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Cerestore Alumina Ceramic: Intra-Coronal Cavity Design and Efficacy

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CERESTORE ALUMINA CERAMIC: INTRA-CORONAL CAVITY DESIGN AND EFFICACY

by

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VITA

Nasreddin A. Takally was born in Tripoli, Libya on August 23, 1952.

After graduation from Tripoli High School, Tripoli, Libya, in 1972, Mr. Takally attended Cairo University in Cairo, Egypt, where he persued a predental program of study. He studied dentistry at the same university from 1973 to May 1977 when he received the degree of Bachelor in Dental Medicine and Surgery.

After one and half years of practice, Doctor Takally went to Loyola University School of Dentistry as a post-graduate student in the Operative Dentistry Department and enrolled in the graduate program in Oral Biology, where he persued the degree of Master of Science in Oral Biology.

DEDICATION

I dedicate this thesis to my wife Firial
and my son Firas,
who have made my studies possible.

TABLE OF CONTENTS

PAGE

LIST OF TABLES

CHAPTER I

INTRODUCTION

Modern technology has introduced a large number of new materials and techniques to dentistry in recent years. The profession has kept pace with this development and has benefited by evolving into a precise discipline. Along with this development has arisen a need for conservative as well as cosmetic dentistry.

The ceramic restoration has evolved from modern technology and a need for an effective cosmetic as well as conservative restorative material. Intra-coronal ceramic restorations have the potential to satisfy clinical requirement for conservative tooth reduction and the patient's desire for an esthetically satisfying restorations.

Many techniques in the past have been advocated to improve the adaptation and the marginal discrepancy of the porcelain inlay. However, the inherent shrinkage of the porcelain resulting in a wide cement line around the restoration margins is still a problem to be solved. A new reportedly non-shrinking ceramic material has been introduced to dentisry and has been used as a single unit full coverage restoration. This material, an alumina ceramic (Cerestore, Coors Biomedical Co.) seems to have the potential to be used as an intra-coronal restoration, and may be the solution to the marginal discrepancy problem that has existed over the years with the use of porcelain inlays.

This experiment was designed to compare the new ceramic material to gold alloy restorations as to marginal integrity and internal adaptation to the cavity walls and floors of two different Class II MOD cavity preparation designs. One design conformed to the geometric preparation that is used for gold alloy intra-coronal restorations, the other was a rounded angle preparation which was an experimental design. It was expected that alumina ceramic intra-coronal restorations made with this new technique would exhibit superior marginal integrity as compared to the previous attempts that were done to improve the marginal integrity of the porcelain inlays and to the gold alloy inlays.

CHAPTER II

REVIEW OF THE LITERATURE

The porcelain inlay has been accepted as the most esthetic and durable anterior restoration, however, it has not been adopted widely because of an exacting technique, time consumption, and consequential expense in fabrication (Myerson and Dogon, 1972). Since the introduction of porcelain inlays by Wood in 1862 and the use of the burnished metal matrix by Rollin in 1880, (McGehee, True and Inskipp 1956), numerous techniques have been devised to increase the accuracy of its fit as well as to improve on the simplicity and ease of the fabrication technique. In reviewing the literature, proper laboratory technique as well as proper cavity preparation design appear to be the major concern in the fabrication of ceramic inlays.

A. LABORATORY TECHNIQUES

According to Ernsmere (1900) inlays made from pulverized glass were advocated by Dr. Wilhelm Herbst of Germany in 1882. The method was to make an impression of the cavity preparation in wax and to make two molds in a mixture of plaster and asbestos. A quantity of the prepared glass was placed in the mold and fused. This was accompanied by shrinkage. The inlay was then transferred to the second mold, more glass added, followed by another fusing. Even in this method the results were not altogether unsatisfactory. There was merit in the idea, and it was not long before there were experiments in this field. Ernsmere also mentioned that the first successful fused porcelain inlay and crown were made by Dr. C. H. Land of Detroit in about 1886. A patent was taken out by Land in 1887 covering the method of burnishing platinum foil in order to make a matrix for fusing porcelain with an aid of a gas furnace. Land also tried to use gold foil as a matrix, but found that porcelain used at this time fused at too high temperature for the gold foil. Gold foil was found easier to burnish to shape than platinum foil. It was for this reason that Land experimented to produce a low fusing porcelain which would be compatible with a gold matrix. However, it seemed that Land had little success at arriving at a lower fusing porcelain.

Capon (1927) mentioned that low fusing porcelain was produced successfully by Jenkin of Dresden, Germany, and at the same time in 1900 Brewster of Chicago brought out the medium fusing porcelain. These attempts to lower the firing temperature are attributed to the desire of using gold foil which produces a better matrix adaptation in addition to ease of fabrication of the gold foil matrix.

An interesting phase in fabrication of porcelain in Dentistry was the introduction of casting molten porcelain into a refractory mold. The technique was described by Wain in 1923, and later by Menzies in 1929. The method was said to be similar to the lost wax method used for casting gold.

Sharp (1959) used porcelain in Class III, V and sometimes in Class IV inlays. A closely adapted matrix which was made from dead soft or highly annealed 0.001 inch platinum foil was used. The matrix was adapted well onto the cavity walls and over the margins by using a shaped art gum eraser and ball and wing burnisher. Baking of the porcelain was done in a vacuum furnace. A superior porcelain restoration was obtained that combined strength and esthetics.

Kinzer (1964) used Loma Linda porcelain inlay investment material which is a high refractory investment for fabrication of porcelain inlays. The author claimed that this material offered accurate marginal adaptation and simplicity in its use. It also eliminated the use of platinum foil which contributed to formation of the faulty marginal adaptation and the tedious technique of construction. After the impression of the cavity preparations were taken, a preweighted bag of the investment was mixed with 2.5 ml. of die hardening liquid, the investment applied into the impressions in small increments and vibrated into place. The investment was allowed to set for at least 45 minutes. The obtained refractory die was preheated at 1800°F before the application of porcelain to burn out organic material which would affect condensation and contaminate the porcelain. The die was soaked in water before the first and the second bake of the porcelain to allow porcelain particles to flow into every detail. The inlays obtained by this method were reported to be clinically acceptable.

Charbeneau (1967) studied three types of porcelain investment materials (Myken, Loma Linda and Whip-Mix investment materials). Each varies significantly from the others in its physical properties. A calibrated Barkmeyer porcelain furnace was used. Apco porcelain (fusing temperature, 1875°F) was used in all investments. The investments and the porcelain inlays were inspected with a low power binocular microscope after the successive firings were made. Sixty inlays were fabricated and the accuracy of fit to a stone reference die was studied. In this study, all investments with the exception of Myken frequently adhered to the light bodied mercaptan impression material. Margin and wall defects were thus produced in the investment dies. No detrimental effects were apparent in any of the three investments after preliminary heating to 2000°F. Myken did not demonstrate cracks which occurred in the other investments after the first firing of the porcelain. The Loma Linda investment separated from the inlays with difficulty, whereas the Whip-Mix material was somewhat easier to clean away. Myken investment cleaned away from the porcelain with ease. The fit of the porcelain inlays made from these investments were not clinically acceptable. Loma Linda and Whip-Mix investments resulted in over-sized inlays. However, the Myken investment produced under-sized inlays. The author concluded that the results of this experiment were less than encouraging.

Katayama et al. (1978) used a model of a Class II cavity preparation in the lower first premolar. Porcel porcelain investment material was used to form the dies. Porcelain material was applied and condensed in the cavity preparation by using two methods. One was to use comparatively large quantities of the porcelain to complete the work in one step, the other was to use small quantities of the porcelain in several steps. The adaptation of transverse, longitudinal, horizontal and vertical sections were examined. The authors concluded that, when small quantities of the porcelain were used the adaptation at the inner surfaces was not so good. However, there was good adaptation at the margins. When a large quantity was used, there was poor adaptation at the margins, but good adaptation at the inner surface.

Katayama et al. (1979) compared Porcel (porcelain inlay investment material) with Multi-Vest, Tai-Vest, Uni-Vest and Hi-Vest investment materials as to adaptation of the porcelain inlays. The results of this study showed that Porcel had the lower expansion and the best adaptation, followed by Multi-Vest, Tai-Vest, Uni-Vest and finally Hi-Vest investments. In general, the adaptation of the inlays was poor, however, Porcel investment provided better results as to adaptation and cinical appearance of the inlays.

Illari (1966) presented a simple and effective technique for making improved porcelain inlays to overcome the disadvantage of the platinum matrix. He fabricated a cast matrix by first making an impression of the cavity preparation using an elastomeric impression material. The impression included tooth tissue surrounding the preparations. While holding the impression by the metal tray, molten casting wax was flowed over the impression. The first application of the wax was sufficiently fluid to flow over the cavity margins. Enough wax was applied to make the pattern of the cavity and the surrounding tooth tissue. The wax pattern was sprued, invested, and cast in 24k gold. The casting wax was then immersed in hydrofluoric acid for 10 hours in order to remove any investment material and then washed in running water. Low fusing porcelain was used. Only body and incisal porcelain were used. The porcelain powder was applied and condensed into the casting and fired at 1825°F which is below the melting temperature of the pure gold (1956°F). Additional porcelain was applied to the surface to compensate for the contraction. When the inlays were finished, two methods were used to remove the inlays from the casting matrix; the first method was by immersing the casting and the inlay in aqua regia (3 parts of hydrochloric acid to 1 part of nitric acid). The second method was used when the porcelain inlay contained iridium pins or other reinforcements, the gold was removed by electrolysis. The latter procedure was slow but permitted removal of the gold without affecting the iridium pins. This technique offered a distinct advantage as to adaptation over the existing technique.

Charbeneau (1967) proposed an alternative technique, a reverse platinum matrix technique. Following the impression, a master die of electroformed copper or silver was fabricated over the improved stone. From this master die, which contain the "concave" cavity form, a resin pattern (Duralay) was formed with its margins liberally overextended. A straight pin was attached to the excess acrylic resin to serve as a handle. The Duralay was allowed to set and was separated from the lubricated die. Then the resin pattern was suspended in a mound of improved stone with the handle projecting into the stone. Care was taken to see that the resin extending over the margins was well supported by the stone.

After careful inspection of the pattern, dead soft 0.001 platinum foil was adapted over the convex pattern (the negative cavity duplication). The platinum foil was then covered by sticky wax, a pin was inserted into the wax to serve as a handle, and the matrix was removed from the Duralay pattern. The sticky wax was then eliminated by melting and burning off the residue at a high temperature. Porcelain inlays were then made in these matrices, and then seated in the metal dies. The final inlays were studied under the microscope, and the following conclusions were drawn: first, it was easy to adapt the platinum foil onto the negative die; second, marginal and internal adaptation were improved; and finally, rapid fabrication of the porcelain inlays occurred.

Engen (1968) and Thoma (1972) have used a technique to restore fractured incisal edges of the anterior teeth. Porcelain fused to metal was used so that the porcelain margins appeared labially. In this technique porcelain inlay investment material rather than stone was used as a die material. The technique provided a conservative cavity preparation and accuracy of fit of the restoration.

Droge (1972) developed a new technique, which he termed "the porcelain press technique" which was used to make inlays, onlays, jacket crowns and other dental restorations. The wax pattern for the cavity preparation or any other preparation was made and invested in a flask in the same manner as used for acrylic resin. The wax pattern was boiled out, and the porcelain was applied and condensed until the desired shape was obtained. The porcelain was reduced to make space for transparent and enamel porcelain. The flask was then preheated to 400°C in a preheated furnace to evaporate moisture from the binders. Then the porcelain was fired under vacuum while in the flask. The author claimed to provide an exact marginal seal, accurate insertion, a strong restoration and possibility of repairing the restoration intra-orally.

Vickery and Badinelli (1969) used a castable refractory ceramic die (Ceramico-Die system) which provided accurate reproduction of the impression in polysulfide or other impression materials. The cast obtained from the impression was fired to 1860°F with a temperature rise of 75°F per minute. The firing time ranged from 1 to 2 minutes or from 2 to 3 minutes depending upon the size of the cast. When coated with separating medium, this die may be employed for direct construction of inlays or crowns without the use of platinum foil. All dies used were recovered intact after the above preparations were finished.

