FISSURE SEALANTS MICROLEAKAGE: COMPARISON OF ACID ETCH VERSUS AIR-ABRASION

A Thesis

Presented in Partial Fulfillment of the Requirements for the degree Master of Science in the Graduate School of The Ohio State University

by

Gary Brian Davis, B.S., D.D.S.

*****

The Ohio State University

1995

Master's Examination Committee:

William Waggoner DDS, MS

Kim Laurell DDS, MS

Stephen Wilson, DMD, MA, PhD

Approved by

William Waggoner, DDS, MS

College of Dentistry

ACKNOWLEDGMENTS

I express sincere appreciation to Dr. William Waggoner for his guidance, patience, and insight throughout the research. Thanks go to the other members of my committee, Drs. Kim Laurell and Stephen Wilson, for their help, suggestions, and support. The technical assistance and support of Dr. Robert Feigal and Paul Herman is gratefully acknowledged. Special thanks to Natalie Clark for help in producing this document.

VITA

December 16, 1964	Born - Brooklyn, New York
1987	B.S., S.U.N.Y. at Stony Brook, New York
1991	D.D.S., University of Michigan, Ann Arbor, Michigan
1991-1992	General Practice Resident, University Hospital, Stony Brook, New York
1992-1993	General Dentist, Dental Associates, Newtown, Connecticut
1993-Present	Graduate Student, College of Dentistry, The Ohio State University, Columbus, Ohio

FIELD OF STUDY

Major Field: Dentistry

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

Recently, the concept of air-abrasion, a phenomenon originally investigated in the 1950's, has been reintroduced to the dental profession with the KCP 2000 (American Dental Technologies, Inc.), the MicroPrep (Sunrise Technology), and the KV-1 (Kreativ, Inc.). Air-abrasion cavity preparation systems use a stream of purified aluminum oxide particles propelled by air pressure. They can be used to excavate decay, cutting through enamel and dentin, to abrade or roughen a tooth surface. This type of cavity preparation system is ideal for use with composite resins, which require minimal tooth preparation and less rigid classic cavity design than does amalgam. Therefore, the potential benefits of this concept have increased dramatically since the 1950's with the advancement in composite resin materials. The KCP 2000 is highly touted by the manufacturer as an alternative to acid etching prior to the placement of sealants or bonding agents. However, at the onset of this study, no clinical or laboratory studies have examined the amount of microleakage that occurs at the sealant-enamel interface when the KCP 2000 is used to condition teeth prior to sealant placement.

Microleakage at the tooth-restoration interface of composite resins may lead to staining, recurrent caries, postoperative sensitivity, adverse pulpal response, or loss of the restoration. Because pit and fissure sealants rely on an intimate bond between resin and enamel for retention, evidence of microleakage under a sealant is an indicator of potential failure. Therefore, any technique used to condition teeth prior to sealant placement should be examined for its ability to promote an adequate seal of the interface.

Microleakage at the sealant-enamel interface of teeth conditioned with the KCP 2000 is an unknown factor. If the microleakage is significant, the sealants may ultimately fail and be lost (Fuks et al., 1984). If, however, the microleakage is not significant, the use of the KCP 2000 in conditioning teeth for sealant placement may significantly improve the delivery of this valuable preventive technique. The purpose of this *in vitro* study is to compare the extent of microleakage at the sealant-enamel interface of human molar teeth conditioned with either the KCP 2000 or 37% phosphoric acid.

CHAPTER II

LITERATURE REVIEW:

Introduction

The present investigation examines the microleakage of pit and fissure sealants of teeth conditioned with either air-abrasion or 37% phosphoric acid. To better understand the significance of this work the literature was reviewed with regard to the following topics: a) rationale for pit and fissure sealants; b) sealants: past and present; c) the acid etch technique; d) clinical effectiveness of sealants; e) microleakage; and f) air-abrasion.

Rationale for Pit and Fissure Sealants

The occlusal surface anatomy of posterior teeth, specifically the pits and fissures, makes these surfaces particularly susceptible to dental caries. Occlusal surfaces account for almost 60% of the carious conditions of children and adolescents according to the 1987 National Dental Caries Prevalence Study (NIDR, 1989). Even more recently, Hicks and Flaitz (1993) reported that over 85% of the lesions in the permanent dentition involve surfaces with pits and fissures.

According to the most recent national surveys, the incidence of smooth surface caries has decreased dramatically over the past two decades (NCHS, 1971; NCHS, 1974; NIDR, 1981; NIDR, 1989). This decrease can be attributed to a number of factors, but playing a major role in this decrease is the usage of systemic and topical fluorides (Hicks et al., 1985). According to a 1987 NIDR study, interproximal caries decreased by 60% in fluoridated communities compared to only 10% for pit and fissure caries (NIDR, 1989).

