For

Figure 11 - Grinding assembly for producing initial cut for establishing a starting point from which subsequent reductions were made

(a) Bench motor and wheelstone
(b) Water tube
(c) Air stream
(d) A modified microscope stage for relating model to surface of grinding stone

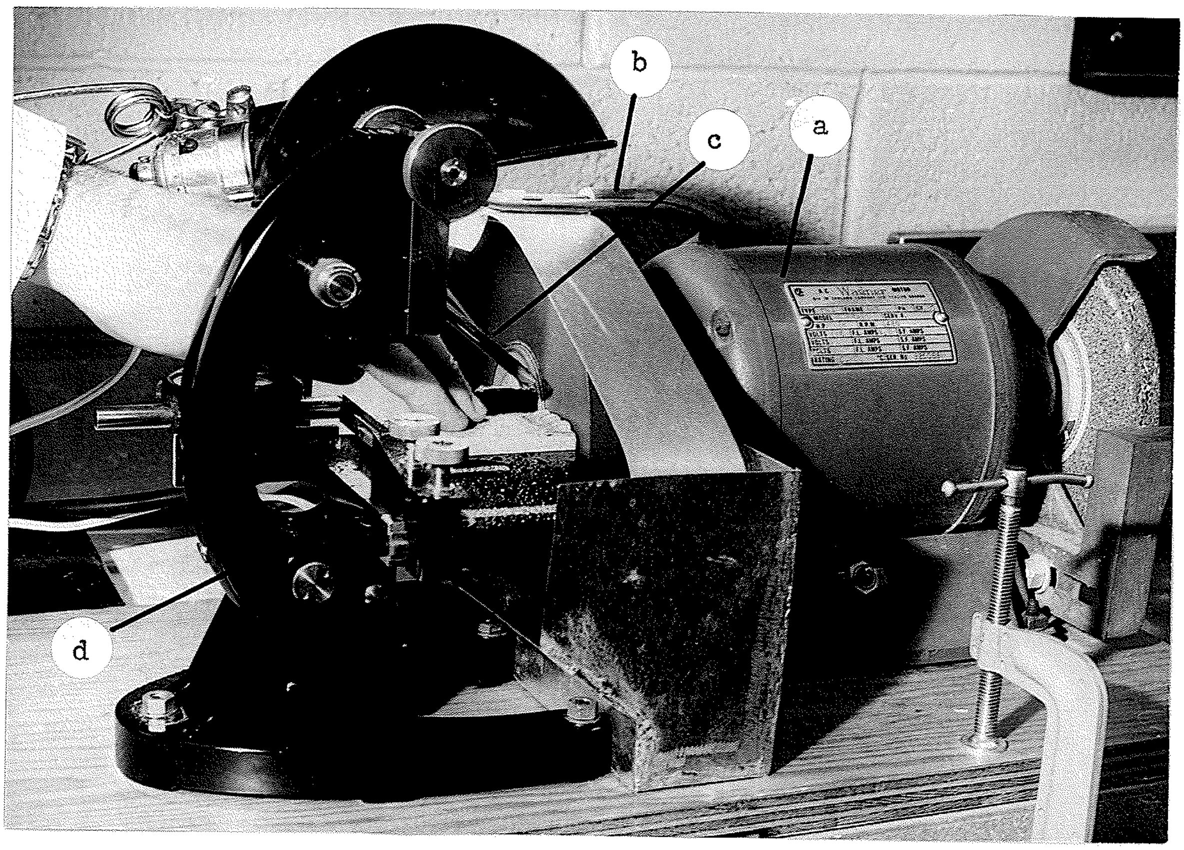


Fig. 11

Figure 12 - A representative section through a model for margin evaluation

(a) Transparent plastic
(b) Metallized model

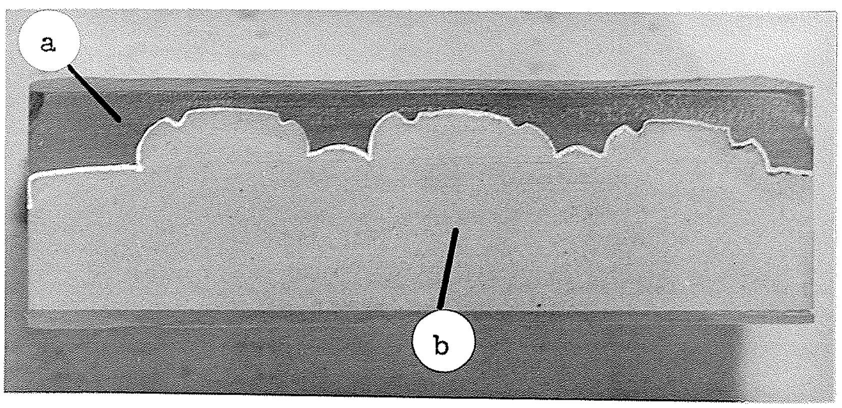


Fig. 12

Figure 13 - Micrographic apparatus for margin evaluation

(a) Metallographic microscope
(b) Specimen
(c) Camera attachment with ground glass viewing plate

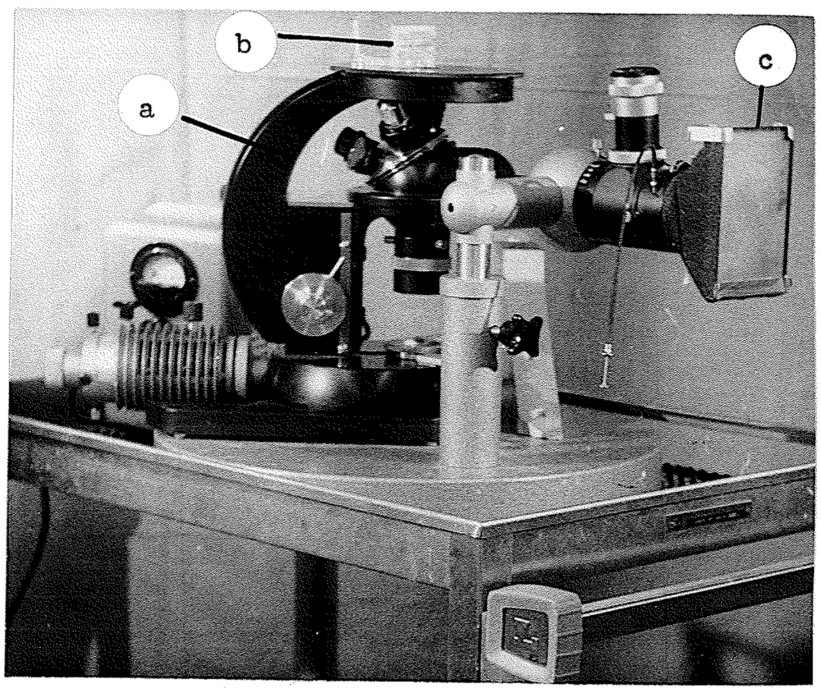


Fig. 13

convenience, a distance of 4 cm. from this point was traced on the graph paper in a direction across the restorative material, to serve as the area for comparison in the evaluation. Fig. 14 illustrates representative images of margin areas for each kind of restorative material as seen on the ground glass plate. Six progressive reductions were performed across each series of restorative materials which provided twelve measurements for each restoration polished with one agent.

Fig. 15 illustrates the magnification of margin areas traced on graph paper. This was the method of measurement employed in evaluating marginal changes.