Amano et al. (1980) studied the marginal adaptation of porcelain inlays when air and vacuum firing techniques were used. A Class V cavity preparation was prepared in an epoxy model, and the porcelain was applied and condensed by using a corner method, i.e. the porcelain was applied first to the corners of the cavity to insure good adaptation in these areas followed by application of the porcelain on the walls and the rest of the cavity preparation. Baking of porcelain was repeated five times for each group at 900°C. When the temperature reached more than 650°C in the vacuum fired group, the atmospheric pressure in the furnace was kept at 700 mm Hg. Upon completion of the baking, the inlays were seated into their models to examine their adaptation at predetermined points. It was found that adaptation of the vacuum fired inlays to the cavity walls and floors was superior over the air fired specimens.

Christensen et al. (1969) used seven types of porcelain inlay investment materials to measure the internal adaptation of the porcelain inlays. The investments used were; Whip-Mix, Neo-Brillat, Ceramico, Ransom and Randolph, Modified Whip-Mix, Loma Linda and Myken. The porcelain inlays were fired in each die in a low fusing oven. A total of four pounds of load was used to seat the inlays in the prepared lava die. The marginal and the internal adaptation were measured by a microscope and mercury micromeasurement technique. Their results showed that, three brands produced inlays which were over-sized. All of Neo-brillat and Ceramico and 66 per cent of the Ransom and Randolph and the modified Whip-Mix porcelain inlays seated completely. Their marginal and internal adaptation was greater than, but remarkably similar to, cast gold inlays for the same dies. However, the authors concluded that the porcelain inlay's success depended upon the cementing medium because of the dentist's inability to close the margins.

Rogers (1979) introduced a technique to produce a gold matrix for porcelain inlay by using electroplating equipment. The apparatus was divided into two basic units; the control unit and the electroplating tank. The system allowed several tanks to be operated at the same time. In 1980 Rogers used this equipment in fabrication of porcelain inlays (Class III and V). The impression material used were silicone, polyether and vinyl polysiloxane. The impression in the tray was attached to the cathode plate and placed in the electroplating bath. Electroplating of pure gold was continued for three hours to produce an electroform with a thickness of 0.225 mm. The electroform was washed and then placed in a tin electrolyte and plated for thirty seconds. After the porcelain inlays were made, it was found that, the inlays had an accurate fit into the cavity preparations and the porcelain surfaces were free from internal porosity.

B. CAVITY PREPARATION

Black (1908) recommended the porcelain inlay as one of the restorations of choice for Class II upper premolars and upper molars for esthetic reasons and when these teeth were extensively decayed. The cavity preparation recommended for a porcelain inlay was almost the same as for gold, and included the same sequence of steps except that, there should be no bevel on the cavo-surface angles except along the gingival floor. Neither should there by any undercuts or convenience points as for gold foil. The walls should be reasonably parallel to the long axis of the tooth or slightly divergent to allow for withdrawal of the impression material and the insertion of the inlay. The gingival floor and the pulpal floors must be as flat as possible. The isthmus portion must be wide and deep, and the cavity in general must be as long as possible which provided a bulky porcelain inlay restoration.

Johnson (1951), McGehee (1939 and 1956) and Schultz et a. (1966) recommended that the outline of the cavity preparation should not necessarily follow the developmental grooves, or cross any ridges at its highest point, owing to the frailty of the porcelain material. The margins should be extended to points least susceptible to crushing stress and the outline form should not be circular. They also recommended that adequate resistance form was a necessity, and maximum retention form was required in all areas subject to internal stress. The line and point angles should not be sharper or deeper than the adaptation of the matrix will permit. Grooves were permitted in the gingivo-axial line angles and other regions for better seating of the inlays. Surrounding walls should meet the basal wall or seat at a slightly obtuse angle; however, the more nearly parallel these walls are, the greater the retention. For edge strength of the porcelain, the walls should enter the cavity at a right angle to the surface of the tooth. Larger preparation was recommended in the regions of the lateral boundaries to give sufficient space for the material and to resist stress and the cavo-surface angle should be 90°. If a bevel exists, it should be a long bevel which included the full length of the enamel and almost half the length of the dentin. This was to avoid a thin margin and afford strength to the porcelain. In a Class II inlay cavity preparation, the buccal and the lingual margins cannot be in an area where stress is high. If they approach the tip of the cusps, the porcelain will not have sufficient bulk to resist the stress exerted by the forces of mastication. This will sometimes involve extensive removal of cuspal tooth structure and carry the cavity wall over onto buccal and lingual surfaces.

Herbert and Vale (1962) mentioned that porcelain inlays are rarely required for occlusal cavities (Black Class I), they are sometimes desirable in interstitial cavities (Black Class II and Class III), but are most suitable for interstitial cavities in the anterior teeth involving the corners (Black Class IV) and for cervical cavities (Black Class V). Unlike gold, porcelain is a brittle material and will not withstand stresses in thin layers, so that any extention for retention in the form of an occlusal dovetail is not satisfactory. The only situation in which porcelain is called for in these cavities is that of a mesial cavity in an upper premolar. If possible this cavity should be prepared in the wedge form as in gold alloy restorations, the only difference being that, the margins should be perfectly square and should have no bevels.

Mosteller, Well and Johnson (1965) mentioned that, there are several peculiarities in the Class V cavity preparation for a porcelain inlay; (1) the outline form should be free from sharp angles, (2) the preparation must be cut a little deeper than for gold foil to provide better resistance form. The axial wall should be made parallel to the labial or the buccal surfaces of the tooth, (3) the cavity walls must be slightly divergent without any bevels. The completed preparation must be free of any undercuts. The outline form can be best established with a tapered diamond stone to create rounded line angles. The internal line angles are defined with a small mono-angle hoe or angle former, but no undercuts may exist in the completed preparation. The cavity margins are finished with a small Wedelsteadt chisel and the axial wall must be planed with an appropriate size hoe form. After taking the impression, additional retention can be provided in the cavity by placing undercuts. The undercuts can be prepared in the occlusal and the gingival walls by using an inverted cone bur.

Kinzer (1964) used high-heat refractory investment material for porcelain inlay fabrication which eliminated the need for platinum foil adaptation. He suggested that the cavity preparation could be modified to allow for the different technique. The outline form should be a continuous curve without sharp angles, the walls could be slightly divergent without bevels, undercuts or undermined enamel. The preparation could be 1.5 to 2 mm. deep. Thus it is somewhat deeper axially than the preparation for a Class V amalgam or gold foil. A No. 700 tapered fissure bur in a high speed hand piece followed by a low speed hand piece to eliminate any irregularity could be used, and a Wedelsteadt chisel may be used to plane the outline and the margins. The axial walls and the internal line angles could be planed with a small mono-angle hoe.

Smith (1967) recommended that the cavity preparation for a porcelain inlay should meet certain criteria. It should be deeper than for an amalgam or gold foil cavity preparation as it must be as retentive as possible to resist displacement. The low thermal conductivity of the porcelain makes this depth possible without irritation or damage to the pulp. All line angles should be rounded to assist porcelain and platinum foil adaptation. The cavo-surface margin must be free of bevels, since any overhang or thin margin in the fired porcelain tends to fracture when the inlay is seated.

Day (1975), Kinzer (1974) and Brinker (1978) recommended that the cavity outline for a Class V porcelain inlay should have a continuous flowing line with no sharp or abrupt angles, since porcelain material has an inherent tendency to shrink into a spherical mass that pulled away from any angular detail. The extent of the outline is dictated by the extent of the decay. Minimal divergency of the inciso-occlusal wall and the gingival wall provides sufficient retention form. The axial wall should be slightly convex to prevent proximity to the pulp. The depth of the preparation should be more than that for amalgam or resin material. Additional retention can be achieved by drilling parallel channels in the dentin. The channels should be located at the farthest extent of the axial wall mesio-distally to avoid proximity to the pulp.

Myerson and Dogon (1972) used 91 extracted molar teeth and prepared 45 Class I and 46 Class II cavity preparations for porcelian inlays. However, they did not describe the criteria for the cavities. This study was intended to examine the marginal integrity and the retention of the porcelain inlays coupled by a silane treatment to composite resins which were used as cementing media and in turn retained by an undercut. These were compared and evaluated against conventionally restored teeth. These included restorations in teeth with undercuts to be filled with unfilled resin, composite, and porcelain inlays cemented with zinc oxyphosphate cements. The results showed that retention and resistance to marginal penetration and adaptation of the porcelain inlays which were cemented with composite were markedly improved and superior to the other restorations.

C. ALUMINA CERAMIC MATERIAL

Starling et al. (1981) invented a so-called shrink-free ceramic material which they referred to as alumina ceramic to be used for fabrication of dental crowns and other dental restorations. The material is a multiphased mixed oxide system of aluminate. Aluminum oxide is the primary component of the chemical compound. By weight the raw batch of the material consists of at least 50% alpha aluminum oxide, at least 5% magnesium oxide, about 5% to 25% glass frit and about 10% to 15% silicone resin. The latter has a SiO content of at least 50% by weight. From 3% to 5% kaolin provides the flow characteristics of the core material, and an organic lubricant is added to allow the particles to slide during processing. They reported that during firing of the material, most of the magnesium oxide reacts with some of the aluminum oxide to form magnesium aluminate spinel ($MgAl_2O_4$), while the glass frit reacts with the silica from the silicone resin to form a glassy phase. Formation of magnesium aluminate spinel leads to an increase in the volume of the matured ceramic. The increase in volume of the matured ceramic compensates for the shrinkage during the maturing of the relatively porous to substantially non-porous fired monolithic body which usually occurs during maturing of the conventional ceramic bodies. The fired compact is not only non-porous but is characterized by high hardness, wear resistance and by high flexure and compressive strength.

Starling et al. also reported copings of crowns and other dental appliances were formed by using a transfer molding technique. The starting ceramic material was preformed in a disc shape called the raw batch. The ceramic material disc is injected into the cavity left by the wax inside a specially designed three-piece flask. The flask is heated to 180°C, then the pre-formed disc is placed on the top part of the flask at which point a pressure of 1500 psi is applied which forces the softened raw material into the mold cavity. The pressure is maintained for 10 minutes at a temperature of 180°C. After 10 minutes the silicone resin is cured, the mold is disassembled and the coping is then fired. Gradual firing to 1315°C plus or minus 10°C is sufficient for formation of magnesium aluminate spinel. The recommended firing cycle of the raw batch starts at room temperature until 500°C is reached, at a rate of about 150°C/hour, and held at this temperature for about 16 hours. Then the temperature is raised from 500°C to 650°C at a rate of about 150°C/hour, and finally from 650°C to 1315°C at a rate of about 420°C/hour. When the temperature reached 1315°C firing of the coping is completed. Firing of the ceramic material from room temperature to 650°C must be done in an oxidizing atmosphere to allow conversion of SiO to SiO_2. They reported that the fired monolithic body consists of 90% crystalline material and 10% interstitial glass phase. They also reported that the density of the material is about 2.8 g/cc; porosity of only 0.2%; flexural strength of about 17,200 psi; compressive strength of about 72,000 psi; hardness of about 41 on the Rockwell 45 N scale and a coefficient of thermal expansion of about 6.3×10^{-6} mm/mm/°C, with the size and shape substantially identical to the size and shape of the prefired body.

Sozio and Riley (1983) described a direct technique for the construction of an all-ceramic crown that used a reportedly non-shrink ceramic material as a substrate and an aluminous porcelain veneer. The alumina ceramic used in this study was a composition unlike conventional ceramic bodies, which undergo considerable shrinkage when fired. Zero shrinkage is obtained by controlling the time and the temperature of the firing cycle. A special epoxy die material was developed for this technique. The epoxy die is a heat stable material so it withstands a high temperature that is used during mold injecting of the substrate ceramic material. The material is said to have an excellent fit that is generated by direct molding, therefore, the preparation of the tooth must be free from any undercuts that would interfere with the withdrawing of the coping after mold injection. By regulating the time and the temperature the coping can be expanded if necessary. The radio-density of this ceramic material is very similar to that of the enamel so it permits radiographic visualization of what is under the crown. The coping must be veneered with porcelain similar to conventional aluminous porcelain.