The morphology of pits and fissures, specifically their form and depth, is what makes them so susceptible to dental caries (Rohr et al., 1991). Many of the pits and fissures present on buccal, lingual, and occlusal surfaces are so narrow and/or deep that they are difficult to debride through daily hygiene practices or professional prophylaxis. This leaves these surfaces susceptible to the collection of plaque containing microorganisms (Galil, 1975).

Another factor contributing to the susceptibility for decay of occlusal surfaces is their close proximity to the DEJ as compared to smooth surfaces. When the occlusal enamel becomes carious the underlying dentin can become rapidly involved. This renders the occlusal surface more susceptible to the advancement of decay (Silverstone, 1984). It has been postulated that this is the reason systemic and topical fluorides are less effective in preventing pit and fissure caries as compared to smooth surface caries (Hicks et al., 1986).

A number of factors make the detection and restoration of pit and fissure caries difficult, particularly in children and adolescents. Houpt et al. (1985) showed that clinical exam for determining pit and fissure caries is quite variable from one practitioner to another, resulting from variations in the examiner judgement, size and shape of the explorer tip, and the force applied. Previous research has indicated that rigorous probing of pits and fissures should be avoided as it may produce traumatic defects of the enamel surface, thus making the fissures more susceptible to lesion progression (Ekstrand et al., 1987). Recent studies have shown that the use of explorer probing might not improve the validity of diagnosis of fissure caries as compared to visual inspection alone (Lussi, 1991; Van Amerongen, 1992). The use of microbial tests to screen preschool children for Streptococcus mutans has been suggested (Edelstein and Tinanoff, 1989). Current research has shown that the use of radiographic exam to detect occlusal caries is unreliable (Flaitz et al., 1986; McKnight-Hanes et al., 1990). Additionally, the potential lack of cooperation of this patient population further complicates the detection and restoration of pit and fissure caries. As is evident, the real challenge facing the dental profession is the prevention of pit and fissure caries.

Sealants: Past and Present

Prior to the advent of sealants, numerous attempts were made to provide an adequate technique to prevent pit and fissure caries. Hyatt (1923) proposed the usage of prophylactic, conservative Class I restorations of amalgam to prevent future, more aggressive caries. Bodecker (1929) introduced the concept of placing cement into the pits and fissures in an attempt to seal them. Later, he introduced the prophylactic odontotomy, which involved widening the fissures in an attempt to make them more cleanable.

The real breakthrough in preventing pit and fissure caries came when Buonocore (1955) introduced a method for mechanical bonding of restorative resin to enamel. He used an 85% phosphoric acid solution and a conditioning time of 30 seconds in vivo to alter the existing enamel and increase the retention of acrylic filling materials 100-fold versus non-treated controls.

During the 1960's a number of different resin materials were tested using the acid etch technique developed by Buonocore. The first clinical trials used pit and fissure sealants composed of a cyanoacrylate substance (Cueto and Buonocore, 1967). These resins proved inadequate due to bacterial degradation over time in the oral environment (Ripa and Cole, 1970). Among the different resins being tested at the time was a dimethacrylate, which was formed by reacting bisphenol A with glycidyl methacrylate. This hybrid monomer resembled an epoxy resin except that the epoxy groups were replaced with methacrylate groups (Bowen, 1962; Bowen, 1963). This type of dimethacrylate resin has become commonly referred to as BIS-GMA (Bowen, 1982). Recognizing this material's ability to seal pits and fissures, the ADA granted provisional acceptance to the first sealant in the 1972 (Council on Dental Materials and Devices, 1972). Today, most commercial sealants are BIS-GMA dimethacrylate or urethane dimethacrylate based products (Ripa, 1993). More recent investigations have focused on the usage of fluoride containing glass ionomer materials as pit and fissure sealants. However, clinical studies have resulted in poor retention rates for the glass ionomer sealants, and additional research is necessary in this area (Boksman et al., 1987; Forss et al., 1994).

Sealants may differ in a number of physical properties, including their method of polymerization. The two methods currently employed are autopolymerization, or chemically cured systems, and photoactivation, or visible light-cured systems. Autopolymerization systems mix a base resin and a catalyst resin. Photoactivation with a visible light source, which has replaced the use of ultraviolet light, is the most popular method used today. Additionally, the laser-curing of visible light-activated resin materials has been investigated recently with favorable results (Blankenau et al., 1991; Westerman et al., 1991). Further research is ongoing in this area.