The results of this experiment were assessed by obtaining measurements from groups of samples retained on four different appliances.

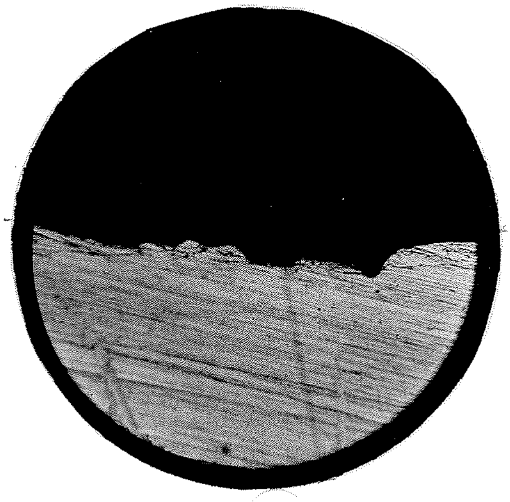
Figure 14 - Representative micrographic images of margin areas of each kind of restorative material

(a) Composite resin No.1
(b) Methyl Methacrylate resin
(c) Silicate cement
(d) Gold foil
(e) Composite resin No.2
(f) Silver amalgam

a

d

b



e

c

f

Fig. 14

Figure 15 - Magnification of margin areas
traced on graph paper

(a) Distance representing 4 cm.

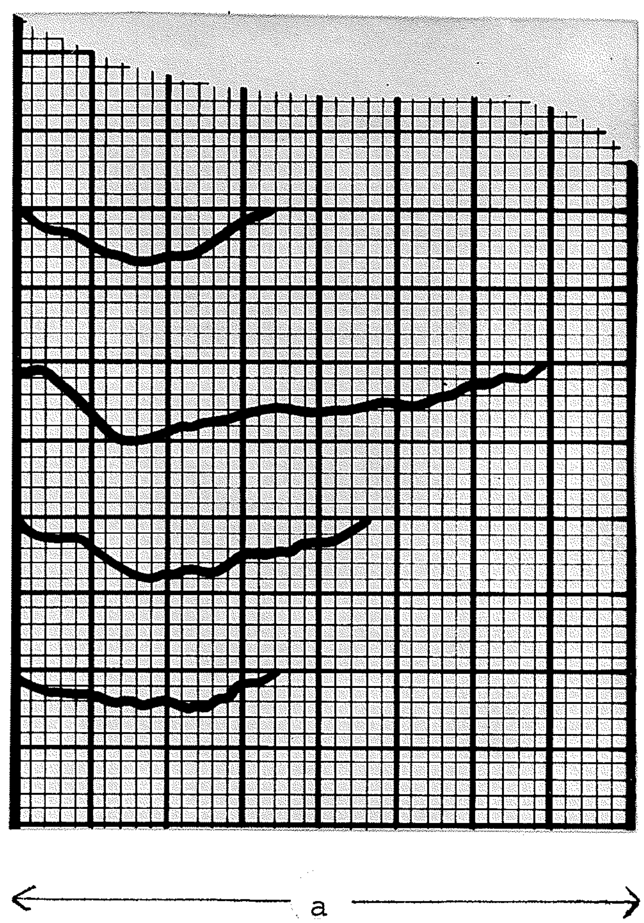


Fig. 15

RESULTS

The arithmetic mean and standard deviation was computed for the twelve measurements taken of margins from each restoration. A statistical analysis* was made of the margin measurements prior to polishing and those obtained after two and one half years and five years of polishing, with two different agents. The results appear in Tables II, III, IV and V. Tables VI and VII illustrate the measurements of the control teeth over similar periods.

At the end of two and a half years of polishing the following results were observed with zirconium silicate. None of the amalgam or silicate specimens were affected. One sample of the No.1 composite resin materials showed deterioration. Similarly the margin of only one of the gold foil specimens became worse. Half of the methyl methacrylate resin fillings were affected and three of the four composite resin No.2 fillings showed similar effects.

At the end of the same period of time, pumice produced no changes in the margin areas of amalgam and gold foil. Only one of the silicate specimens was adversely affected. Two of the specimens restored with composite resin No.2 showed

* Analysis of variance combined with the least significant difference test.

TABLE II

THE EFFECT OF ZIRCONIUM SILICATE PROPHYLAXIS PASTE ON THE MARGINS* OF SIX RESTORATIVE MATERIALS APPLIED OVER A PERIOD EQUIVALENT TO TWO AND ONE HALF YEARS**

MATERIAL	AMALGAM		COMPOSITE RESIN NO. 1		COMPOSITE RESIN NO. 2		GOLD FOIL		RESIN FILLING MATERIAL		SILICATE	
	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.
SPECIMEN GROUP 1												
Before polishing	16	3.2	50	14.2	24	15.8	14	10.3	53	21.0	50	36.0
After polishing	14	8.0	29	15.1	64	35.1	17	10.2	75	28.5	55	46.0
Significance***	Nil		Yes		Yes		Nil		Yes		Nil	
SPECIMEN GROUP 2												
Before polishing	6	2.4	12	5.9	22	8.8	8	4.0	13	5.7	50	38.0
After polishing	6	3.2	24	10.2	39	18.1	16	8.2	17	8.5	31	21.5
Significance	Nil		Yes		Yes		Yes		Nil		Nil	
SPECIMEN GROUP 3												
Before polishing	11	3.9	39	15.9	48	20.4	11	6.0	44	22.0	173	117.0
After polishing	8	5.2	31	17.5	76	32.5	17	9.8	63	25.7	151	132.0
Significance	Nil		Nil		Yes		Nil		Nil		Nil	
SPECIMEN GROUP 4												
Before polishing	4	1.7	33	15.5	43	20.2	12	4.7	28	12.7	41	20.0
After polishing	5	1.0	26	19.0	38	16.5	16	9.6	64	23.7	41	27.0
Significance	Nil		Nil		Nil		Nil		Yes		Nil	

*Average margin area ($\bar{x}$) expressed in units of 12 measurements per restoration.
**Equivalent to 10 prophylaxis treatments applied semi-annually.
***Difference at 5% level of confidence.

TABLE III

THE EFFECT OF FLOUR OF PUMICE PROPHYLAXIS PASTE ON THE MARGINS* OF SIX RESTORATIVE MATERIALS APPLIED OVER A PERIOD EQUIVALENT TO TWO AND ONE HALF YEARS**

MATERIAL	AMALGAM		COMPOSITE RESIN NO. 1		COMPOSITE RESIN NO. 2		GOLD FOIL		RESIN FILLING MATERIAL		SILICATE	
	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.
SPECIMEN GROUP 1												
Before polishing	25	15.2	43	21.6	62	34.0	21	9.0	57	20.5	60	34.0
After polishing	22	13.3	87	44.0	71	29.6	17	9.0	89	28.5	80	31.0
Significance***	Nil		Yes		Nil		Nil		Yes		Yes	
SPECIMEN GROUP 2												
Before polishing	6	2.5	13	5.7	33	13.7	11	4.0	34	33.0	47	20.0
After polishing	8	3.9	22	5.1	48	25.8	9	5.0	44	19.5	58	34.8
Significance	Nil		Yes		Yes		Nil		Nil		Nil	
SPECIMEN GROUP 3												
Before polishing	8	2.9	26	8.3	47	24.0	12	10.4	58	24.4	67	51.5
After polishing	8	4.8	49	25.0	47	27.0	14	9.3	96	35.0	111	95.0
Significance	Nil		Yes		Nil		Nil		Yes		Nil	
SPECIMEN GROUP 4												
Before polishing	7	4.7	51	36.5	35	16.5	18	13.0	68	27.7	57	41.5
After polishing	7	1.7	80	51.2	54	21.5	19	15.0	95	30.2	47	25.6
Significance	Nil		Yes		Yes		Nil		Yes		Nil	

*Average margin area ($\bar{x}$) expressed in units of 12 measurements per restorative material.
**Equivalent to 10 prophylaxis treatments applied semi-annually.
***Difference at 5% level of confidence.