D. GOLD INLAY CASTING

Teteruck and Munford (1966) investigated the accuracy of fit of gold alloy restorations onto different tooth preparations, when different materials and techniques were used. They studied the combination of the following alloys and investments; (1) Micro-Bond platinum series alloy and investment, (2) Ney G3 gold and Cristobalite investment, (3) Ney G3 gold and Whip-Mix Hygrotrol investment, (4) Ceramco No. 1 alloy and Whip-Mix Ceramigold investment and (5) Ceramco No. 1 alloy and Ransom-Randolph H.F.G. investment. Four different tooth preparations were used. These were; (1) preparation of a central incisor for cast alloy full coverage, (2) partial tooth preparation (three quarter) of a premolar, (3) preparation of a molar for full coverage cast alloy restoration, and (4) a MOD Bureau of standards preparation that has 1 degree tapered walls. The wax pattern of the MOD was formed by pouring molten wax into a preheated metal sleeve which had been made to fit the die. A constant pressure was applied and maintained during hardening of the wax. All wax patterns were sprued and invested according to the manufacturer's directions. The fabricated castings were examined for gross defects prior to being placed on the dies. A sharp hand instrument was used to remove any small bubbles which could be easily removed. The author concluded that all castings evaluated failed to seat completely. The most superior castings from the stand-point of over all adaptation to the dies were those made with Ceramco No. 1 alloy and Whip-Mix Ceramigold investment. The results obtained with Ney G3 and Cristobalite as well as Ceramco No. 1 and Ransom-Randolph H.F.G. investment were comparable. The data indicated that these investments could produce sufficient expansion to fit the less critical preparations found in clinical practice. The other investments produced the worst results. All MOD castings showed a definite pattern of distortion. The proximal lengths of MOD castings were shorter than the corresponding lengths on the dies, which led to larger open margins at the gingival wall areas.

Custer and Desalvo (1968) investigated nine investment materials: Shiny Brite Cristobalite, Beauty Cast, Hygrotrol, R & R No. 1, Gray Investment, Cristobalite and control powder, Baker Scientific Investment and Healey's Perfected Investment. The purpose was to study the accuracy of fit of MOD cavity preparations as well as Class I and full crown preparations. Type II gold alloy was used for this study. All investments were manipulated according to the manufacturer's directions. Only one die for each type of casting was used throughout the experiment, and all castings of one type were made before the next was started. A total of 232 castings were made. The results obtained were that all MOD castings were slightly undersized. The average distance of failure of the inlays to seat ranged from 0.04 mm. with Hygrotrol to 0.09 mm. with Cristobalite and control Powder. The authors concluded that, whether or not the MOD castings would be clinical failures could not be stated.

Jenkins and Phillips (1971) evaluated five investment materials (Kerr's Cristobalite, Luster Cast, Beauty Cast, Hygrotrol and Ceramigold) with respect to the accuracy of fit of castings possible with these investments. The patterns were prepared on five metal dies which represented a range of conventional-type crown and cavity preparations. They contained a long parallel-wall full crown for a molar, a short tapered-wall full crown for a molar, a three-quarter crown for a premolar, an MOD cavity for a premolar, and a small mesio-occlusal cavity for a premolar. The wax patterns were formed by dipping the warmed and lubricated dies into molten wax. The full crown and the MOD patterns were sprued in the center of the occlusal surfaces. The three-quarter was sprued similarly on the tip of the lingual cusp. The MOD pattern was sprued on the proximal surface. All patterns were sprued with 1.5 mm. orthodontic steel tubing. The water/powder ratio for the Kerr's Cristobalite was 19 ml./50gm., for Luster Cast 15.5 ml./50 gm. was used, for Beauty Cast it was 15 ml./50 gm. With this last investment hygoroscopic expansion was obtained with a water bath at 100°F. The water/powder ratio used with Ceramigold investment was 11 ml. of special liquid to 60 gm. of the powder, and a water bath of 100°F was used for hygroscopic expansion. For Hygrotrol the ratio used was 16 ml./50 gm. with 0.6 ml. of added water and a 100°F water bath. A maximum of 0.05 mm. of marginal discrepancy was classified as being clinically acceptable for castings. The results of this study showed that Ceramigold investments produced castings for all 5 preparations that had a mean value discrepancy of less than 0.05 mm. However, with Luster Cast the MOD castings showed a mean discrepancy of 0.07 mm. on the occlusal keyway. Statistically there was no difference in fit of the MOD castings made with the various investments.

CHAPTER III

MATERIALS AND METHODS

A. CAVITY PREPARATION

Two different designs of Class II MOD cavity preparations were prepared in maxillary first molar ivorine teeth. The first cavity design was the geometric design which is characterized by sharp point and line angles, all walls were slightly divergent to nearly parallel. The isthmus width was about 1/3 of the intercuspal distance. The pulpal and the gingival floors were flat and axio-pulpal line angles were sharp. The occlusal depth was about 2 mm. The outline of the cavity included all grooves so that buccal lingual extensions of the occlusal surfaces were prepared to simulate a clinical situation. The buccal and the lingual walls of the occlusal portion were connected to the buccal and the lingual walls of the proximal boxes so that no angles were prepared. The experimental design was characterized by rounded point and line angles and rounded axio-pulpal line angles. The pulpal and the gingival floors were slightly curved (concave). All other characteristics of this design were similar to the geometric design. The cavity preparations of both designs were prepared so that no bevels existed at the cavo-surface line angles (Fig. 1).

Instruments

The instruments used in this study include: 1158 Dome shaped bur, 15-15-3 Wedelsteadt chisel, 74/75 Spoon excavator, 6½-2½-4 Hoe monoangle, 4-5 Discoid chisel and 10-6-14 Hatchet.

From the above two teeth, 60 epoxy models were prepared by Columbia Dentoform*, 30 models for each. The 60 models were divided into 4 groups; Group I - 15 geometric for gold alloy inlays, Group II - 15 rounded designs for gold inlays, Group III - 15 geometric for ceramic inlays and Group IV - 15 rounded designs for the ceramic inlays.

B. IMPRESSION

Equal length of base and catalyst of vinyl polysiloxane impression material ** were applied on a clean plastic pad and mixed following the manufacturer's directions. Small plastic tubes of about ½ of an inch in diameter and 1 inch long were used as trays. The inside of the tube was coated with the adhesive which was provided with the impression material. The impression material was applied first to the critical areas of the cavity preparations with a syringe. The models with the impression were embedded into the tubes that were full of the impression material. About 3/4 of the total length of the models were embedded in the impression material. After 10 minutes from the start of mixing any excess of impression material was removed with a No. 12 laboratory knife. At this stage all of the impressions and their corresponding models were numbered for later identification. The models were separated carefully from the impressions (Fig. 2). Any impression with a defect was repeated. All

* Columbia Dentoform 49 East 21st. St. New York, N.Y. 10010
** Cinch-Vinyl, No. S435. Parkell, Bio-Materials Division. Farmingdale, N.Y. 11735.

impressions were sprayed with one coat of Epoxy die separator*, gently air dried, and then poured 60 minutes later. Permanent mending tape** was applied around the impression end of the plastic tubes to provide sufficient base thickness to the dies.

C. GOLD CASTING

Groups I and II of 15 geometric and rounded angles designs were used for gold alloy inlays. Vel Mix stone*** was used for making the dies for the gold casting. A water powder ratio of 24 ml./100gm. was used, and the material was mixed in a new bowl with a clean metal spatula. The mixture was totally spatulated and the bowl was placed on the vibrator to eliminate the air bubbles. When the mixture was homogenous and had a smooth texture, a small camel-hair brush was used to apply the stone into the critical areas of the impression. With a spatula the stone was carried in increments to fill the rest of the impression under vibration. The stone was allowed to set over night before separation of the dies from the impressions. Dies with any defects were remade in a new impression.

Die spacer**** was used to coat the internal walls of the stone die. Two thin coats were applied to the walls except about ½ mm. below the cavo-surface margins of the buccal and the lingual walls as well as the gingival floors which were left clean from the die spacer. The die

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* Cerestore Epoxy Die Separator, Coors Bio-Medical Co. Lakewood, Colo.
** Scotch Tape 3M St. Paul, MN. 55144
*** Sybron/Kerr Romulus, Michigan 48174
**** Pactra Industries Inc., Los Angeles, CA. 90028

spacer was allowed to set for about an hour then die lubricant* was applied with a small camel-hair brush and air-dried.

1. Wax Pattern

Blue inlay casting wax** was used to form the wax pattern. A No. 7 wax spatula and No. 2 Thomas waxing instrument were used to insure good adaptation of the wax against the cavity walls. The wax patterns were inspected visually for any marginal discrepancy, and any correction needed was done at this time. A 12 guage wax sprue** was attached to the mesial marginal ridge and angled at 45° to the horizontal plane. The wax was then allowed to cool and additional wax was added at the junction of the sprue to the wax patterns, allowing a flaring of the opening to the mold. The wax patterns were carefully removed from the dies and the sprues were attached to the crucible former using inlay wax. Additional wax was added at this junction to help direct the gold flow. The patterns were positioned at about 8 mm. from the top of the crucible former. Two wax patterns were attached to each crucible former (Fig. 3).

2. Investing

The casting rings were lined with a single layer of liner.*** . The liner met end to end and was adapted on the inner side of the rings and was maintained in place by sticky wax. The rings were immersed in water for 15 seconds at room temperature to wet the liner. Wax pattern

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* Jelenko, Die Separator Lubricant, 99 Business Pk. Dr. Armonk, N.Y. 10504

** Sybron/Kerr, Emeryville, CA. 94608

*** Flask Liner, Sybron/Kerr Romulus, Michigan 48174 cleaner* was used to clean the pattern from any dirt or residue from the die lubricant, and rinsed with room temperature water and air dried. The rings and the crucible former were carefully assembled and placed in the cover of the vacuum mixer.

Preweighted Luster Cast investment** was used with a water powder ratio of 16 ml./50gm. Tap water was measured by a graduate cylinder. A metal spatula and a clean dry bowl were used to first mix the investment manually until all powder was mixed into the water, then vacuum mixed for about 25 seconds. The bowl was then placed upright on the vibrator to concentrate the mixture at the bottom, and the bowl was then tipped on its side with the ring in a down position to vibrate the mixture into the casting ring. The rings were removed from the bowl cover and any needed additional investment was added with a metal spatula. The rings were placed on the bench away from any vibration for 45 minutes. Then the crucible former was carefully separated from the ring and the investment was examined for defects.

3. Wax Elimination and Heating

An electrical burn-out oven was used. The oven was preheated to 600°F and the rings were placed in the oven so that the sprue holes were down and the oven temperature was advanced to 1250°F. After the oven reached this temperature the burn out and heating was continued for about

* J.F. Jelenko & Co. New Rochelle, N.Y. 10801
** Sybron/Kerr Romulus, Michigan 48174

20 minutes. Total burn out and heating was approximately one hour. At the end of one hour period the rings were inverted in order to have the sprue holes up.

4. Casting

Type III gold alloy* and centrifugal casting machine were used. Three counterturns were used to spring load the arm of the centrifugal machine. An air-gas torch was adjusted to develop a conventional casting flame with a reducing zone. The reducing zone is in between the slightly greenish combustion zone and the outer or oxidizing zone. The area near the tip of the reducing zone was used to melt the gold alloy. The crucible was heated for about two minutes, then 4 dwt. of alloy were laid in the crucible and the reducing zone of the flame was directed onto the alloy. When the alloy started to slide down to the bottom of the crucible, the ring was brought from the furnace and securely placed in the casting cradle. As the alloy began to liquify a small amount of borax flux** was sprinkled onto the alloy. When the alloy became fluid and light orange in color, and tended to spin as it responded to slight movement of the flame, the casting was made. The machine was allowed to stop on its own, and the ring was placed on the bench for about ½ minute before quenching. Any remaining investment was then brushed from the castings. All castings were pickled in 50 per cent hydrochloric acid for about 2 minutes and then removed by plastic tongs and scrubbed under

* Firmilay, Jelenko Co. 99 Business Park Drive, Armonk, N.Y. 10504

** Reducing Flux. Jelenko & Co., 99 Business Park Drive. Armonk, N.Y. 10504 running water.

The castings were separated from the sprues by scoring with a carborundum disc in a straight hand piece followed by a side cutter. Any casting with a defect was remade. All inlay castings were seated in their corresponding epoxy models.

D. ALUMINA CERAMIC INLAYS

The remaining 30 models (15 geometric and 15 rounded angles designs) were used for fabrication of ceramic inlays. The dies for these groups were made from special epoxy material.* Pre-measured epoxy liquid and powder in sealed plastic package was used. The plastic clamp that separated the liquid "A" and the powder "B" was removed and mixed with a special roller provided by the manufacturer. Mixing was continued until all powder was dissolved in the liquid, this can be seen by direct visualization through the transparent plastic package. Mixing did not exceed five minutes. The epoxy mixture was then pushed to one end of the package, and the empty end was cut with a scissors. Catalyst (70 μl) was measured with a microliter syringe and mixed with the epoxy mixture for about 30 seconds with a metal cement spatula. The mixture was then poured in a plastic container and placed in a vacuum dessicator to eliminate air bubbles. Evacuation was completed when the liquid mixture raised, broke and fell. Vacuum was maintained for 10 seconds after the liquid fell and then

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* Cerestore, Coor Biomedical Co., Lakewood, Colo.

was considered ready for pouring into the impression.