<u>The Acid Etch Technique</u>

The use of an acid solution to etch the enamel surface is an essential prerequisite for the successful bonding of resins to tooth structure. Since Buonocore's work using 85% phosphoric acid to etch enamel, a number of other materials have been studied as potential etching agents. Pyruvic (Retief et al., 1976), lactic (Oshawa, 1972), and citric acids (Bruer and Termini, 1972) have also been used to etch enamel prior to the placement of a resin. Although etching of enamel was achieved with these acid solutions, the bond strengths of resin to enamel were all inferior as compared to those achieved with phosphoric acid.

Silverstone et al. (1975b) have demonstrated three basic etching patterns that are produced by the placement of an acid on enamel surfaces. Type I etching pattern shows a preferential demineralization of the prism cores; Type II etching pattern demonstrates the reverse effect in which the prism peripheries are removed preferentially; and in the Type III pattern, the surface shows no morphological evidence of a prism pattern. All three patterns may be found to occur on a single tooth surface from a single etch. Additionally, a strong bond will occur between resin and enamel with all three patterns.

When a sealant is applied to etched enamel surfaces, resin monomer infiltrates the micropores to form a mechanical lock upon polymerization. The early studies on the depths of these micropores were conflicting. In vitro studies by Gwinnett and Buonocore (1965) reported an average tag length of 10 microns. An in vivo study by Gwinnett and Ripa (1973) produced an average tag length of 25 microns. Silverstone, however, showed average tag depths to be 50 microns (Silverstone, 1974). Silverstone (1975a) addressed these discrepancies when he described three microscopic levels at which etched enamel is affected. The first is an etched zone of enamel approximately 10 microns in depth. This zone results in a more reactive surface, an increase in surface area, and a reduced surface tension. The second zone is the qualitative porous zone consisting of large porosities reaching 20 microns in depth. In combination, the first two zones reach about 30 microns in depth. The deeper third zone, the quantitative porous zone, contains small porosities identified by quantitative methods using polarized light. This third zone allows penetration up to 50 microns and had not been identified prior to this study. Silverstone used this finding to explain the reported variability in porosity depth.

Conlon and Silverstone (1982) examined the effect of etching various tooth surfaces by performing an in vivo and in vitro study in which all five tooth surfaces in a single tooth were etched. The results showed a more distinct etch found on the smooth surfaces as compared to the occlusal surface.

Numerous studies over the last few decades have focused on the appropriate concentration, etching time, and rinsing time to produce optimum results with minimum loss of tooth structure. With regard to the optimum concentration of phosphoric acid, Manson-Rahamtulla et al. (1984) used concentrations of phosphoric acid ranging from 10 to 70% in 10% increments to determine the amount of calcium removed and the depth of etch. The results showed the total amount of calcium dissolved and the depth of etch increased with an increase in acid concentration and reached a maximum at 40%. A further increase in acid concentration resulted in a decrease in the depth of etch and total calcium dissolved. While comparing etching characteristics of various agents, Silverstone (1974) concluded that an unbuffered solution of 30% phosphoric acid produced the most even distribution of etched enamel. Gross et al. (1984) examined the microleakage of class V composite resins using phosphoric acid solutions ranging from 10 to 70% in increments of 10%. The results showed etching with 10 to 60% phosphoric acid reduced marginal leakage significantly as compared to an unetched control. Etching with a 70% solution did not significantly reduce the microleakage. In an <u>in vitro</u> study, Gottlieb et al. (1982) demonstrated that the tensile bond strengths of composite resin bonded to enamel surfaces etched with 10 to 60% phosphoric acid were not significantly different. However, etching with 70% phosphoric acid resulted in significantly lower tensile bond strengths.

For many years manufacturers recommended an acid etch application of 60 seconds, but there have been numerous challenges recently to this once widely accepted 60 second conditioning time. Tensile bond strengths of an orthodontic resin cement were compared for 15, 30, 60, 90, or 120 second etching times with 37% phosphoric acid on the enamel of young permanent teeth (Wang and Lu, 1991). The results showed no statistical differences between the 15, 30, 60, or 90 second etching times, and a significant decrease in tensile bond strength for the 120 second etching time. These results are in general agreement with the findings of Tandon et al. (1989), who found no statistical differences in the bond strength of sealants and on the etch pattern of permanent enamel of 15, 30, 60, and 120 second 37% phosphoric acid etch. Stephen et al. (1982) showed a 100% two year retention rate for sealants on first molars using a 20 second acid etching time. Eidelman et al. (1988) demonstrated comparable results in retention rates of sealants after three years using 20 second etching times in comparison to 60 seconds. Reports have also demonstrated satisfactory marginal sealing can be achieved with reduced enamel etching times (Crim and Shay, 1987; Fuks et al., 1984). Barkmeier et al. (1985, 1986) used scanning electron microscopy to show no difference in the type of etch patterns between a 15 or 60 second acid conditioning time. Currently, based on the studies, a 20 second etch is widely viewed as acceptable for bonding procedures.