TABLE IV

THE EFFECT OF ZIRCONIUM SILICATE PROPHYLAXIS PASTE ON THE MARGINS* OF SIX RESTORATIVE MATERIALS APPLIED OVER A PERIOD EQUIVALENT TO FIVE YEARS**

MATERIAL	AMALGAM		COMPOSITE RESIN NO. 1		COMPOSITE RESIN NO. 2		GOLD FOIL		RESIN FILLING MATERIAL		SILICATE	
	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.
SPECIMEN GROUP 1												
Before polishing	16	3.2	50	14.2	24	15.8	14	10.3	53	21.0	50	36.0
After polishing	7	5.7	22	10.5	36	36.3	16	10.2	55	20.5	42	30.5
Significance***	Yes		Yes		Nil		Nil		Nil		Nil	
SPECIMEN GROUP 2												
Before polishing	6	2.4	12	5.9	22	8.8	8	4.0	13	5.7	50	38.0
After polishing	5	2.2	23	12.0	38	17.3	8	4.0	23	7.0	19	15.0
Significance	Yes		Yes		Yes		Nil		Nil		Yes	
SPECIMEN GROUP 3												
Before polishing	11	3.9	39	15.9	48	20.4	11	6.0	44	22.0	173	117.0
After polishing	7	3.8	32	15.5	40	24.5	16	12.7	58	22.8	53	26.0
Significance	Yes		Nil		Nil		Nil		Nil		Yes	
SPECIMEN GROUP 4												
Before polishing	4	1.7	33	15.5	43	20.2	12	4.7	28	12.7	41	20.0
After polishing	4	1.0	30	12.0	35	24.3	14	6.4	62	26.0	38	21.5
Significance	Nil		Nil		Nil		Nil		Yes		Nil	

*Average margin area ($\bar{x}$) expressed in units of 12 measurements per restorative material.
**Equivalent to 10 prophylaxis treatments applied semi-annually.
***Difference at 5% level of confidence.

TABLE V

THE EFFECT OF FLOUR OF PUMICE PROPHYLAXIS PASTE ON THE MARGINS* OF SIX RESTORATIVE MATERIALS APPLIED OVER A PERIOD EQUIVALENT TO FIVE YEARS**

MATERIAL	AMALGAM		COMPOSITE RESIN NO. 1		COMPOSITE RESIN NO. 2		GOLD FOIL		RESIN FILLING MATERIAL		SILICATE	
	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.
	SPECIMEN GROUP 1											
Before polishing	25	15.2	43	21.6	62	34.0	21	9.0	57	20.5	60	34.0
After polishing	17	14.0	54	28.0	62	22.7	16	8.0	96	29.0	64	24.0
Significance***	Nil		Nil		Nil		Nil		Yes		Nil	
	SPECIMEN GROUP 2											
Before polishing	6	2.5	13	5.7	33	13.7	11	4.0	34	33.0	47	20.0
After polishing	11	6.4	27	10.5	61	18.1	7	2.2	53	20.5	45	21.0
Significance	Yes		Yes		Yes		Yes		Yes		Nil	
	SPECIMEN GROUP 3											
Before polishing	8	2.9	26	8.3	47	24.0	12	10.4	58	24.4	67	51.5
After polishing	6	4.1	34	9.7	57	34.0	16	10.0	100	21.5	115	88.0
Significance	Nil		Nil		Nil		Nil		Yes		Nil	
	SPECIMEN GROUP 4											
Before polishing	7	4.7	51	36.5	35	16.5	18	13.0	68	27.7	57	41.5
After polishing	8	2.7	28	16.0	45	17.0	21	10.2	95	33.8	50	44.5
Significance	Nil		Nil		Nil		Nil		Yes		Nil	

*Average margin area ($\bar{x}$) expressed in units of 12 measurements per restorative material.
**Equivalent to 10 prophylaxis treatments applied semi-annually.
***Difference at 5% level of confidence.

TABLE VI

THE EFFECT ON THE MARGINS* OF SIX RESTORATIVE MATERIALS USED AS A CONTROL. (TWO AND ONE HALF YEAR PERIOD)**

MATERIAL	AMALGAM		COMPOSITE RESIN NO. 1		COMPOSITE RESIN NO. 2		GOLD FOIL		RESIN FILLING MATERIAL		SILICATE	
	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.
SPECIMEN GROUP 1												
Zero period	22	14.2	54	21.6	30	24.8	20	11.3	53	18.5	55	24.5
$2\frac{1}{2}$ year period	16	1.0	56	16.8	48	26.9	18	10.5	61	26.0	60	42.0
Significance***	Nil		Nil		Nil		Nil		Nil		Nil	
SPECIMEN GROUP 2												
Zero period	5	1.4	28	13.0	35	22.0	5	3.0	35	22.5	69	45.5
$2\frac{1}{2}$ year period	6	2.5	23	10.5	38	21.0	7	2.4	29	17.0	85	43.0
Significance	Nil		Nil		Nil		Nil		Nil		Nil	
SPECIMEN GROUP 3												
Zero period	8	5.8	62	41.0	51	27.5	16	15.6	44	15.6	32	25.1
$2\frac{1}{2}$ year period	5	3.0	75	56.9	51	20.3	15	13.0	44	16.0	33	20.0
Significance	Yes		Nil		Nil		Nil		Nil		Nil	
SPECIMEN GROUP 4												
Zero period	6	3.2	33	22.4	27	10.0	15	14.8	48	20.5	61	44.5
$2\frac{1}{2}$ year period	7	3.5	28	17.0	24	12.0	14	11.8	51	33.0	69	55.6
Significance	Nil		Nil		Nil		Nil		Nil		Nil	

*Average margin area ($\bar{x}$) expressed in units of 12 measurements per restoration.
**Represented by 20 days in the oral environment.
***Difference at 5% level of confidence.