A No. 3 plastic bristle brush was used to apply the epoxy mixture onto the critical areas of the impression. The remainder was poured very slowly. The working time of the mixture did not exceed 10 minutes from the time of addition of the catalyst. The epoxy dies were allowed to cure at room temperature for a minimum of six hours, then they were carefully separated from the impressions. Any damaged or defective dies were rejected, and replaced. The epoxy dies were placed in an oven at room temperature and post cured for two hours at 160°C (320 F).

One layer of release film* was applied to the dies. The margins as well as the gingival floors were left clean from the release film. Then the dies were placed in the oven at 160°C for one minute. Next, one layer of die-spacer was applied in the same manner as was the release film, and the dies were placed in the oven at 160°C for five minutes. Die-Sep lubricant was applied and carefully air-dried (Fig. 4).

1. Waxing

The same procedure was followed as with the gold alloy except that the wax patterns were extended to the cavo-surface margins to within 1 mm. of the occlusal and the proximal surfaces. A U shaped wax sprue (12 gauge) was used to sprue the wax patterns (Fig. 4). The sprues were attached to

* Cerestore system, Coors Biomedical, Lakewood, Colo.

the mesial and the distal portions of the patterns away from the margins. A 12 gauge wax sprue was attached at the highest point of the U Shaped sprue to form the main sprue. All wax patterns were slightly removed from the dies and then reseated to insure that no undercut was created by the die spacer which could interfere with the removal of the ceramic copings after mold injection of the ceramic material.

2. Investing

Investing of the copings was done while the wax patterns were seated on the epoxy dies. A hard die stone* was mixed with water to a thin mix and a few drops of separating medium supplied by the manufacturer were dropped in the mixture. With a plastic brush a layer of 1 mm. of the mixture was applied on the wax patterns and sprues and about 5 mm. below the cavity margins on the epoxy dies. The stone was allowed to set for about ½ hour. The whole unit at this time is called a stucco (Fig. 5). The stucco was then positioned on a base plate with putty.* The base part of a specially designed three-piece flask* was set over the stucco and the sprue was centered in the flask base opening. The top of the coping was placed approximately 5 mm. below the top of the flask base. A thin mix of laboratory plaster** was used for investing the stucco (Fig. 6). After 30 minutes from the start of mixing the plaster, the excess

* Cerestore system, Coors Biomedical, Lakewood, Colo.

** Powderey No. 1. Fast set plaster. Lance Gypsum and Lime. 4225 Ogden Avenue Chicago, Ill. 60623 plaster and the sprues were trimmed flush with the top of the flask base by a Buffalo Plaster Knife No. 12 (Fig. 7). The putty was removed from the bottom of the flask and was ready for wax elimination. Wax was eliminated from the base of the flask by clean boiling water for about 5 minutes. A medicine dropper was used to aid in elimination of the wax under pressure, and then the cavity was air-dried. The flask base was cleaned from any plaster or dust.

3. Heating and Mold Injection

A Thermolyne oven* (Fig. 8) was preheated to a temperature of 180°C for a minimum of 90 minutes. The flask bases and tops were placed in the oven in the following arrangement; the flask base inserted bottom down and the flask top inserted top down. Two ovens were used and two flasks were placed in each oven and arranged as shown in (Fig. 9). The heating was maintained for 60 minutes at 180°C. At the end of 60 minutes the flask top and base were assembled by using a large clamp and a raw batch disc of alumina ceramic was placed in the flask top opening. The cold plunger (the third piece of the flask) was then placed into the opening (Fig. 10). The assembly was then placed on the base of the press machine* and slid against and between the two vertical positioning pins. The plunger was aligned to slide into the cut-out of the press push rod head. The press was actuated by pulling out the knob, and then a maximum of 100 psi. pressure was applied at 180°C for 10 minutes. At this

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* Cerestore system. Coors Biomedical; Lakewood, Colo.

pressure and temperature the ceramic disc melted and flowed into the mold. The pressure was then released and the flask assembly was removed from the press base. The base and the top were separated and the flask base was placed inside a plastic dipper and filled with hot water and kept for about 2 minutes or until the air bubbles that were coming from the investment stopped. Then the flask was cooled in running water for approximately 30 seconds.

The conical shaped plaster in the flask base was carefully separated by light finger pressure applied to the top end of the plaster (Fig. 11). The plaster was carefully removed by light finger pressure and the hard stone was separated with a small laboratory knife. The ceramic copings were washed and dried. At this time the coping is considered to be in a green stage (Fig. 12). With a gentle axial motion all copings were withdrawn from their dies and inspected for any damages or defects. Any damaged or defective coping was rejected and another one was made.

4. Coping Firing Procedure

A programmable furnace* was used (Fig. 13). The copings were placed on a 2 x 2 inch ceramic plate and arranged in the same manner as their corresponding dies that were arranged on the bench. Enough space between the copings was provided as recommended by the manufacturer. The copings were then inserted in the muffle at room temperature and placed on a ceramic ring. The removable muffle door was replaced. The program was

* Cerestore system. Coors Biomedical; Lakewood, Colo.

set-up as described in Figure 14, by adjusting the time and the temperature which is read directly on a digital display. A peak temperature of 1296°C was reached and 11.5 hours total time was used. A maximum of 8 copings were fired at one time. After the firing was completed, the sprues were separated from the copings by using a small round diamond in a slow speed hand piece.

The copings were initially seated into their corresponding dies. Any interferring point or area was marked by using an indicator*. A thin coat of the indicator was painted on the entire cavity surfaces of the dies and carefully dried. Then the copings were gently seated and any marked area was ground. A combination of rounded and tapered shaped diamond stones were used in a slow speed hand piece.

E. EXAMINATION

Marginal adaptation of the gold alloy and the ceramic inlays was examined visually and by means of an explorer and stereo microscope** (magnification X30), for any open margins or marginal discrepancy.

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* Liqua-Mark, The Wilkinson Company

** Model 655, American Optical, Buffalo, N.Y. 14217

CHAPTER IV

RESULTS

Gold Alloy Inlays

Twenty two gold alloy inlay castings out of thirty seated completely, including twelve geometric and ten rounded angle designs. The other eight castings; five rounded and three geometric designs were shorter than the corresponding lengths of their dies at the proximal portions. The areas of interference were the axio-pulpal line angles and approximately 1 mm. below these angles at the axial walls. After slight grinding of the unseated castings at the axial walls, all eight inlays were seated (Fig. 15). Marginal openings of seven MOD inlays were detected by explorer and the optical microscope at the gingival margins (Fig. 16).

Alumina Ceramic Inlays

All ceramic, rounded and geometric inlays were completely seated at the green stage after mold injection of the ceramic material. The following results were obtained after firing of the ceramic inlays: all alumina ceramic inlays failed to seat completely (Figs. 17 and 18). From slight to extensive grinding of the inner surfaces was carried-out to seat the inlays. Two ceramic inlays fractured after the firing cycle, one geometric and one rounded angle design. The fracture line extended from the occlusal surface to the pulpal surface of the copings in the bucco-lingual direction and at the occlusal portions of the copings.

Eight rounded angle design inlays were slightly ground on the buccal, lingual and the axial walls of the proximal boxes. The restorations were then seated. Areas of open margins were detected visually and by explorer at the buccal and lingual extensions of the occlusal portions of three inlays. Open margins at the gingival seat areas were found in five inlays.

Two ceramic, rounded angle design inlays, were moderately ground on buccal, lingual and the axial walls of the proximal boxes. The buccal and the lingual extensions of the occlusal portions were slightly ground. Open margins at the buccal and lingual walls of the occlusal portions were detected visually and by explorer in the two inlays. The restorations were then seated in their corresponding models.

Three ceramic, rounded angle design inlays were extensively ground on all surfaces except the pulpal and the gingival floors. Two out of three did not seat completely. Open margins were found at the gingival margins and the occlusal portion of the seated inlay.

One ceramic, rounded angle design inlay fractured. The fracture line was observed immediately after the coping was removed from the muffle. The fracture line was mesial to the buccal extension of the occlusal portion.

Ten ceramic geometric design inlays were slightly ground on the buccal, lingual and the axial walls of the proximal boxes. Margins were open in seven of them at the buccal and the lingual extension of the occlusal portions as well as the gingival seat areas (Fig. 19). All of these inlays were seated.

One ceramic, geometric design inlay, was slightly to mederately ground on the buccal, lingual and the axial walls of the proximal boxes and on the buccal and the lingual extensions of the occlusal portion.

One ceramic, geometric design inlay, was extensively ground on all walls except the gingival and the pulpal floors. The inlay did not seat completely.

After the firing cycle, one ceramic geometric design inlay, was found fractured at the junction of the mesial box and the occlusal portion of the inlay.

Three ceramic inlays; two geometric and one rounded design were ground on all surfaces except the buccal walls of the mesial boxes and the lingual walls of the distal boxes as well as the pulpal and the gingival floors.

TABLE I

DEGREE OF GRINDING OF THE CERAMIC INLAYS

Amount of Grinding	Geometric Design	Rounded Angle Design
Slight	10 Copings	8 Copings
Moderate	1 Coping	2 Copings
Extensive	3 Copings	4 Copings

TABLE II

NUMBER OF THE SURFACES OF THE CERAMIC INLAYS THAT NEEDED GRINDING

Cavity Design	No. of Inlays	No. of Surfaces
Rounded Design	9 Copings	6 Surfaces
Rounded Design	5 Copings	8 Surfaces
Geometric Design	12 Copings	6 Surfaces
Geometric Design	2 Copings	8 Surfaces

TABLE III Comparison of the Results of Both Ceramic and Gold Alloy Inlays

	Fit	Marginal Adaptation Open Margins After Grinding Occlusal	 Proximal	Success - Failure
Gold Alloy Inlays	15 Castings			12 Clinically Acceptable
Group I geometric	12 - seated 3 - ground then seated	15 castings no open margins	15 castings 3 - open 12 - closed margins	3 Clinically Unacceptable
Group II Rounded Angle	15 Castings 10 - seated 5 - ground then seated	15 castings no open margins	15 castings 4 open margins 11 closed margins	11 Clinically Acceptable 4 Clinically Unacceptable
Ceramic Inlays Group III Geometric	15 Copings 14-not seated 1-fractured	15 copings 11 open 1-fracture 3-close margins*	15 copings 11-open 1-fracture 3-closed margins*	2 Clinically acceptable 13 Clinically Unacceptable
Group IV Rounded Angle	15 Copings 14-not seated 1-fractured	15 Copings 7-open 1 fractured 7 closed	15 Copings 8-open 1-fractured 6 closed margins	3 - Clinically Acceptable 12 - Clinically Unacceptable

* The three copings are not corresponding

CHAPTER V

DISCUSSION

The results of this study showed that ten rounded angle designs and twelve geometric design gold alloy castings seated completely. The other eight castings; five rounded design and three geometric design were seated after slight grinding of the inner surfaces. There was no apparent difference between the two cavity preparation designs. This was not unexpected since one could expect that the gold alloy casting is almost an exact duplication of its wax pattern. However, it was not expected to find open margins at the gingival areas since the technique used in this study should provide accurate marginal fit of intra-coronal restorations. It has been reported in the literature (Jenkins and Phillips 1971) that MOD castings had the largest discrepancy in the occlusal keyway involving the buccal and the lingual margins of the occlusal portion of the restorations when Luster Cast investment material was used. This is in disagreement with the results of this experiment, since accurate fit of the occlusal margins was obtained when examined visually, by explorer and under optical microscope.

Christensen (1966) reported that all margins of MOD overlays were microscopically open before beginning of the finishing procedures. Gingival margins were reported to have the largest discrepancy when compared to the proximal and the occlusal margins. The author recommended that all margins must be finished in order to close these margins. It appears that he was expecting to find open margins, therefore, he proposed a procedure to minimize the marginal discrepancies. In this study, it was not intended to finish any open margins, and no attempt was made to minimize the discrepancy which was found at the gingival seat areas only.