Differing opinions also exist with regard to the optimal rinsing time of acid etched surfaces. Schulein et al. (1986) used shear bond strengths of composite resins to acid etched enamel to show no statistical difference between 20 or 40 second rinse times. Summit et al. (1992) found no significant differences in shear bond strength of composite resin bonded to etched, flattened enamel between groups rinsed with either water or air/water spray for 1, 2, 3 , 5 or 20 seconds following 20 second etch with 37% phosphoric acid gel. This study suggested that one to five second rinse times per tooth surface with either a stream of water or an air/water spray should adequately remove the etching gel from the etched enamel surface to provide adequate bonding of composite resin.

Clinical Effectiveness of Sealants

Sealants act as a physical barrier, preventing oral bacteria and other nutrients from collecting within the fissures and from producing the acidic conditions necessary for caries initiation (Ripa, 1973). Numerous studies over the past two decades have attempted to evaluate important factors influencing the clinical effectiveness of sealants, including caries incidence and retention rates. Sealant effectiveness was originally studied by comparing the caries inhibition of sealant-treated teeth to teeth in the same mouth that were not treated. These types of studies may have introduced an unintentional bias on the part of the examiner into the results (Stephen and Strang, 1985). A number of problems existed with the early sealant studies which had a significant influence on the varied results which were obtained. A number of variables, including the type of sealant tested, the position of the teeth in the mouth, the clinical skills of the operator, and the age of the child, undoubtedly influenced the results obtained (Ripa, 1980). In addition, the majority of clinical studies used a single application of sealant followed by periodic evaluations without any attempts to repair the sealants. Yet another factor influencing the results of early sealant studies was the discovery of inadequate early lights and materials to ensure complete polymerization of the material (Young et al., 1977, 1978). Additionally, the importance of etch time, rinsing, and drying weren't completely understood. For these reasons, mixed results were obtained in the early clinical trials examining sealant effectiveness.

In the past decade, however, more consistent positive results have been obtained. Simonsen (1987) reported that 78% of treated fissures were either completely (57%) or partially covered (21%) 10 years after a single sealant application. This study used chemically polymerized sealants to treat first permanent molars. Even after 15 years, Simonsen (1991) reported 63% of the treated fissures were either completely (28%) or partially covered (35%).

Recent clinical studies in which sealants were reapplied when they were lost have had more impressive results (Charbeneau, 1982; Straffon and Dennison, 1988). Retention rates ranging from 88-96% have been reported at each annual evaluation. Even more impressive is the fact that this type of reapplication protocol was found to be 100% effective in preventing pit and fissure caries.

Ripa (1993) summarized 14 clinical studies which compared retention rates of visible light activated sealants to either chemical or ultraviolet activated sealants. The results of this comparison showed the performance level for visible light activated sealants to be similar to chemical polymerized sealants and better than ultraviolet polymerized sealants with an observation period up to 5 years.

Microleakage

Microleakage is defined as the ingress of fluids and/or microorganisms into the space between tooth structure and restorative materials (Trowbridge, 1987). Because of the different coefficients of thermal expansion of restorative material and tooth structure, prolonged and repeated expansion and contraction of material due to thermal changes may lead to an increase in leakage as the two materials separate. The success of a sealant is directly related to its ability to act as a physical barrier between oral fluids and bacteria and the pits and fissures of occlusal surfaces. The retention rate of a sealant is directly related to an intimate micromechanical bond between resin and enamel. Therefore, the performance of a sealant will be affected by the amount of microleakage that occurs (Houpt and Shey, 1983; Simonsen, 1980; Simonsen, 1981).

A number of different methods have been employed to study the phenomenon of microleakage. In vitro methods have included radioactive tracers, dye penetration, bacterial penetration, electrochemical analysis, silver nitrate staining, scanning electron microscopy, and fluorometric assay (Barnes et al., 1993). Two of the more commonly used methods employed to detect microleakage are the immersion of specimens in solutions of dye or radioisotopes. Crim et al. (1985) showed that the use of a dye or an isotope was equally effective and penetrated the tooth-restoration interface to a similar degree. Silver nitrate is currently the most commonly used staining technique for microleakage and is stable, readily available, and relatively inexpensive (Barnes et al., 1993).

The thermal changes of the oral environment that restorations are subjected to are simulated by a thermocycling procedure that exposes the restorations to alternating temperature extremes over selected time intervals. Crim et al. (1985) compared the effect of dwell time and timing of dye immersion using basic fuchsin dye and Ca^{++} isotope tracer.