TABLE VII

THE EFFECT ON THE MARGINS* OF SIX RESTORATIVE MATERIALS USED AS A CONTROL. (FIVE YEAR PERIOD)**

MATERIAL	AMALGAM		COMPOSITE RESIN NO. 1		COMPOSITE RESIN NO. 2		GOLD FOIL		RESIN FILLING MATERIAL		SILICATE	
	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.	Margin Area	S.D.
SPECIMEN GROUP 1												
Zero period	22	14.2	54	21.6	30	24.8	20	11.3	53	18.5	55	24.5
5 year period	12	5.6	66	34.0	44	17.8	13	3.8	55	21.0	76	44.0
Significance***	Yes		Nil		Nil		Nil		Nil		Nil	
SPECIMEN GROUP 2												
Zero period	5	1.4	28	13.0	35	22.0	5	3.0	35	22.5	69	45.5
5 year period	3	2.7	24	3.9	38	19.9	7	5.3	32	18.0	80	40.0
Significance	Yes		Nil		Nil		Nil		Nil		Nil	
SPECIMEN GROUP 3												
Zero period	8	5.8	62	41.0	51	27.5	16	15.6	44	15.6	32	25.1
5 year period	5	1.4	78	61.5	39	22.3	9	3.3	72	32.0	73	47.0
Significance	Yes		Nil		Yes		Nil		Yes		Yes	
SPECIMEN GROUP 4												
Zero period	6	3.2	33	22.4	27	10.0	15	14.8	48	20.5	61	44.5
5 year period	7	3.0	28	17.3	23	8.7	17	11.0	45	58.5	60	43.4
Significance	Nil		Nil		Nil		Nil		Nil		Nil	

*Average margin area ($\bar{x}$) expressed in units of 12 measurements per restoration.
**Represented by 40 days in the oral environment.
***Difference at 5% level of confidence.

wear at the margins. The margins of three of the methyl methacrylate resin fillings were affected. All of the composite resin No.1 filling materials revealed marginal changes.

At the end of the five year period, when zirconium silicate was used as the polishing compound, no deleterious changes were evident with gold foil, amalgam or silicate. Each of the resin filling materials revealed one affected margin.

Flour of pumice produced no adverse changes on gold foil or silicate specimens at the end of the five year period. Each of the composite resins and amalgam exhibited one specimen which had been adversely affected at the margin. Methyl methacrylate resin specimens were all adversely affected.

At the end of two and a half years none of the control teeth showed any evidence of adverse changes at the margins. At the end of the five year period, with the control teeth, only one silicate and one methyl methacrylate restoration showed significant adverse changes. All other margins in the control group were unaffected.

As a group, the metallic restorations showed less deleterious changes than did the non-metallic ones. In the metallic group, only the amalgam showed any deleterious change at the end of the five year period and this was produced by flour of pumice. Generally, flour of pumice appeared more destructive to the margins of non-metallic materials than did zirconium silicate. In the non-metallic group, methyl methacrylate resin suffered the greatest, followed by composite resin, with silicate showing the least damage.

With time, a consistent trend appeared to develop with all of the restorative materials except methyl methacrylate resin. Defective margins, which were found at the end of the two and a half year portion of the study, seemed to reduce in severity when polishing was continued to the end of the five year period.

Methyl methacrylate resin, however, continued to deteriorate during this extended period. Figure 16, in the form of a bar graph, illustrates the relative degree of change produced on the cavo-surface margins of six restorative materials, by two prophylaxis polishing compounds, after a period equivalent to five years.

Figure 16 - Bar graph showing cavo-surface margin changes after ten prophylaxis polishing treatments

(a) Indicates specimens at the zero level

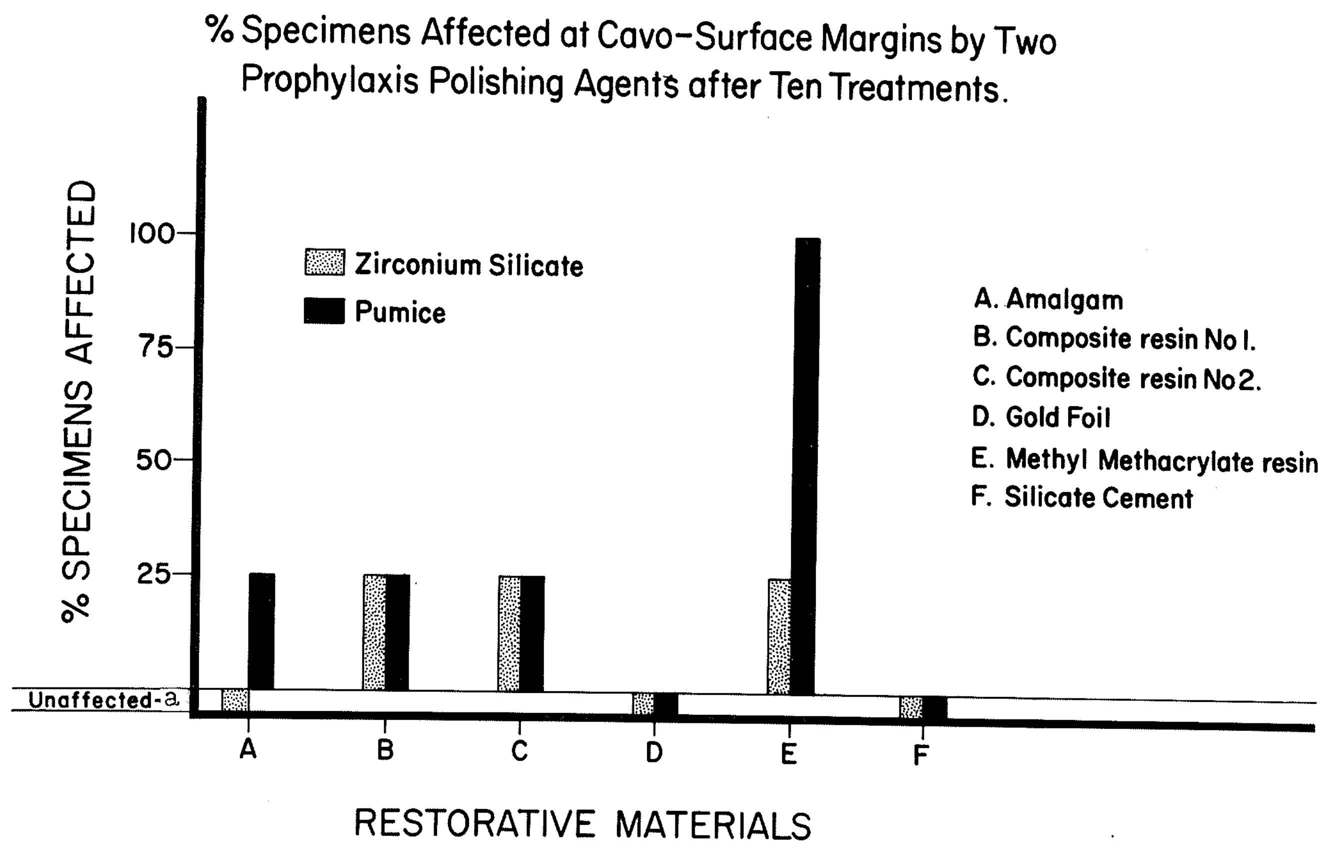

% Specimens Affected at Cavo-Surface Margins by Two Prophylaxis Polishing Agents after Ten Treatments.
% SPECIMENS AFFECTED
100
75
50
25
Unaffected-a
Zirconium Silicate
Pumice
A. Amalgam
B. Composite resin No 1.
C. Composite resin No 2.
D. Gold Foil
E. Methyl Methacrylate resin
F. Silicate Cement
A
B
C
D
E
F
RESTORATIVE MATERIALS

Fig. 16

DISCUSSION

Human teeth selected for this study were obtained randomly from a common pool without regard to age or developmental and environmental influences of natural or artificially applied fluoride. Hardness and resistance to abrasion are properties of enamel which could be altered by these factors. It was felt that these differences would not affect the results appreciably, because changes which might be produced as a result of multiple prophylaxis procedures would more likely occur in the restorative material to a greater degree than in the tooth structure.