Teteruch and Mumford (1966) found that all MOD castings failed to seat completely. The castings generally showed binding between the axio-pulpal line angles in a mesio-distal direction. A definite pattern of distortion was noted on all MOD castings. Spaces were noted also at the gingival seat, the occlusal end in a bucco-lingual direction and at the proximal surfaces along the walls near the gingival seat. They reported that the space formation may have been due to a stretching of the wax in a mesio-distal direction and shrinkage in directions at right angle to this. It seemed conceivable to them that this same effect could possibly occur during the shrinkage of the alloy in the mold. They also reported that all MOD castings were shorter in their proximal length than the corresponding distances on the dies, no explanation was given for this. The results of this study disagree with their findings in that open margins at the gingival seat were found. This could be due to the insufficient expansion of the investment in the occluso-gingival direction to compensate for the thermal contraction of the alloy. The water/powder ratio and the heating temperature could also be factors in such distortion, since the strength of the investment is affected by these factors, the stronger investment tends to restrict the alloy and produce a distortion

(Phillips 1982). Distortion of the wax pattern during the hardening of the investment could be considered as another factor.

All alumina ceramic inlays were accurately seated after direct molding. This was not unexpected because of the fact that the ceramic material was injected directly to the epoxy dies with a temperature of 180°C and pressure of 100 psi. The flowing of the ceramic material resulted in clinically acceptable marginal adaptation when examined visually and by explorer. All line and point angles as well as the walls and the floors of the ceramic restorations were carefully examined at this time (the green phase of the ceramic material) and were found complete. It appears that the copings fit accurately into the cavity preparations when seated and withdrawn several times and no distortion could be detected at this stage. Therefore, it seems there was no difference in the marginal integrity and the adaptation between the geometric and the rounded angle restoration designs prior to the firing procedure.

After the firing procedure, all ceramic restorations failed to seat in their corresponding dies. The definite pattern of grinding of the restorations indicates that expansion of the ceramic material occurs during the firing schedule. It has been reported in the literature (Starling et al. 1981) that the magnesium aluminate spinel formed during the firing procedure tends to occupy the greater volume of the ceramic material. This increase in volume of the ceramic material compensates for the decrease in volume due to the shrinkage of the ceramic material during firing schedule. They also reported that the longer the time and the higher the temperature of the firing schedule the more spinels are formed and the volume increases. In this study, twenty-five ceramic restorations were slightly to extensively ground on all surfaces of the proximal boxes. This aspect of the inlays contained the largest mass of the ceramic material. However, seven inlays were ground on the occlusal portion which contained a smaller mass of the ceramic material. Therefore, it appears that the larger volume of the ceramic material has more spinel formation and thus more expansion resulted. It seems that the firing schedule used in this study was high enough to form more spinel than was needed to compensate for the shrinkage that took place. This resulted in more expansion of the ceramic copings. The open margins of the inlays at the occlusal portions and the large open margins at the proximal portion of the three copings could be due to distortion of the inlays during the firing procedure. This could be due to sliding of the ceramic fillers at a high temperature that led to slight changing in the configuration of the copings.

Sozio and Riley (1983) used the same alumina ceramic material in fabrication of an extra-coronal restorations and reported that an excellent fit was obtained. However, the authors did not provide any numerical data or criteria to establish fit. It is clear that the nature of this experiment is different from theirs since the expansion of the ceramic material is adventageous to a degree and permits an easier fit of the extra-coronal restorations, however, expansion of the ceramic inlay counteracts the fit and prevents seating of the wedge shaped inlay.

In this study the firing temperature used and recommended by the manufacturer was 7°C below the firing temperature used for extra-coronal restorations. It appears that further modification of the firing schedule is needed, so that a lower peak temperature as well as less time at this peak temperature should be used. However, the new firing schedule must be high enough to prevent shrinkage of the ceramic copings. Therefore, it seems conceivable that a peak temperature of 10°C to 15°C below the firing temperature used in this study could result in complete seating of the inlays and possibly a more accurate fit of the restorations. Modification of the technique can be done by applying a few more layers of die spacer so that more space will be provided between the wax patterns and the cavity walls. The size and shape of the restoration could be another factor that resulted in such failure. However, no modifications are suggested, because they would not serve the objective of conservation of tooth structure during cavity preparation.

On the basis of the above observations, it appears that porcelain inlays which have been reported to have marginal discrepancies as low as 15μ (Christensen and Brown 1968), still maintain superiority over the alumina ceramic inlays. Accurate marginal seal and clinically acceptable adaptation of porcelain inlays have been reported by (Chabeneau, 1967, Kinzer, 1974, Illari, 1966 and Droge, 1972). The results of this study showed unacceptable marginal discrepancies. As such the inlays were not cemented and SEM observation was not used.

A review of the results are that the gold castings were superior over the ceramic restorations as far as seating is concerned. The firing schedule appears to be an important factor that may have resulted in incomplete seating of the ceramic restorations. No difference can be observed between the geometric and the rounded angle designs for both castings and the ceramic restorations.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Two different Class II MOD cavity designs, a geometric and a rounded angle design, were prepared in two ivorine teeth. Thirty epoxy models for each cavity design were formed. The 60 models were divided into 4 groups; group I geometric design for gold alloy inlay; group II rounded angle design for gold alloy inlay; group III geometric design for ceramic inlay and group IV rounded angle design for ceramic inlays. The technique used to fabricate the ceramic inlays was evaluated. The marginal discrepancy and the internal adaptation of all inlays were evaluated and compared by the methods that are commonly accepted, clinically and by the optical microscope. All ceramic inlays failed to seat, from slight to extensive grinding needed to be carried out to seat the inlays. Twenty-two gold castings seated and eight castings seated after minor adjustment. Open margins at the gingival seat were observed in some of the castings.

Conclusion

1. No differences between the geometric and the rounded angle ceramic restorations can be found at the green stage after direct molding of the ceramic material onto the dies.
2. After the firing schedule, all ceramic inlays failed to seat. A modification of the technique to control the size and shape of the

ceramic inlays is needed. Further study is suggested, and emphasis should be placed on the firing schedule.

3. Based on the results of this study, gold alloy cast restorations of both cavity preparation designs showed superiority over the ceramic restorations made following the method described.

BIBLIOGRAPHY

Amano, Y., et al.: The Studies on the Adaptation of Aluminox Procelian Inlay. Bull. Josai. Univ., 9:55-59, 1980.

Barnes, I.E.: Replica Models for the Scanning Electron Microscope. Brit. Dent. J., 133:337-342, 1972.

Baum, L., Phillips, R.W. and Lund, M.R.: Textbook of Operative Dentistry: Cast Gold Restorations: Laboratory Procedure. Philadelphia, W.B. Saunders Co., pp. 456-500, 1981.

Baum, L.: Advanced Restorative Dentistry: Intermediary Base and Cementation. Philadelphia, W.B. Saunders Co., pp. 59-72, 1973.

Black, G.V.: A Textbook of Operative Dentistry: Volume II, Porcelain and Gold Inlays, pp. 330-337, 1908.

Brinker, H.A.: Simplified Porcelain Inlays. J. Prosth. Dent., 40:44-49, 1978.

Capon, W.A.: "Porcelain - its properties". JADA 14. 8. 1459, 1927.

Charbeneau, G.T.: An Evaluation of Porcelain Inlay Investment Materials and a Reverse Platinum Matrix Technic. JADA, 75:142-146, 1967.

Christensen, G.J., Brown, T.A. and Babb, R.: Accuracy of Fit of Direc-Firing Porcelain Inlays. J. Prosth. Dent., 46:198, 1968, (Abst.).

Christensen, G.T., Brown, T.A. and Babb, R.: Accuracy of Fit of Direct-Firing Porcelain Inlays. J. Prosth. Dent., 22:46-53, 1969.

Christensen, G.J.: Marginal Fit of Gold Inlay Casting. J. Prosth. Dent. 16: 297-305, 1966.

Combe, E.C. and Grant, A.A.: The Selection and Properties of Materials for Dental Practice. Two Dental cements and Fissure sealants. Brit. Dent. J., 138:58-60, 1973.

Custer, F. and DeSalvo, J.: The Accuracy of Casting Produced by Various Investments. J. Prosth. Dent., 19:273-280, 1968.

Day, J.A.: Porcelain is a Basic Restorative Material. Dental Student, 53:36-7.55, 1975.

Dennison, J.D. and Powers, J.M.: A Review of Dental Cements Used for Permanent Retention of Restoration. Journal of the Michigan Dental Association, 56:116-125, 1974.

Despain, R.R., Lloyd, B.A. and Brown, W.S.: Scanning Electron Microscope Investigation of Cracks in Teeth Through Replication. JADA, 81:580-584, 1974.

Droge, G.G.J.: The Porcelain Press Technique, J. Prosth. Dent., 28:209-214, 1972.

Eames, et al.: Proportioning and Mixing of Cements: A Comparison of Working Times. Operative Dentistry, 2:97-104, 1977.

Eames, et al.: Techniques to Improve the Seating of Castings. JADA, 96:432-437, 1978.

Engen, D.W.: Porcelain Fused to Gold Inlay for Restoration of Incisal Angles. JADA, 77:84-87, 1968.

Ernsmere, J.B.: Porcelain Dental Work. Brit. J. Dent. Sci. 43:547, 1900.

Franco, S.J. and Kelaey, W.P.: Evaluation of a Technique Alloy for use in Teaching Intra-coronal Cast Gold Procedure. Journal of Dental Education, 44:642-644, 1981.

Fusayama, T., et al.: Cement Thickness Between Cast Restorations and Preparation Walls. J. Prosth. Dent., 13:354-364, 1963.

Fusayama, T., Kimiko, I. and Itiroyasu, H.: Relief of Resistance of Cement of Full Cast Crowns. J. Prosth. Dent., 14:95-106, 1964.

Going, R.E. and Mitchen, J.C.: Cements for Permanent Luting: A Summarizing Review. JADA, 19:107-117, 1975.

Herbert, W.E. and Vale, W.A.: Porcelain Inlay: Operative Dental Surgery, 8th. Edition. PP 210-332, 1962.

Howard, R.J., et al.: Intra-coronal Pressure During Crown Cementation. J. Prosth. Dent., 40:520-525, 1978.

Illari, R.E.E.: Cast Matrix for Porcelain Inlays. J. Prosth. Dent., 16:766-771, 1966.

Iwaku, M., Takatsu, T. and Fusayama, T.: Comparison of Three Luting Agents. J. Prosth. Dent., 43:423-425, 1980.

Jacobsen, P.H. and Von Fraunhofer, J.A.: Assessment of Micro-Leakage Using a Conductimeter. J.Prosth. Dent., 54:41-48, 1980.

Jenkins, C.B.G. and Phillips, R.W.: An Evaluation of Five Inlay Investing Techniques Employed with Different Types of Wax Patterns. J. Prosth. Dent., 25:211-220, 1971.

Jepson, S.G., Jampieson, S. and Johnson, C.: Porcelain Inlays Serve Function, Esthetics. Dental Student, 54:37-38,42,48, 1976.

Johnson, I.C.N.: A Textbook of Operative Dentistry; Chapter XV, Preparation of Cavities for Inlays, pp. 271-280, 1915.

Jones, D.: Ceramics in Dentistry. Dental Technique, 6:55-60, 1971.

Jorgensen, K.D.: Factors Affecting the Film Thickness of Zinc Phosphate Cements. Acta. Odont. Scand., 18:474-490, 1960.

Jorgensen, K.D. and Peterson, G.F.: The Grain Size of Zinc Phosphate Cements. Acta. Odont. Scand., 21:255-270, 1963.

Jorgensen, K.D. and Shimokobe, H.: Adaptation of Resinous Restorative Materials to Acid Etched Enamel Surface. Scand. J. Dent. Res., 83:31-36, 1975.

Katayama, I., et al.: Adaptation of Class II Procelain Inlay with Various Direct by Fired Investments. Bull. Josai Dent. Univ., 8:65-70, 1979.

Katayama, I., et al.: Adaptation of the Porcelain Inlay, Especially in Class II Cavities. Bull. Josai Dent. Univ., 7:105-111, 1978.

Kaufman, E.G., et al.: Factors Influencing the Retention of Cemented Gold Casting: The Cementing Medium. J. Prosth. Dent., 16:731-739, 1966.

Kinzer, R.L.: Porcelain Inlays Fabrication with a New High Heat Refractory Investment. J. Prosth. Dent., 14:980-989, 1964.

Kinzer, R.L.: Porcelain Inlays Utilizing Retentive Pins. Journal of Indiana Dental Association, 53:8-10, 1974.