The results showed the depth of microleakage was independent of the dwell time in the thermal baths. They also showed no difference in the depth of tracer penetration between specimens placed in the tracer during thermocycling and those immersed in the tracer after thermocycling.

Crim (1987) also examined how the storage time of the teeth before thermocycling and the length of the thermocycling protocol may affect the results of microleakage studies. Results of the study indicated that the degree of basic fuchsin dye penetration that occurred in specimens cycled immediately after finishing the restorations and those stored for 24 hours in water before testing was not significantly different. The results also revealed that the degree of dye penetration was not significantly different regardless of the number of thermal cycles to which the specimens were subjected.

Barnes et al. (1993) compared the microleakage of <u>in vitro</u> and <u>in vivo</u> Class V composite restorations. The <u>in vivo</u> samples were extracted approximately 6 weeks after placement of the composites, and the <u>in vitro</u> samples were thermocycled 540 times. All restorations were stained with silver nitrate. The <u>in vitro</u> samples showed statistically more microleakage than the <u>in vivo</u> samples. Litkowski et al. (1989) concluded that thermocycling actually increases the amount of leakage of composite resin restorations and may exaggerate the clinical significance of the results. It appears that thermocycling may provide a "worst case" amount of leakage.

Studies have used the microleakage concept to investigate the effect of various factors, such as etch time (Fuks et al., 1984) and etch concentration (Gross et al., 1984), on the enamel-resin interface.

Air Abrasion

In 1945, Robert Black (1945) described a technique for the nonmechanical preparation of teeth. He described the phenomenon of air-abrasion as a process that employed for its action a very fine stream of compressed air into which a suitable, finely divided abrasive agent was introduced. Black went on to describe the features of the Airdent (SS White), an air-abrasion system, which was composed primarily of a unit and a handpiece. The unit contained a small, silent motor, a compressor, an abrasive vessel, a means of controlling the mixture of abrasive with air, and a vacuum recovery receptacle with filter, which stored the abrasive.

The suggested clinical applications of the Airdent included extrinsic stain removal, prophylactic odontotomy and tooth preparation, and removal of faulty amalgam. The abrasive used in the unit was aluminum oxide, which was described by Black as having the following favorable characteristics: chemically stable, non-toxic, readily available, inexpensive, and being of a neutral color. Black described the two major drawbacks of this unit to be the retrieval of abrasive from the mouth and the mixing apparatus for incorporating the abrasive with air.

By January 1951, approximately 20 dental schools had started a postgraduate course in the air-abrasion technique (Morrison and Berman, 1953). A survey of 143 dentists who had completed a course at New York University revealed that if price were not a consideration, 100% of the respondents would have had an Airdent unit in their office. The respondents reported three major advances with this unit over the handpieces available at the time were the reduction in: a) noise; b) vibration; and c) the use of local anesthetic. In 1955, Black (1955) reevaluated the Airdent unit based on 10 years experience gained in over 8,000 procedures. He noted additional advantages to the ones already stated to be decreased fatigue for the operator, rapid removal of tooth structure, and decreased danger of injury to the soft tissue.

In spite of the positive results obtained from some of the early work with air-abrasion, it virtually disappeared from the dental environment in the late 1960's and the 1970's. Contributing factors to the disappearance of air-abrasion were the cost of the unit and the need for rotary instrumentation as an adjunct in many procedures (Morrison and Berman, 1953). The concept of air-abrasion has recently been revisited with the development of the KCP 2000 Kinetic Cavity Preparation system by American Dental Technologies (Plate 1) and other similar units. Since the introduction of the first kinetic cavity preparation system in 1945, there have been major advances in the area of dental materials that have made the usage of this concept more applicable.

In comparison to the 1950's models, the KCP 2000 is a more compact and portable unit. Its components include a console that contains the internal components, a high pressure delivery system and handpiece assembly, an evacuation hose and handpiece, an air input line and compressor connector, and a two-stage foot switch. Important to this unit is a high-volume air evacuator to combat the problem of collection of abrasive particles and tooth debris. The control for the unit features a power touch pad, three touch pads to select cutting speed, two touch pads to select particle size, and an operate touch pad to allow the evacuation system to operate independently. The cutting speed options are: high (160 psi), medium (120 psi), and slow (80 psi) speeds. The high speed allows for faster cutting action, while the slow speed allows for more precise shaping and cutting. The abrasive particles are aluminum oxide, which are supplied as 2 sizes, 50 microns and 27 microns.