The choice of silver-plated rubber-base impressions for recording margin adaptation was made on the basis of studies conducted by Henry and Phillips.[68] They demonstrated that such a technique was capable of reproducing minute detail in the order of three microns.

The oral environment was selected as the storage medium for the teeth carrying restorative materials because it provides the ideal controlled conditions not possible to obtain with artificial media. Factors such as viscosity, pH and flow-rate of saliva, humidity and temperature, are readily controlled and equally applied to the specimens. The appliance which retained the teeth in this environment played in important role. The design and location were important factors to be considered, for an uncomfortable appliance would deter a patient from full cooperation in retaining specimens in the oral cavity as directed. The maxillary partial appliance proved to be the most satisfactory.

It was felt that the relatively small number of specimens was adequate for this preliminary investigation. It is recommended, however, a larger sample size be included in future extended studies along similar lines.

A high magnification factor was selected for measuring relatively small changes detected in the margin area. No attempt was made to measure the width of the crevice between tooth structure and restoration; only the distance between the cavity wall and a predetermined point on the restorative material was measured to compare changes produced by the polishing pastes. The total time of actual contact with a polishing compound amounted to five minutes. This is considerably less than is required when effects of tooth-brushing and dentifrices are evaluated.

It is apparent from the results tabulated that the adaptation of metallic materials to cavity walls is superior to the non-metallic ones, after initial placement. This may be explained by the fact that condensing procedures are employed with gold foil and amalgam fillings but not with non-metallic ones. As well, only metal is capable of having its margins improved by finishing procedures.

The results of an earlier study[43] which compared adaptation of filling materials with cavity-wall texture can be open to question. Although reduced penetration by Ca^{45} was demonstrated in those cavities having rough walls compared to those with smooth walls, the area or extent of travel of the tracer may be of equal magnitude because of the increase in surface area present in the rough texture of the cavity wall. The selection of the tracer element may also be questioned. Because calcium and phosphorous are capable of ionic exchange with hydroxyapatite, an accurate determination of the leakage pattern may be interfered with. The use of elements other than calcium or phosphorous is therefore suggested.

Generally, all restorations normally placed in teeth, require some form of alteration to their contour or surface after insertion. Metallic filling materials react favorably to such a procedure and marginal adaptation may therefore be improved. Non-metallic materials, however, do not react in the same manner, and any attempt at removal of excess or contour adjustment results in a reduced relationship compared to that immediately after insertion. There appears to be increasing evidence that the space which is present between a material and tooth structure may be filled in by mineralization of plaque in a rather short period of time.

The volunteer subjects who wore the appliances carrying specimen teeth ranged between the ages of twenty-two and fifty years. All were found to produce salivary calculus which accumulated on the teeth held by appliances. No brushing procedures were undertaken between prophylaxis treatments, therefore plaque adhering to the experimental teeth, could undergo mineralization similar to that which might occur on normal teeth in the oral cavity.

The filling-in by corrosion products likewise cannot be ignored. Abrasion of tooth structure adjacent to the restorative material is also possible. All of these factors can contribute to what appears to be an improved relationship, with time.

The behavior of silicate material as compared to the resin restorative materials would indicate that it is superior to the resin. Clinical experience, however, does not bear this out, and solubility rather than abrasion resistance is probably the factor most responsible for its failure.

Pumice produced the most deleterious changes at the cavo-surface interface. Methyl methacrylate resin proved to be most vulnerable. Such a prophylaxis polishing compound is not indicated as a material of choice for routine prophylaxis polishing procedures, where restorations in teeth are involved.

Volume loss or margin loss of a restorative material can invite increase in plaque formation and food retention with accompanying inflammatory reactions to adjacent soft tissues, particularly in the gingival area.

This study restricted itself to two basic polishing materials, pumice and zirconium silicate. The former is representative of a common abrasive material used for many years in the past and the latter, relatively new, was selected because it has received a good deal of attention recently. Further studies are indicated and should be extended to include other commercially available prophylaxis compounds as well as those combined with fluoride.

SUMMARY

Results of this study indicate that certain restorative materials may suffer cavo-surface margin changes from the abrasive effects of prophylaxis polishing agents.

The effect on the margins of six different restorative materials was determined following prophylaxis procedures with two common polishing agents. The influence of the oral environment was controlled by attaching filled specimen teeth to removable appliances and storing them in the mouths of volunteer subjects.

Effects were determined by replicating the surfaces of the specimens in the form of metallized models after polishing procedures were applied. These models were then sectioned at various increments at the margin areas and changes were measured micrographically by tracing the images on transparent graph paper. The average of twelve such readings was determined from the margin areas of each restorative material and served as the yardstick for evaluating changes.

Each appliance housed all of the restorative materials subjected to the two prophylaxis polishing agents as well as a group of specimens which served as controls. Four appliances were made for this investigation which provided a total of seventy-two restorations for studying marginal area changes produced by the polishing procedures equivalent to a period of five years.

There appears to be sufficient evidence to indicate that commonly used abrasives for dental prophylaxis procedures can influence the integrity of the margins of restorative materials in varying degrees with time, and that certain compounds produce this effect with greater severity than others.

This study illustrates the value of using the oral environment as a storage medium in preference to artificial media and that suitably designed appliances can be fabricated to satisfy the oral tolerance of a human subject.

The variable effects of abrasive materials in contact with restorations in teeth would suggest that care should be exercised when prophylaxis polishing procedures are performed for patients.

Further investigation along the same lines using additional compounds, and in particular those combined with fluoride solutions, should be undertaken.

CONCLUSIONS

1. When all of the filling materials were considered as a group, flour of pumice appeared to affect the margins to a greater degree than did zirconium silicate.

2. As a routine prophylaxis polishing agent, zirconium silicate was less harmful than flour of pumice on the margins of certain restorative materials.

3. Of all the restorative materials included in the study, methyl methacrylate resin was the most vulnerable to changes.

4. The composite resin materials were more resistant to the effects of flour of pumice than methyl methacrylate resin.

5. Silicate cement was more resistant to abrasion than amalgam when flour of pumice was used as the abrasive.

6. With the exception of silicate cement, metallic restorative materials in general, resisted abrasive changes to a greater degree than did the non-metallic ones.

7. It is suggested that, in those cases where apparent improvements in the tooth-restoration interface area were noticed following polishing procedures, this might have been due to mineralized plaque filling the space.

8. The maxillary partial appliance proved to be the most satisfactory type of vehicle for storing specimens in the oral environment.

REFERENCES

1. Easlick, K.A. (ed.): Dental caries; mechanism and present control techniques as evaluated at the University of Michigan workshop, Michigan. University School of Public Health, St. Louis, Mosby, 1948.

2. Shafer, W.G., Hine, M.K. and Levy, B.M.: A textbook of oral pathology, W.B. Saunders Co., p.337, (2nd Ed., 1963).

3. Phillips, R.W.: Research on dental amalgam and its application in practice, J.A.D.A. 54:309-318, 1957.

4. Baumgartner, W.J., Bustard, R.E. and Feierabend, R.F.: Marginal leakage of amalgam restorations, J. Pros. Dent. 13:346-353, 1963.

5. Schouboe, T. and MacDonald, J.B.: Prolonged viability of organisms sealed in dentinal caries, Arch. Oral Biology 7:525-526, 1962.

6. Fisher, F.J.: The viability of microorganisms in carious dentine beneath amalgam restorations, B.D.J. 121:413-416, November, 1966.