Knight, T.: The Marginal Adaptation of Gold Castings: A Scanning Electron Microscope Study. Journal of DASA, pp. 51-59, 1975.

Koyano, E., Iwaku, M., and Fusayama, T.: Pressuring Technique and Cement Thickness for Cast Restoration. J. Prosth. Dent., 40:544-548, 1978.

Long, H.K., et al.: Method for Evaluation the Margins of Cast Intracoronal Restorations. Quintessene International, 5:31-36, 1979.

Megehee, W.H.O.: A Textbook of Operative Dentistry: Chapter XXII, Ceramics - The Porcelain Inlay - Construction the Matrix - Composition and Characteristics of Porcelain. pp. 623-648, 1939.

Megehee, W.H.O., True, H.A., and Inskipp, E.F.: A Textbook of Operative Dentistry, The Porcelian Inlay and The Acrylic Inlay. pp. 498-521, 1956.

Menzies, C.: Porcelain Casting. Br. Dent. J. 50:838, 1929.

Mitchen, J.C. and Gronas, D.G.: Continued Evaluation of the Clinical Solubility of Luting Cements. J. Prosth. Dent., 45:289-291, 1981.

Mjor, I.A. and Espevik, S.: Assessment of Variables in Clinical Studies of Amalgam Restorations. J. Dent. Res., 59:1511-1515, 1980.

Mjor, I.A. and Ryge, G.: Comparison of Technique for the Evaluation of Marginal Adaptation of Amalgam Restoration. Int. Dent. J., 31:1-5, 1981.

Mosteller, J.H., Wells, H.R., and Johnsons, D.L.: Clinical and Laboratory Procedures for Class V Porcelain Inlays. The Journal of Alabama Dental Association, 49:27-37, 1965.

Muller, H.J.: Electron Microscope Sample: Replication Using Dental Inlay Wax. J. Oral Rehabilitation, 8:191-192, 1981.

Mumford, G. and Ridge, A.: Dental Porcelain. Dent. Clinic of North Am., 15:33-42, 1971.

Myerson, R. and Dogon, I.L.: The Role of Porcelain Inlay in Restoration Dentistry. J. Biomed. Mater. Res. Symposium, 2:405-441, 1972.

Nortwich, W.T., Gettleman, L.: Effect of Internal Relief, Vibration, and Venting on the Vertical Seating of Cemented Crowns. J. Prosth. Dent., 45:395-399, 1981.

Oliveira, J.D., et al.: Influence of Pressure and Vibration During Cementation. J. Prosth. Dent., 41:173-177, 1979.

Phillips, R.W.: Skinner's Science of Dental Materials: Dental Cements for Luting and Thermal Insulation. Cement Bases. 8th ed., Philadelphia, W.B. Saunders Co., pp. 452-479, 1982.

Rogers, O.W.: The Dental Applications of Electroformed Pure Gold. I. Porcelain Jacket Crown Technique. Australian Dental Journal, 24:163-170, 1979.

Rogers, O.W.: The Dental Application of Electroformed Pure Gold. II. A. Porcelain Inlay; B. Cast Coping with Adaptable Electroformed Gold Margins. Australian Dental Journal, 25:1-6, 1980.

Saltzberg, D.S., et al.: Scanning Electron Microscope Study of the Junction Between Restorations and Gingival Cavo-surface Margins. J. Prosth. Dent., 36:517-522, 1976.

Schultz, et al.: A Textbook of Operative Dentistry: The Porcelain Inlays. pp. 256-260, 1966.

Sela, M., et al.: Adaptation of silicate and adaptic to the Margins of Cavities. J. Oral Rehabilitation, 2:117-124, 1975.

Sharp, T.B. Preparation for and Construction of Baked Porcelain Crowns and Inlays. J. Prosth. Dent., 9:113-118, 1959.

Smith, B.B.: Porcelain Inlays for the General Practitioner. Dental Clinic of North Am., pp. 191-202, 1967.

Sozio, R.B. and Riley, E.J.: The Shrink-Free Ceramic Crown. J. Prosth. Dent., 49:182-187, 1983.

Stanford, J.W. and Ryge, G.: Recommended Format for Protocol for Clinical Research Program. Clinical Comparison of Several Anterior and Posterior Restorative Materials. Int. Dent. J., 27:46-57, 1977.

Starling, L.B., Stephan, J.E., Stroud, R.D., Sozio, R.B. and Riley, E.J.: Shrink-Free Ceramic and Method and Raw Batch for the manufacture thereof. United States Patent, 4, 265, 669, May 5, 1981.

Teteruk, W.R. and Mumford, G.: The Fit of Casting Alloys Using Different Investing Materials and Techniques. J. Prosth. Dent., 16:910-927, 1966.

Thoma, G.E.: Esthetic Inlays: Porcelain-To-Gold. Dental Survey, 48:24-5, 1972.

Tucker, R.V.: Variation of Inlay Cavity Design. JADA, 84:616-620, 1972.

Vickery, R.C. and Badinelli, L.A.: The Direct Fabrication of Restorations Without Foil on a Refractory Die. J. Prosth. Dent., 21:227-234, 1969.

Wain, D.: Porcelain Casting. Brit. Dent. J., 44:1364, 1923.

APPENDIX

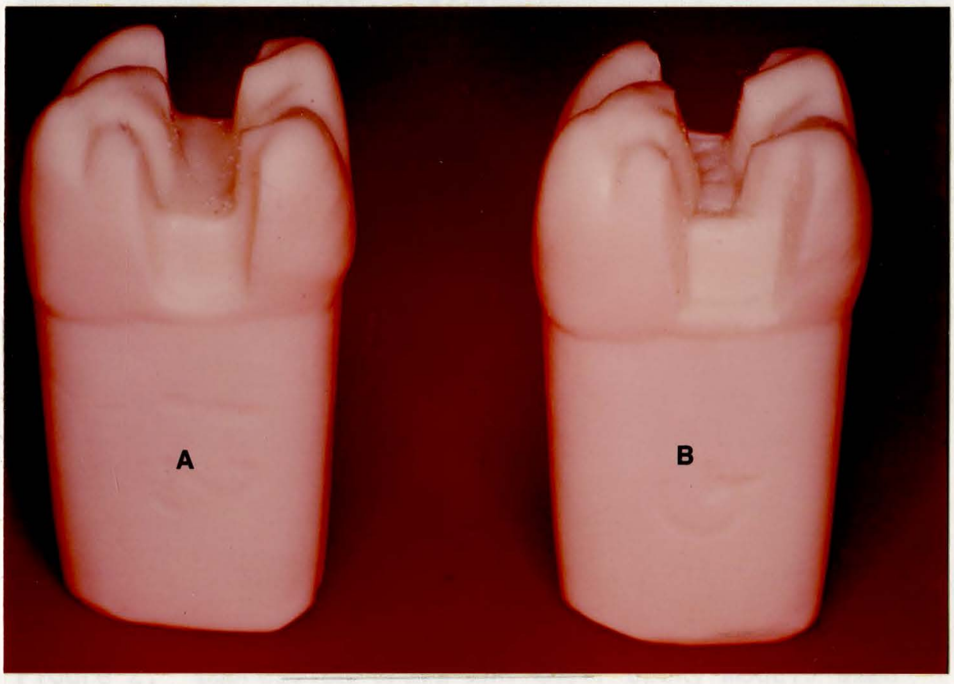

Figure 1. Cavity preparation designs. A, rounded angle design. B, geometric design.

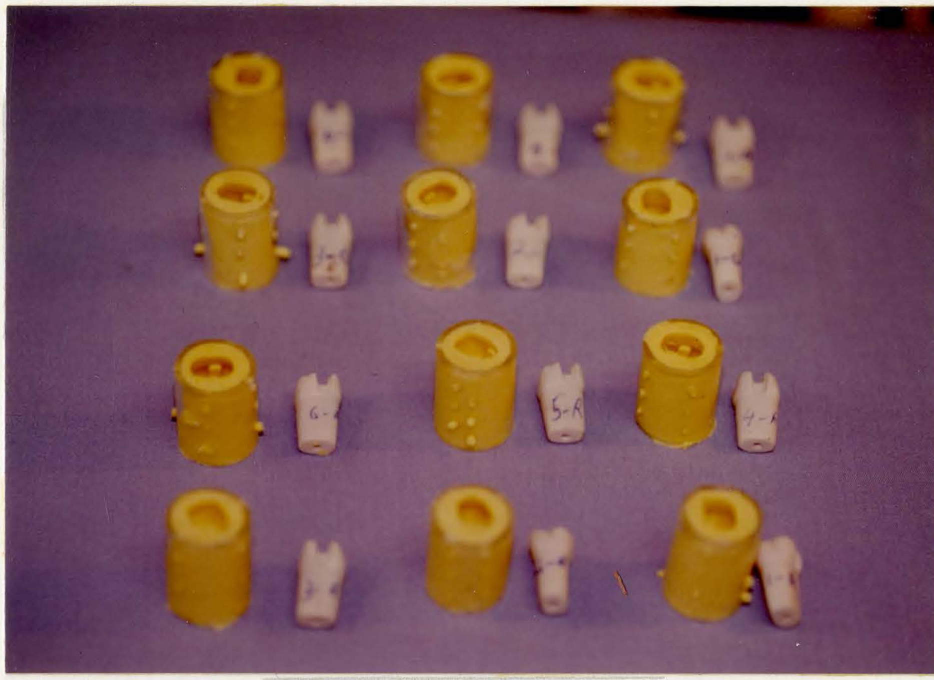

Figure 2. Impression trays and their epoxy models used for gold alloy and alumina ceramic inlays.

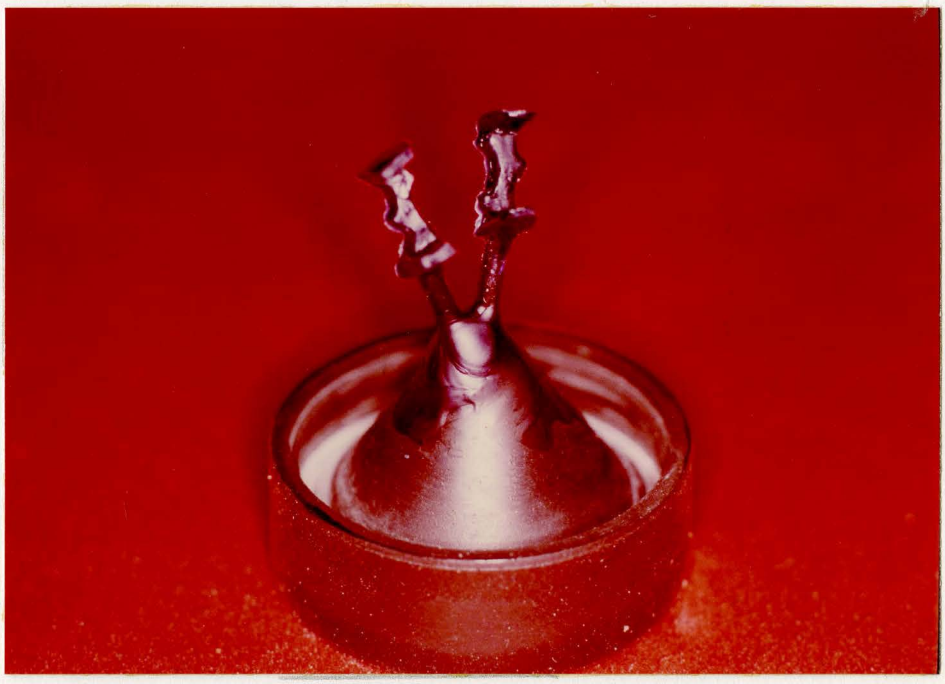

Figure 3. Two wax patterns attached to the crucible former in the preparation of the gold inlay. Note: preparation on right is rounded design; preparation on left is geometric design.