By utilizing an air driven abrasive, the KCP 2000, as did the Airdent, converts the mechanical energy of the motor into the kinetic energy of the particles as they pass through the handpiece to promote the cutting action. The KCP is designed so the cutting action is accomplished without physical contact between the handpiece and the tooth. The distance between the nozzle and the tooth affects the cutting speed. To maximize the cutting speed, the manufacturer recommends holding the nozzle 1-2 mm from the target. Increasing the distance decreases the cutting speed. Other variables affecting the cutting speed include the velocity chosen (pressure), the particle size used, the flow rate of the particles, and the type of tissue being cut, with hard tissue being removed at a faster rate than soft tissue.

The manufacturer claims the KCP 2000 may be used in place of the conventional dental armamentarium for certain procedures and as an adjunct in others. The KCP 2000 can effectively penetrate and excavate dentin and enamel, and is most useful in preparing Class I cavity preparations, and when access allows, Class II, III, IV, and V preparations. Other uses recommended by the manufacturer include pit and fissure sealant tooth conditioning, removal and repair of composite materials, veneer preparations, repair of fractured porcelain and facings, and etching the inner surface of crowns for added retention.

There are specific safety precautions outlined by the manufacturer regarding eye protection, barrier materials, the evacuation system, and the use of a mouth mirror. There are also specific contraindications, which include endodontic and soft tissue procedures.

Because the KCP 2000 has only recently been introduced, there is limited information in the dental literature with regard to its effectiveness and utilization. However, the material available for review has been promising in regard to bond strength, dentin permeability, pulpal effects, and depth of etch.

The pulpal effects of air-abrasion cavity preparation in dogs were investigated by Laurell et al. (1993b). The study examined the histological effects of air-abrasion at 80 and 160 psi, using 27 and 50 micron particle size. These effects were compared to the histological effects of high speed bur preparation. Class V preparations to various depths were prepared in the premolars and molars of dogs. The results indicated that the use of air-abrasion for the preparation of teeth is comparable to, or may even have fewer potentially damaging effects on the pulp than conventional high speed preparation using copious water spray.

The pulpal effects of composite and amalgam removal with air-abrasion was also investigated by Laurell et al. (1994b). This study looked at the histological effects of air-abrasion for the removal of composite and amalgam in dogs. One test group served as a control and received no treatment, while 4 received class V amalgams and 4 received class V composites. The restorations were then removed from 6 test groups using either high speed with water spray, air-abrasion at 80 psi or at 160 psi. Fifty micron size particles were used. Samples were evaluated for the extent of displacement, disruption, inflammation, and necrosis of pulpal structure. There were no significant differences found between the groups when comparing composite removal. However, there were significantly more adverse pulpal effects in the disruption and inflammation categories for air-abrasion removal of amalgam at 80 psi than high speed removal of amalgam.

Eakle et al. (1994) examined the effect of air-abrasion on dentin permeability and bond strength. The results of this study showed that the highest shear bond strength of composite to dentin was achieved with 50 micron size particles and high cutting speed as compared to low speed and to 27 micron size particles and high and low speeds. Dentin permeability was also shown to increase with 50 micron size particles and high cutting speed.

Laurell et al. (1994a) also examined the air-abrasion effects on dentin permeability. Their results showed no statistically significant differences in permeability between air-abrasion and high speed bur treated teeth. A significant decrease in dentin permeability was noted with 27 micron size particle compared to a 50 micron size particle.

An SEM study recently completed by Doty et al. (1994) investigated the depth of bonding agent penetration into enamel between acid etch and KCP 2000 prepared teeth. Teeth were prepared using the 27 micron and the 50 micron size particles at 160 and 80 psi. The control teeth were prepared using 37% phosphoric acid. The prepared sites were coated with light cured bonding agent. The enamel was then decalcified with dilute nitric acid, leaving the resin tags to be examined. The control group exhibited a characteristic honeycomb appearance with average tag depth of 6 microns. The KCP prepared teeth exhibited average depths ranging from 4 to 15 microns, although the pattern was described as irregular. The researchers concluded the KCP 2000 has the potential to prepare enamel bonding surfaces equal to those obtained from acid etching.

Laurell et al. (1993a) studied the effect of air-abrasion on the shear bond strength of composite resin to enamel and dentin <u>in vitro</u>. In this study, a 50 micron size particle and various cutting speeds were used. For some specimens, the enamel was prepared using either an acid etch alone, air-abrasion at various cutting speeds, or etch and air-abrasion in combination. The teeth used in the dentin bonding portion of the study were prepared using dentin primer alone, KCP alone, or KCP and dentin primer. The teeth were restored with dentin bonding agent and resin cylinders. The results showed there was no significant difference in the shear bond strength to enamel between an acid etched and a KCP treated surface at 160 psi. The examiners also found that KCP treatment of dentin significantly increased the shear bond strength whether or not a dentin primer was used.