7. Phillips, R.W., Gilmore, H.W., Swartz, M.L. and Schenker, S.I.: Adaption of restorations in vivo as assessed by Ca^{45}, J.A.D.A. 62:9-20, January, 1961.

8. Volker, J., Bekaris, B. and Melillo, S.: Some observations on the relationship between plastic filling materials and dental caries, Tufts Dental Outlook 18:4-8, May, 1944.

9. Phillips, R.W. and Swartz, M.L.: Effects of certain restorative materials on solubility of enamel, J.A.D.A. 54:623-636, May, 1957.

10. Crawford, W.H. and Larson, J.H.: Fluid penetration between fillings and teeth using Ca^{45}, J.D. Res. 35: 518-522, August, 1956.

11. Waerhaug, J.: Effect of rough surfaces upon gingival tissue, J.D. Res. 35:323-325, April, 1956.

12. Zander, H.A.: Effect of silicate cement and amalgam on the gingiva, J.A.D.A. 55:11-15, 1957.

13. Waerhaug, J. and Zander, H.A.: Reaction of gingival tissues to self-curing acrylic restorations, J.A.D.A. 54:760-768, 1957.

14. Trott, J.R.: Effect of Class II amalgam restorations on health of the gingiva: a clinical survey, J.Can.D. Assoc. 30:766-770, December, 1964.

15. Jorgensen, K.D.: Mechanism of marginal fracture of amalgam fillings, Acta Odont. Scand. 23:347-389, 1965.

16. Bjorndal, A.M. and Sahs, E.A.: Comparative microphotographic study of marginal adaptation of amalgam and gold inlay restorations, Iowa D.J. 46:12-14, February, 1960.

17. Paffenbarger, G.C.: American Dental Association. Council on Dental Research. List of certified dental materials 1960-61 4th Ed.:69, Chicago, 1960.

18. Armstrong, W.D. and Simon, W.J.: Penetration of radiocalcium at the margins of filling materials: a preliminary report, J.A.D.A. 43:684-686, December, 1951.

19. Going, R.E., Massler, M. and Dute, H.L.: Marginal penetrations of dental restorations as studied by crystal violet dye and I^{131}, J.A.D.A. 61:285-300, September, December, 1960.

20. Going, R.E., Massler, M. and Dute, H.L.: Marginal penetration of dental restorations by different radioactive isotopes, J.D. Res. 39:273-284, March-April, 1960.

21. Wainwright, W.W., Stowell, E.C., Jr. and Taylor, J.B.: Microleakage of in vitro amalgam fillings to I^{131} labelled human serum albumin and NaI^{131}, J.D. Res. 38:749, July-August, 1959. (abst.)

22. Barber, D., Lyell, J. and Massler, M.: Effects of saliva and sulphide solutions on the marginal seal of amalgam restorations, J.D. Res. 43:375-379, May-June, 1964.

23. Barber, D., Lyell, J. and Massler, M.: Effectiveness of copal resin varnish under amalgam restorations, J. Pros. Dent. 14:533-536, May-June, 1964.

24. American Dental Association. Council on Dental Research. Guide to dental materials. (3rd Ed.; Chicago, A.D.A. 1958).

25. Skinner, E.W. and Phillips, R.W.: The science of dental materials. (6th Ed.; Philadelphia, W.B. Saunders Co., p.28-50, 1967).

26. Iwaku, M. et al.: Edge strength of powdered gold filling, J.D. Res. 45:1468-1472, September-October, 1966.

27. Mahler, D.B. and Terkla, L.G.: Analysis of stress in dental structure, Dent. Clin. N. Amer. p.789-798, November, 1958.

28. McDonald, R.E. and Phillips, R.W.: Clinical observations on a contracting amalgam alloy, J.D. Res. 29:482-485, August, 1950.

29. Wing, G.: The marginal seal of amalgam restorations. Aust. D.J. 11:81-86, April, 1966.

30. Kasloff, Z., Swartz, M.L. and Phillips, R.W.: An in vitro method for demonstrating the effects of various cutting instruments on tooth structure, J. Pros. Dent. 12:1166-1175, November-December, 1962.

31. Kleinberg, I.: Studies on Dental Plaque. I. The effect of different concentrations of glucose on the pH of dental plaque in vivo, J.D. Res. 40:1087-1111, November-December, 1961.

32. Shapiro, M.: The scientific bases in dentistry, W.B. Saunders Co., p.306, 1966.

33. Shell, J.S. and Hollenback, G.M.: Wear tests on enamel and dentine, J. Calif. D.A. 42:222-224, June, 1966.

34. Shell, J.S., Hollenback, G.M. and Villanyi, A.A.: Comparative abrasion rates on restorative materials, J. Calif. D.A. 42:521-524, December, 1966.

35. Swartz, M.L. and Phillips, R.W.: In vitro studies on the marginal leakage of restorative materials, J.A.D.A. 62:141-151, February, 1961.

36. Phillips, R.W.: Advancement in adhesive restorative dental materials, J.D. Res. 45:1662, November-December, 1966.

37. Christen, A.G. and Mitchell, D.F.: A fluorescent dye method for demonstrating leakage around dental restorations, J.D. Res. 45:1485-1492, September-October, Part 2, 1966.

38. Mortensen, D.W., Boucher, N.E. and Ryge, G.: A method of testing for marginal leakage of dental restorations with bacteria, J. Dent. Res. 44:58-63, 1965.

39. Going, R.E. and Sawinski, V.J.: Microleakage of a new restorative material, J.A.D.A. 73:107-115, July, 1966.

40. Langeland, L.K., Guttuso, J., Jerome, D.R. and Langeland, K.: Histologic and clinical comparison of addent with silicate cements and cold-curing materials, J.A.D.A. 72:373-385, February, 1966.

41. Hatt, S.D.: Relationship of amalgam to the cavity wall, D. Practitioner and D. Record 10:76-86, December, 1959.

42. Jorgensen, K.D.: Amalgams adaptability, Tandlaegebladet, 68:378-389, August, 1964.

43. Menegale, C., Swartz, M.L. and Phillips, R.W.: Adaption of restorative materials as influenced by roughness of cavity walls, J.D. Res. 39:825-835, July-August, 1960.

44. Nelson, R.J., Wolcott, R.B. and Paffenbarger, G.C.: Fluid exchange at the margins of dental restorations, J.A.D.A. 44:288-295, March, 1952.

45. Jorgensen, K.D. and Palbol, O.P.: Experiments on the relationship between the strength and the angle of amalgam margins, Acta Odont. Scand. 23:513-520, 1965.

46. Dolven, R.C.: Micromeasurement of cavity lining, using ultraviolet and reflected light, and the effect of the liner on marginal penetration, evaluated with Ca^{45}, J.D. Res. 45:12-15, January-February, 1966.

47. Dawes, C., Dept. of Oral Biology, Faculty of Dentistry, University of Manitoba, Personal Communication, June, 1967.

48. Manly, R.S.: A structureless recurrent deposit on teeth, J.D. Res. 22:479-486, December, 1943.

49. Meckel, A.H.: The formation and properties of organic films on teeth, Arch. Oral Biology 10:585-597, July-August, 1965.

50. Lenz, H. and Muhlemann, H.R.: In vivo and in vitro effects of saliva on etched or mechanically marked enamel after certain periods of time, Helv. Odont. Acta 7:30-33, April, 1963.