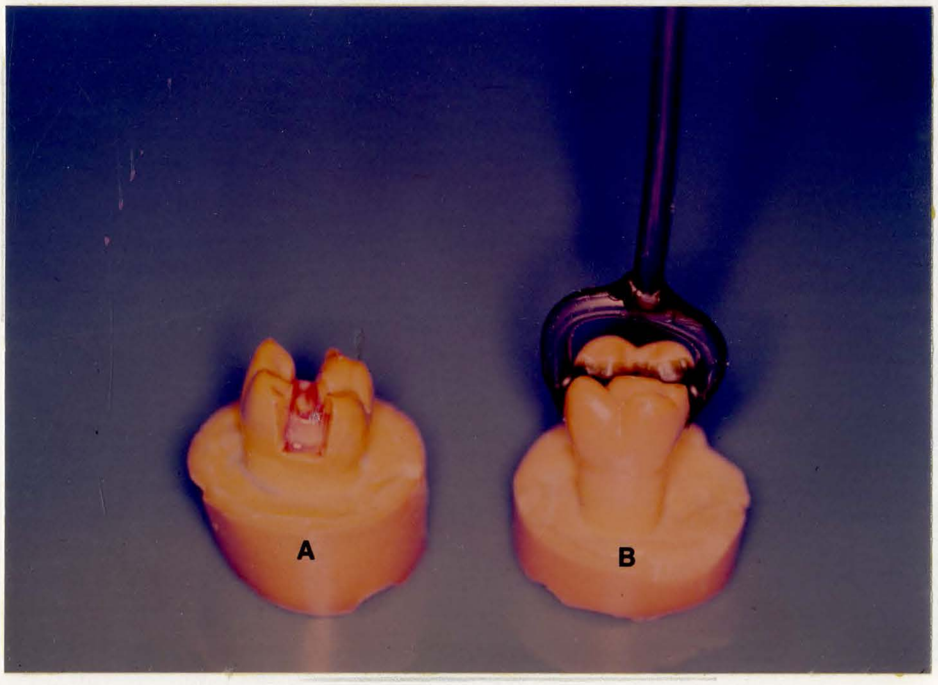

Figure 4. A, Cured epoxy resin die with die spacer. B, Wax-up sprued. Dies A and B were made for alumina ceramic inlays.

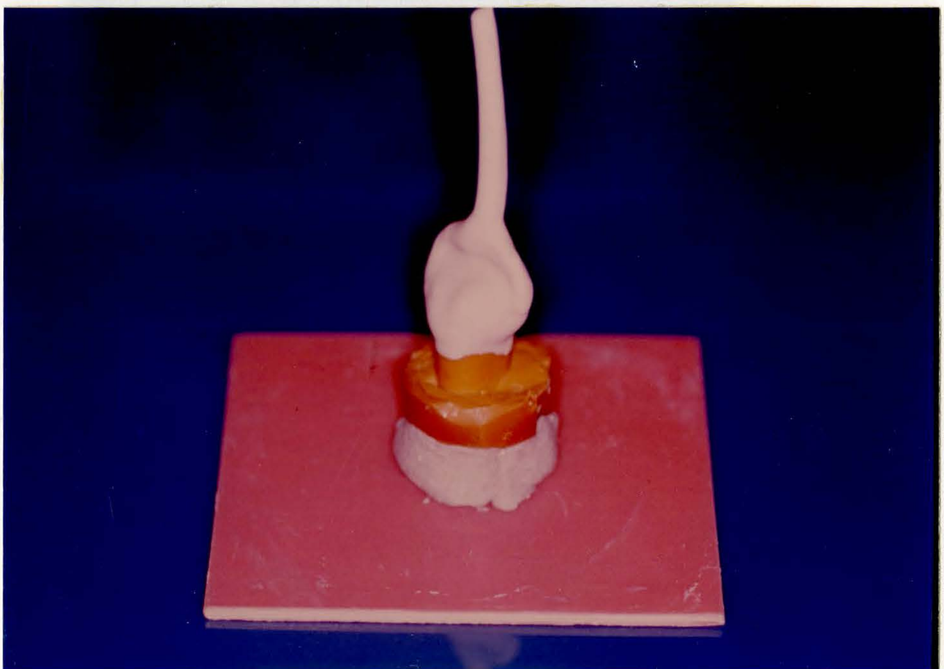

Figure 5. Stucco unit prepared for alumina ceramic inlays.

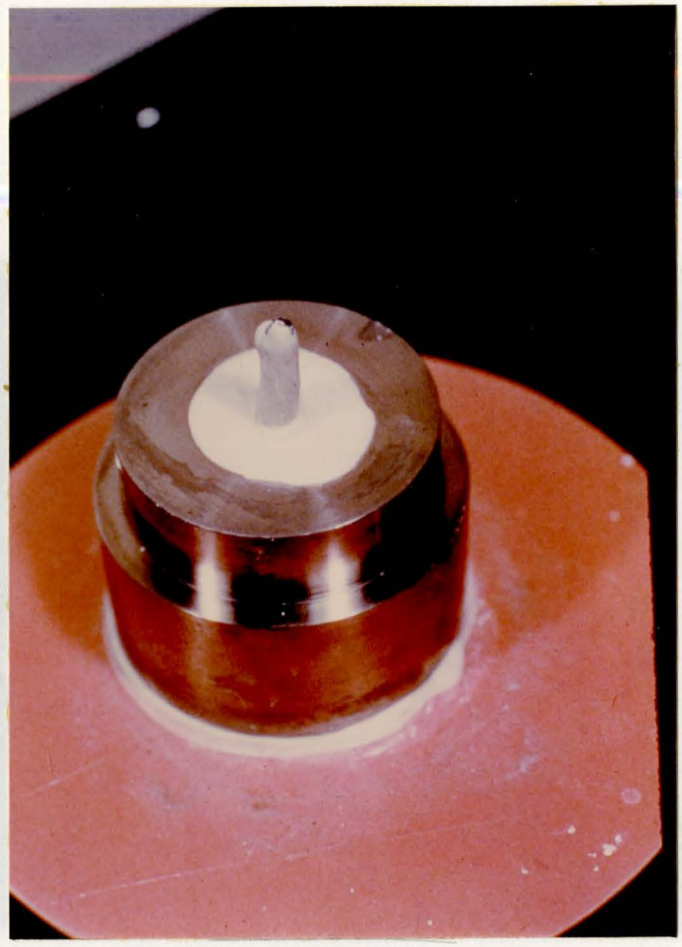

Figure 6. Wax-up with die invested in the flask base with the plaster.

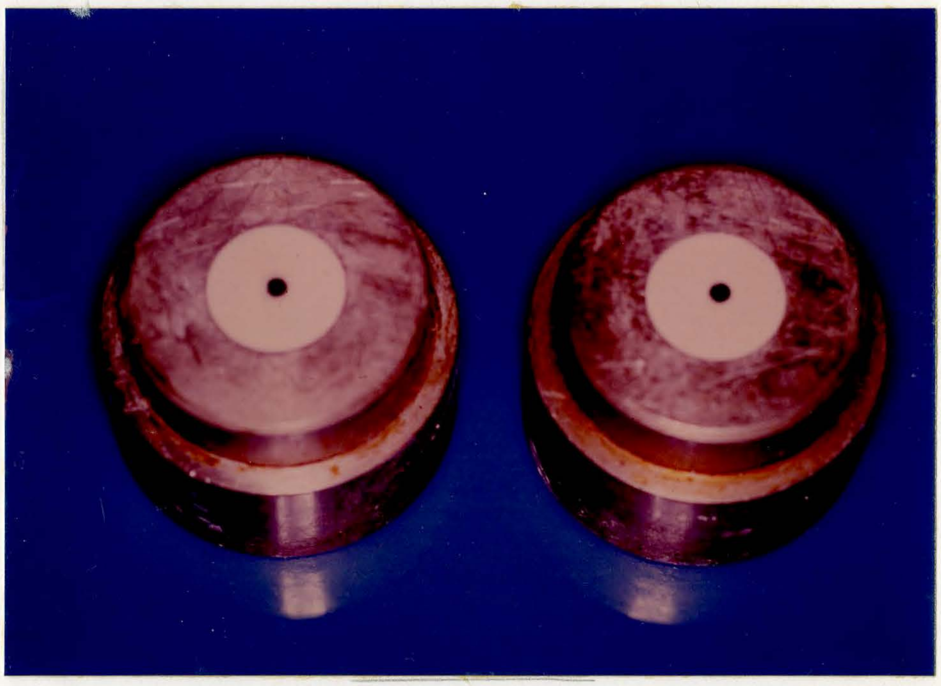

Figure 7. The excess plaster and sprues were trimmed flush with the top of the flask base before wax elimination.

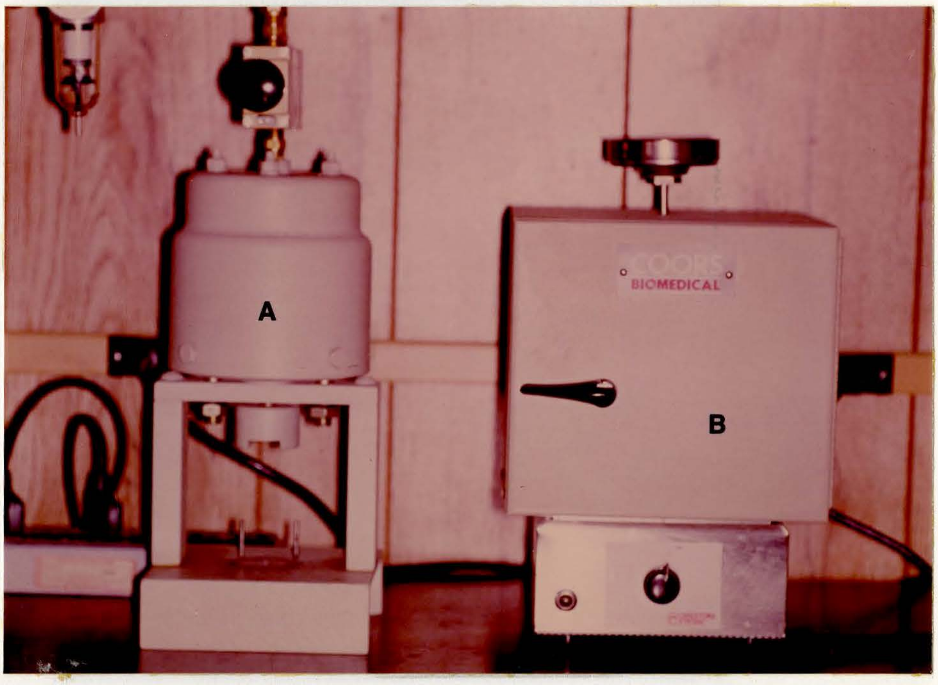

Figure 8. A, Air press machine used to mold inject the ceramic material. B, A Thermolyne oven used to heat the flask base and top.

Figure 9. Heating oven with flask assemblies arranged as shown above.

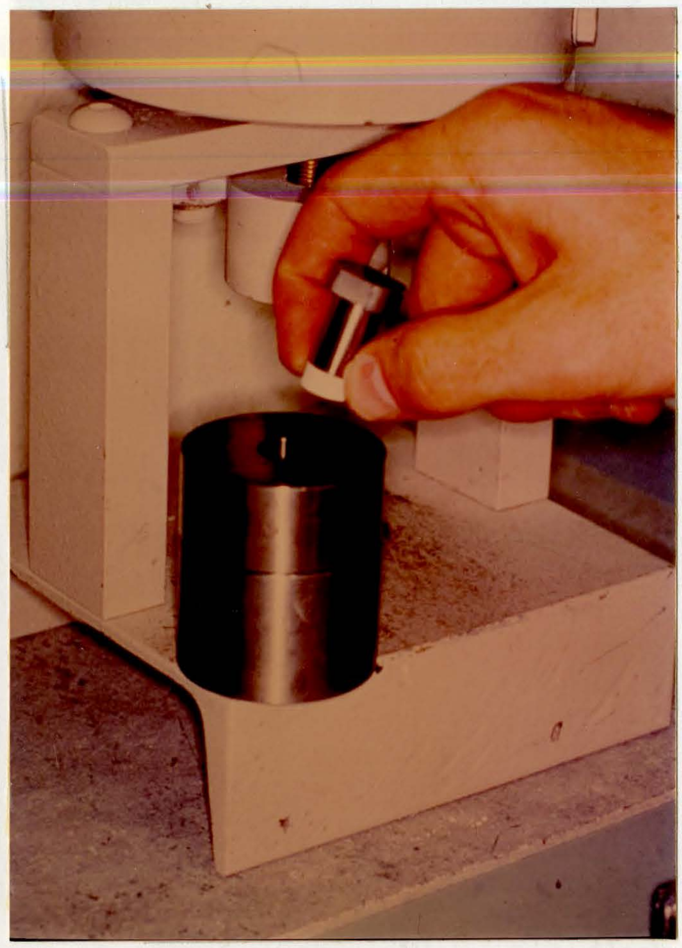

Figure 10. Heated flask assembly and ceramic pellet ready for mold injection.