The shear bond strengths of composite to enamel, dentin, and composite were evaluated by Keen et al. (1994). Phosphoric acid and air-abrasion (KCP 2000) surface preparation were evaluated. In this study the KCP 2000 unit produced enamel, dentin, and composite to composite bond strengths equal to or superior to acid etching.

Roeder et al. (1994) reported on the tensile bond strength of composite to air-abraded enamel and dentin. This in vitro study used 50 and 27 micron size particles and three treatment combinations for enamel and dentin. A group acting as a control was prepared without air-abrasion. The study groups received light cured composite resin cylinders with or without the use of bonding agent. Particle size did not affect the bond strength of composite to enamel or dentin. Air abraded enamel surfaces had highest bond strengths when they were also etched. Air abraded dentin had the highest bond strengths when the bonding agent with primer was used. Surfaces that were air abraded alone had the lowest bond strengths. Roeder concluded the preparation of tooth structure by air-abrasion did not alleviate the need for conditioning of the tooth prior to bonding.

Bonding of hybrid ionomer to air abraded enamel and dentin was investigated (Berry et al., 1994). In vitro tensile bond strengths of a hybrid ionomer to human enamel and dentin were tested using three cutting speeds (80, 120, and 160) with 27 micron size particles in the KCP 2000. Selected conditioned with 10% polyacrylic acid and others were not. After treatment, a hybrid ionomer was bonded. Results showed conditioning enamel and dentin with polyacrylic acid significantly improved bond strength compared to not conditioning. Bond strength to enamel only was improved by air-abrasion at pressures of 120 and 160 psi. The researchers concluded that air-abrasion does not replace the need for conditioning of teeth with polyacrylic acid before bonding with a hybrid ionomer.

As previously mentioned, Black identified some very important potential advantages to the use of kinetic cavity preparation (Black, 1945). The air-abrasion principle potentially decreases the amount of heat, vibration, local anesthetic, pressure and unpleasant noise associated with tooth preparation. Many of these factors are associated with the fear of the dentist that exists for many patients and can be a significant deterrent to keep a patient from seeking dental care (Milgrom and Weinstein, 1993). If these fear producing factors can be minimized, the KCP may offer an alternative for patients who avoid the dentist because of disproportionate fear. Additionally, when used in the pediatric population to condition teeth for sealant placement, the KCP 2000 may mean decreased chair time and operator time for this patient population.

After reviewing the literature, it is evident that the prevention of pit and fissure caries remains both a necessity and a challenge. Sealants are very effective in preventing decay when fully retained on the teeth. Loss of sealants are often a result of leakage between the resin and enamel. Measuring this microleakage is an effective means of anticipating successful retention. Etching the enamel with phosphoric acid has been the standard technique used to condition teeth prior to sealant placement for decades. Air-abrasion is a promising new technique with some potential clinical advantages. The KCP 2000 is touted by the manufacturer as a substitute for acid etch as a tooth conditioner. However, the microleakage that occurs with teeth conditioned with the KCP 2000 is untested. Therefore, the purpose of this study is to compare the extent of microleakage at the sealant-enamel interface of human molar teeth conditioned with either the KCP 2000 or 37% phosphoric acid.

CHAPTER III

METHODS AND MATERIALS

Forty extracted human, non-carious, permanent molars which were stored in physiological saline prior to experimentation were disinfected by placing them in a 50% solution of sodium hypochlorite for five minutes. The teeth were placed in a jar, shaken up, and then randomly assigned to one of four groups of 10 teeth each.

The occlusal surfaces of the teeth were protected from contamination during the mounting process by covering them with alginate. Each tooth was mounted in epoxy resin using one inch mold cups which were lined with vaseline. The teeth were suspended into the cups in an upright position, around which epoxy resin liquid was poured, covering the roots and gingival 3/4 of the crown to within 2-3 mm of the occlusal surface (Plates 2 and 3).

A single operator performed all of the experimental procedures. The occlusal surfaces were cleaned thoroughly with a slurry of coarse pumice and a rubber cup mounted on a slow speed handpiece. The teeth were rinsed copiously with water and dried thoroughly with compressed air.

The occlusal surface of each tooth was treated as follows for each group:

Group A (Control Group): No conditioning was performed to the tooth surface after the prophylaxis.

Group B (Etch Group): The occlusal surfaces were etched with 37% phosphoric acid gel for 20 seconds. The surfaces were then rinsed copiously with water for 20 seconds and dried thoroughly with air. The teeth were visually inspected to demonstrate a uniform, frosty appearance.