51. Schroeder, H.E., Lenz, H. and Muhlemann, H.R.: Microstructure and mineralization of early dental calculus, Helv. Odont. Acta 8:1-16, 1964.

52. Fehr, F.R. von der, and Steinnes, E.: The solubility rate of unabraded, abraded and exposed human enamel surfaces studied by means of activation analysis, Arch. Oral Biology 11:1405-1418, 1966.

53. Stowell, E.C. et al.: Influence of saliva on marginal penetration in amalgam fillings in vitro, I.A.D.R. 40:18, 1962.

54. Brannstrom, M. and Soremark, R.: Penetration of Na^{22} ions around amalgam restorations with and without cavity varnish, Odont. Revy. 13:331-336, 1962.

55. Stookey, G.K., Hudson, J.R. and Muhler, J.C.: Studies concerning the polishing properties of zirconium silicate on enamel, J. Periodont. 37:200-207, May-June, 1966.

56. Phillips, R.W. and Swartz, M.L.: Comparison of bacterial accumulations on rough and smooth enamel surfaces, J. Periodont. 28:304-307, October, 1957.

57. Buonocore, M.G., Matsui, A. and Yamaki, M.: Abrasion of restorative materials, N.Y.D.J. 32:395-400, November, 1966.

58. Manly, R.S., Wiren, J. and Manly, P.J.: A method for measurement of abrasion of dentine by toothbrush and dentifrice, J.D. Res. 44:533-540, May-June, 1965.

59. Ashmore, H.: Dental enamel abrasion. An in vitro method using interference microscopy, B.D.J. 120:309-314, April, 1966.

60. Rank Taylor Hobson (Canada) Ltd.: Personal Communication, March, 1967.

61. Bjorn, H. and Lindhe, J.: Abrasion of dentine by toothbrush and dentifrice. A methodological study, Odont. Rev. (Malmo) 17:17-27, 1966.

62. Charbeneau, G.T.: A suggested technic for polishing amalgam restorations, J. Mich. S.D. Assoc. 47:320-325, November, 1965.

63. Craig, R.G. and Peyton, F.A.: Microhardness of enamel and dentine, J.D. Res. 37:661-668, August, 1958.

64. Stanford, J.W., Weigel, K.V., Paffenbarger, G.C., and Sweeney, W.T.: Compressive properties of hard tooth tissues and some restorative materials, J.A.D.A. 60:746-756, June, 1960.

65. Eames, W.B.: Preparation and condensation of amalgam with a low mercury-alloy ratio, J.A.D.A. 58:78-83, April, 1959.

66. Koulourides, T. and Volker, J.F.: Changes of enamel microhardness in the human mouth, Alabama J. Med. Sciences 1:435-437, October, 1964.

67. Pollard, L., Bergman, W. and Kasloff, Z.: Polishing effects of certain dental prophylaxis compounds on tooth enamel and restorative materials, I.A.D.R. 45:82, 1967. (abst.)

68. Henry, R.W. and Phillips, R.W.: Reproducing surface detail with electroplated impressions, Dental Progress 2:33-38, October, 1961.

BIBLIOGRAPHY

American Dental Association. Council on Dental Research. Guide to dental materials. (3rd Ed.; Chicago, A.D.A. 1958)

Armstrong, W.D. and Simon, W.J.: Penetration of radiocalcium at the margins of filling materials: a preliminary report, J.A.D.A. 43:684-686, December, 1951.

Ashmore, H.: Dental enamel abrasion. An in vitro method using interference microscopy, B.D.J. 120:309-314, April, 1966.

Barber, D., Lyell, J. and Massler, M.: Effects of saliva and sulphide solutions on the marginal seal of amalgam restorations. J.D. Res. 43:375-379, May-June, 1964.

Barber, D., Lyell, J. and Massler, M.: Effectiveness of copal resin varnish under amalgam restorations, J. Pros. Dent. 14:533-536, May-June, 1964.

Baumgartner, W.J., Bustard, R.E. and Feierabend, R.F.: Marginal leakage of amalgam restorations, J. Pros. Dent. 13: 346-353, 1963.

Bjorn, H. and Lindhe, J.: Abrasion of dentine by toothbrush and dentifrice. A methodological study, Odont. Rev. (Malmo) 17:17-27, 1966.

Bjorndal, A.M. and Sahs, E.A.: Comparative microphotographic study of marginal adaptation of amalgam and gold inlay restorations, Iowa D.J. 46:12-14, February, 1960.

Brannstrom, M. and Soremark, R.: Penetration of Na^{22} ions around amalgam restorations with and without cavity varnish, Odont. Revy. 13:331-336, 1962.

Buonocore, M.G., Matsui, A. and Yamaki, M.: Abrasion of restorative materials, N.Y.D.J. 32:395-400, November, 1966.

Charbeneau, G.T.: A suggested technic for polishing amalgam restorations, J. Mich. S.D. Assoc. 47:320-325, November, 1965.

Christen, A.G. and Mitchell, D.F.: A fluorescent dye method for demonstrating leakage around dental restorations, J.D. Res. 45:1485-1492, September-October, Part 2, 1966.

Craig, R.G. and Peyton, F.A.: Microhardness of enamel and dentine, J.D. Res. 37:661-668, August, 1958.

Crawford, W.H. and Larson, J.H.: Fluid penetration between fillings and teeth using Ca^{45}, J.D. Res. 35:518-522, August, 1956.

Dawes, C., Dept. of Oral Biology, Faculty of Dentistry, University of Manitoba, Personal Communication, June, 1967.

Dolven, R.C.: Micromeasurement of cavity lining, using ultraviolet and reflected light, and the effect of the liner on marginal penetration, evaluated with Ca^{45}, J.D. Res. 45: 12-15, January-February, 1966.

Eames, W.B.: Preparation and condensation of amalgam with a low mercury-alloy ratio, J.A.D.A. 58:78-83, April, 1959.

Easlick, K.A.(ed.): Dental caries; mechanism and present control techniques as evaluated at the University of Michigan workshop, Michigan. University School of Public Health, St. Louis, Mosby, 1948.

Fehr, F.R. von der, and Steinnes, E.: The solubility rate of unabraded, abraded and exposed human enamel surfaces studied by means of activation analysis, Arch. Oral Biology 11:1405-1418, 1966.

Fisher, F.J.: The viability of microorganisms in carious dentine beneath amalgam restorations, B.D.J. 121:413-416, November, 1966.

Going, R.E., Massler, M. and Dute, H.L.: Marginal penetration of dental restorations by different radioactive isotopes, J.D. Res. 39:273-284, March-April, 1960.

Going, R.E., Massler, M. and Dute, H.L.: Marginal penetrations of dental restorations as studied by crystal violet dye and I^{131}, J.A.D.A. 61:285-300, September, December, 1960.

Going, R.E. and Sawinski, V.J.: Microleakage of a new restorative material, J.A.D.A. 73:107-115, July, 1966.

Hatt, S.D.: Relationship of amalgam to the cavity wall, D. Practitioner and D. Record 10:76-86, December, 1959.

Henry, R.W. and Phillips, R.W.: Reproducing surface detail with electroplated impressions, Dental Progress 2:33-38, October, 1961.

Iwaku, M. et al.: Edge strength of powdered gold filling, J.D. Res. 45:1468-1472, September-October, 1966.