Figure 11. Plaster mold released from flask before separating the plaster and the hard stone from the ceramic coping.

Figure 12. Three epoxy resin dies..A, Epoxy die with die spacer. B, Epoxy die with wax pattern. C, Ceramic coping at green stage seated completely on its epoxy die.

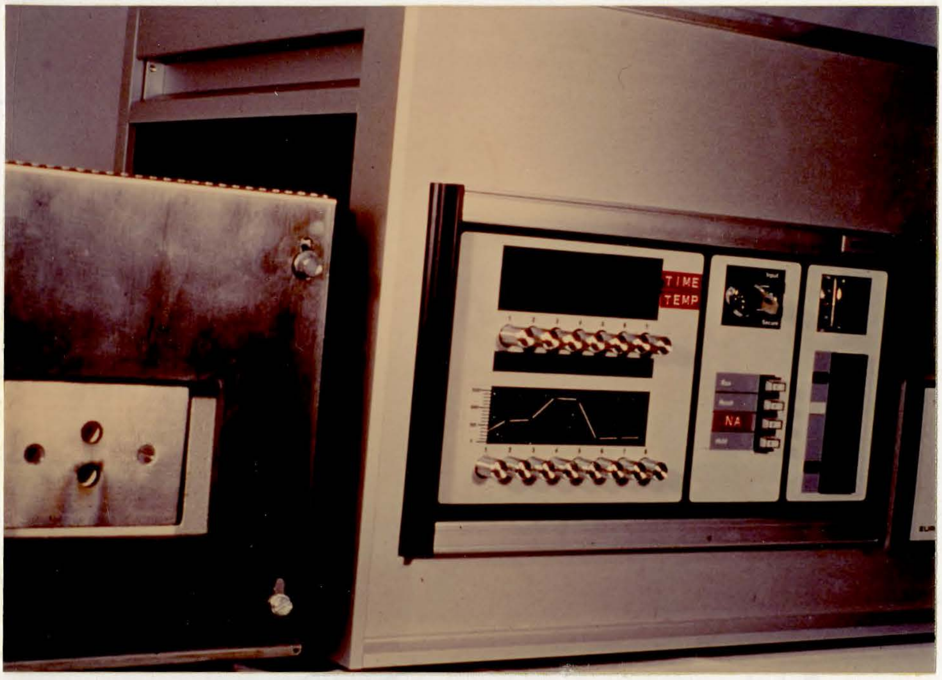

Figure 13. Programmable furnace especially made for firing the ceramic copings.

Program

	T_1	T_2	T_3	T_4	T_5
Temp. (°C)	18-500	500	500-1296	1296	1296-18
Time (hrs)	3.5	2	5	0.5	0.5

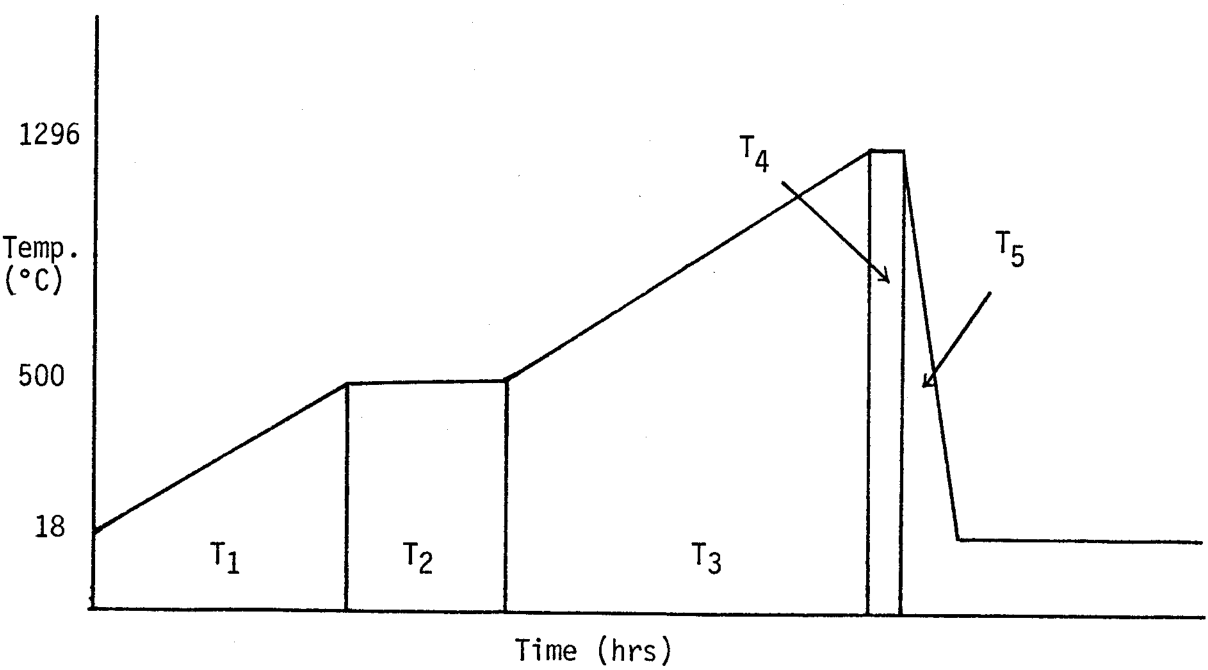

Figure 14. Eurotherm firing cycle for fabrication of alumina ceramic inlays.

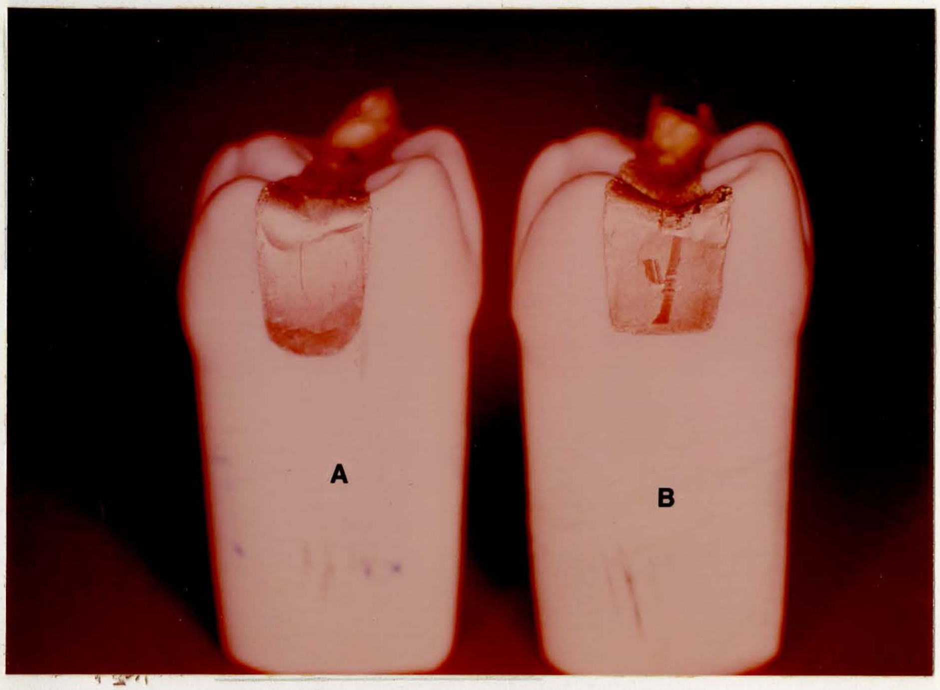

Figure 15. Gold alloy inlays seated completely in their corresponding models. A, Rounded angle design. B, Geometric design.

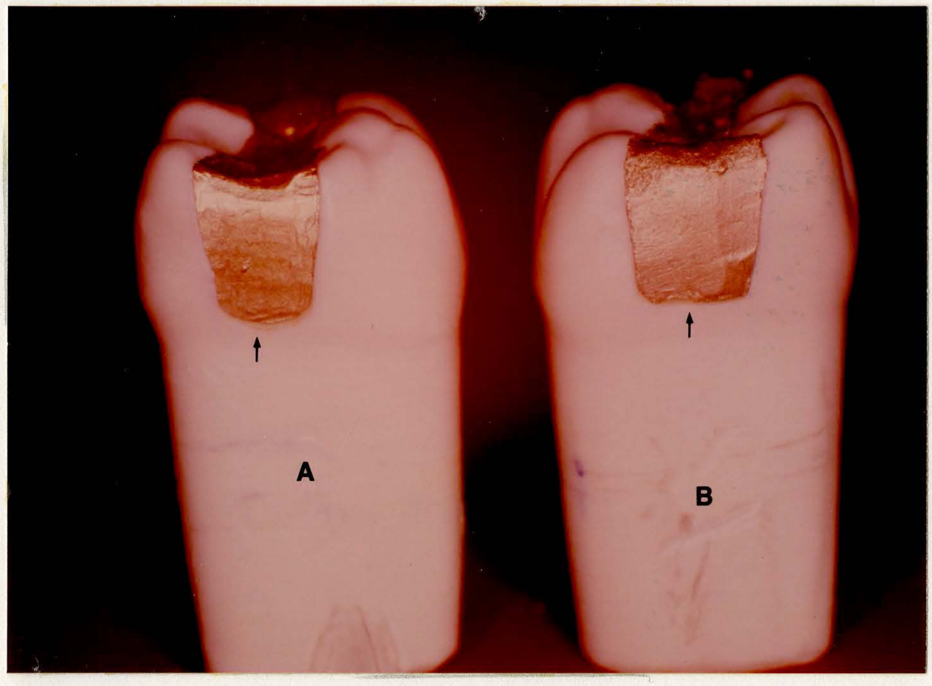

Figure 16. Gold alloy inlays with open margins at the gingival seat (arrows). A, Rounded angle design. B, Geometric design.

Figure 17. Ceramic inlays failed to seat completely into their corresponding epoxy models.

Figure 18. Magnified view of the unseated ceramic inlay into its corresponding epoxy model.

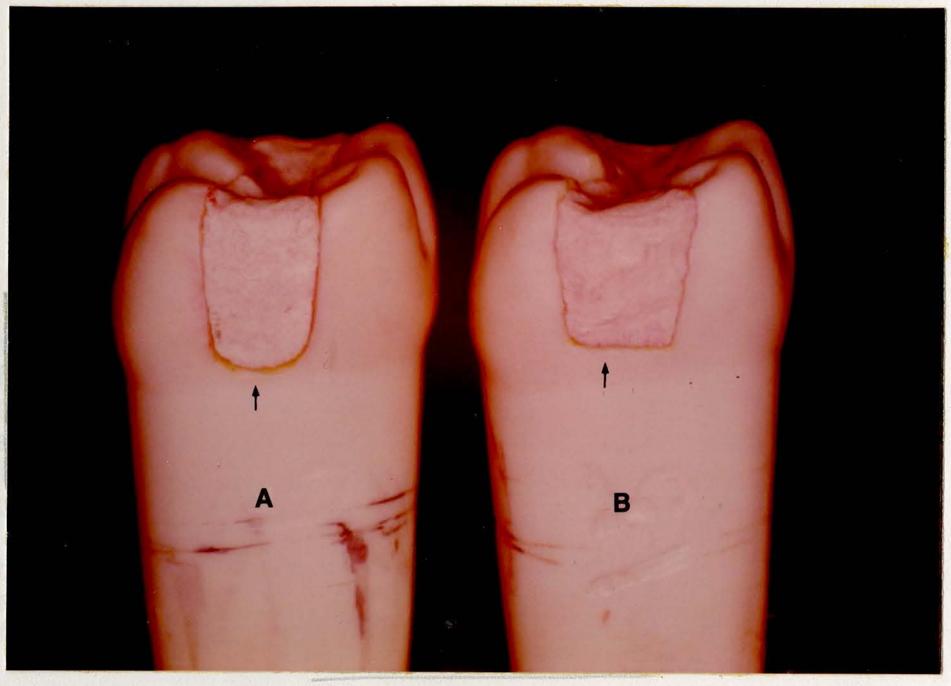

Figure 19. Ceramic inlays after grinding. Open margins at the gingival seat areas (arrows). A, Rounded angle design. B, Geometric design.

APPROVAL SHEET

The thesis submitted by Nasreddin A. Takally has been read and approved by the following committee:

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The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the Committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science in Oral Biology.

July 11, 1983
Date

James L. Sandrik
Director's Signature