Jorgensen, K.D.: Amalgams adaptability, Tandlaegebladet, 68:378-389, August, 1964.

Jorgensen, K.D.: Mechanism of marginal fracture of amalgam fillings, Acta Odont. Scand. 23:347-389, 1965.

Jorgensen, K.D. and Palbol, O.P.: Experiments on the relationship between the strength and the angle of amalgam margins, Acta Odont. Scand. 23:513-520, 1965.

Kasloff, Z., Swartz, M.L. and Phillips, R.W.: An in vitro method for demonstrating the effects of various cutting instruments on tooth structure, J.Pros. Dent. 12:1166-1175, November-December, 1962.

Kleinberg, I.: Studies on Dental Plaque. I. The effect of different concentrations of glucose on the pH of dental plaque in vivo, J.D. Res. 40:1087-1111, November-December, 1961.

Koulourides, T. and Volker, J.F.: Changes of enamel microhardness in the human mouth, Alabama J. Med. Sciences 1:435-437, October, 1964.

Langeland, L.K., Guttuso, J., Jerome, D.R. and Langeland, K.: Histologic and clinical comparison of addent with silicate cements and cold-curing materials, J.A.D.A. 72:373-385, February, 1966.

Lenz, H. and Muhlemann, H.R.: In vivo and in vitro effects of saliva on etched or mechanically marked enamel after certain periods of time, Helv. Odont. Acta 7:30-33, April, 1963.

Mahler, D.B. and Terkla, L.G.: Analysis of stress in dental structure, Dent. Clin. N. Amer. p.789-798, November, 1958.

Manly, R.S.: A structureless recurrent deposit on teeth, J.D. Res. 22:479-486, December, 1943.

Manly, R.S., Wiren, J. and Manly, P.J.: A method for measurement of abrasion of dentine by toothbrush and dentifrice, J.D. Res. 44:533-540, May-June, 1965.

McDonald, R.E. and Phillips, R.W.: Clinical observations on a contracting amalgam alloy, J.D. Res. 29:482-485, August, 1950.

Meckel, A.H.: The formation and properties of organic films on teeth, Arch. Oral Biology 10:585-597, July-August, 1965.

Menegale, C., Swartz, M.L. and Phillips, R.W.: Adaption of restorative materials as influenced by roughness of cavity walls, J.D. Res. 39:825-835, July-August, 1960.

Mortensen, D.W., Boucher, N.E. and Ryge, G.: A method of testing for marginal leakage of dental restorations with bacteria, J. Dent. Res. 44:58-63, 1965.

Nelson, R.J., Wolcott, R.B. and Paffenbarger, G.C.: Fluid exchange at the margins of dental restorations, J.A.D.A. 44: 288-295, March, 1952.

Paffenbarger, G.C.: American Dental Association. Council on Dental Research. List of certified dental materials 1960-61 4th Ed.:69, Chicago, 1960.

Phillips, R.W.: Research on dental amalgam and its application in practice, J.A.D.A. 54:309-318, 1957.

Phillips, R.W.: Advancement in adhesive restorative dental materials, J.D. Res. 45:1662, November-December, 1966.

Phillips, R.W., Gilmore, H.W., Swartz, M.L. and Schenker, S.I.: Adaption of restorations in vivo as assessed by Ca^{45}, J.A.D.A. 62:9-20, January, 1961.

Phillips, R.W. and Swartz, M.L.: Effects of certain restorative materials on solubility of enamel, J.A.D.A. 54: 623-636, May, 1957.

Phillips, R.W. and Swartz, M.L.: Comparison of bacterial accumulations on rough and smooth enamel surfaces, J. Periodont. 28:304-307, October, 1957.

Pollard, L., Bergman, W. and Kasloff, Z.: Polishing effects of certain dental prophylaxis compounds on tooth enamel and restorative materials, I.A.D.R. 45:82, 1967. (abst.)

Rank Taylor Hobson (Canada) Ltd.: Personal Communication, March, 1967.

Schouboe, T. and MacDonald, J.B.: Prolonged viability of organisms sealed in dentinal caries, Arch. Oral Biology 7:525-526, 1962.

Schroeder, H.E., Lenz, H. and Muhlemann, H.R.: Microstructure and mineralization of early dental calculus, Helv. Odont. Acta 8:1-16, 1964.

Shafer, W.G., Hine, M.K. and Levy, B.M.: A textbook of oral pathology, W.B. Saunders Co., p.337, (2nd Ed., 1963).

Shapiro, M.: The scientific bases in dentistry, W.B. Saunders Co., p.306, 1966.

Shell, J.S. and Hollenback, G.M.: Wear tests on enamel and dentine, J. Calif. D.A. 42:222-224, June, 1966.

Shell, J.S., Hollenback, G.M. and Villanyi, A.A.: Comparative abrasion rates on restorative materials, J. Calif. D.A. 42: 521-524, December, 1966.

Skinner, E.W. and Phillips, R.W.: The science of dental materials. (6th Ed.; Philadelphia, W.B. Saunders Co., p.28-50, 1967.

Stanford, J.W., Weigel, K.V., Paffenbarger, G.C., and Sweeney, W.T.: Compressive properties of hard tooth tissues and some restorative materials, J.A.D.A. 60:746-756, June, 1960.

Stookey, G.K., Hudson, J.R. and Muhler, J.C.: Studies concerning the polishing properties of zirconium silicate on enamel, J. Periodont. 37:200-207, May-June, 1966.

Stowell, E.C. et al.: Influence of saliva on marginal penetration in amalgam fillings in vitro, I.A.D.R. 40:18, 1962.

Swartz, M.L. and Phillips, R.W.: In vitro studies on the marginal leakage of restorative materials, J.A.D.A. 62:141-151, February, 1961.

Trott, J.R.: Effect of Class II amalgam restorations on health of the gingiva: a clinical survey, J.Can.D. Assoc. 30:766-770, December, 1964.

Volker, J., Bekaris, B. and Melillo, S.: Some observations on the relationship between plastic filling materials and dental caries, Tufts Dental Outlook 18:4-8, May, 1944.

Waerhaug, J.: Effect of rough surfaces upon gingival tissue, J.D. Res. 35:323-325, April, 1956.

Waerhaug, J. and Zander, H.A.: Reaction of gingival tissues to self-curing acrylic restorations, J.A.D.A. 54:760-768, 1957.

Wainwright, W.W., Stowell, E.C., Jr. and Taylor, J.B.: Microleakage of in vitro amalgam fillings to I^{131} labelled human serum albumin and Na^{131}, J.D. Res. 38:749, July-August, 1959. (abst.)

Wing, G.: The marginal seal of amalgam restorations, Aust. D.J. 11:81-86, April, 1966.

Zander, H.A.: Effect of silicate cement and amalgam on the gingiva, J.A.D.A. 55:11-15, 1957.

VITA

Murray A. May

Jan. 17th, 1922	Born in Sydney, Australia
1940-45	Royal Australian Air Force (Air Crew)
1947	Grade XII--War Service Matriculation
1948-52	B.D.Sc. University of Queensland
1952-58	Dental Officer Royal Australian Air Force Squadron Leader
1966-67	Dental Science Graduate Programme, Dept. of Dental Materials, Faculty of Dentistry, University of Manitoba.

Professional Societies

Australian Dental Association

The Dental Circle--Postgraduate Study Group

Brisbane, Australia