Group C (KCP 160 Group): The teeth were prepared using the Kinetic Cavity Preparation System (KCP 2000) as per the manufacturer's recommendations as follows: using the 50 micron size particles and a speed setting of "high" (160 psi), the teeth were prepared holding the nozzle tip 2-3 mm from the tooth surface and slightly offset from perpendicular. The operator used a quick, steady, sweeping motion along the anatomy of the occlusal surface to achieve a uniform, frosty appearance. The excess particles were blown off with air and the surface was not rinsed.

Group D (KCP 120 Group) : These teeth were treated exactly as those in group C except the cutting speed was set at 120 psi instead of 160 psi.

An unfilled, light cured pit and fissure sealant (Delton Opaque light curing pit and fissure sealant, Ash Dental) was applied to all occlusal surfaces using the manufacturer's supplied applicator handle and disposable cartridges (Plate 4). By depressing the lever slowly on the applicator and moving the cartridge tip along all occlusal pits and fissures, the sealant was applied. The sealants were then polymerized with a visible light source (Model 106 Caulk Dentsply) for 20 seconds as per the manufacturer's recommendations.

Next, the teeth were thermocycled 750 times between two water baths of 5 and 55 degrees Celsius with a 60 second dwell time (Plate 5). Following thermocycling the prepared teeth were immersed in 50% silver nitrate dye for two hours in a dark environment, and then placed into radiographic developer solution for eight hours under fluorescent light. After removal from the developing solution the teeth were washed in water to remove the surface dye.

Next, three buccolingual sections were obtained by sectioning the teeth through the occlusal surface with a five inch diamond cutting blade (Leco Corp.) on a vari-cut sectioning machine (Leco Corp., St. Joseph, MI).

One examiner, blinded to group identity, measured the amount of dye penetration under the sealant of two separate sections per tooth chosen randomly from the three sections produced by the sectioning procedure. The sections were randomly numbered 1-80 by another investigator independent of the examiner, and the key to this identification system was recorded in a private log. Each section was examined for leakage using a digital image analyzer system (Fryar Co., Cincinati, OH) (Plate 6). This system utilizes a light microscope (Nikon SMZ-2T, Melville, N.Y.) to view the sections at magnifications up to 60x. The microscope is linked to a PC 486 Express IBM compatible computer via a video camera (ultra chip high resolution CCD, Javelin Corp., Los Angelos, CA). The capture board housed in the computer allows the examiner to capture an image of each section on the computer screen. The images were captured at either 10x or 20x to allow the examiner to view the entire section. If necessary, after the images were captured, the examiner further assessed the microleakage on the light microscope up to magnifications of 60x. The curvilinear depth of dye penetration was assessed and measured in pixels using the Image Pro Plus software program (Media Cybernetics, Westchester, PA), and later converted to millimeters. The right and left sealant-enamel incline interface of each section from the periphery to the central fissure were measured and assigned an independent score. If dye penetration was interrupted, the measurement assigned was from the periphery to the point of initial interruption (Plate 7). The leakage for each section was recorded as a percentage of dye penetration as related to the total length of the sealant from margin to depth of the fissure.

A one-way analysis of variance (ANOVA) statistical test was performed ($p<.001$) to examine for a difference in percent dye penetration between groups, and a Scheffe post-hoc analysis was done to identify which group or groups were different.

To test intra-examiner reliability 10 random sections were scored twice with at least a 24 hour separation between evaluations. A Pearson Product Moment Correlation Coefficient was used to determine the degree of association between the two measurements.

CHAPTER IV

RESULTS

A one-way ANOVA indicated that there was a significant difference in the percent dye penetration ($F = 99.03$, $df = 3$, $p<.001$) as a function of group. A Scheffe post-hoc analysis indicated that Group B (etch) had significantly less percent penetration than any other group. No other groups were significantly different from one another. The ranking of mean percent penetration from most to least was KCP 120 (96%), KCP 160 (81%), control (80%), and etch (10%), respectively (Figure 1). The mean and standard deviation of the percent dye penetration and dye penetration in millimeters for each group are shown in Table 1. Table 2 shows the results of the one-way ANOVA and the post-hoc statistical tests. Figure 1 demonstrates the mean percent penetration as a function of occlusal conditioning.

A two-factor ANOVA was done to determine if there was any significant effect on percent penetration as a function of side of sealant evaluated (right versus left) and groups. There was no significant effect attributable to the side evaluated ($F = 0.193$, $df = 1$, $p = 0.661$), but again, the effect of group was significant ($F = 96.7$, $df = 3$, $p< 0.001$).

There was no interactive effect of group and side of tooth evaluated. These results can be seen in Table 3.

To determine intra-examiner reliability in measuring the leakage, a random sample of 10 sections were evaluated on two different occasions separated by at least 24 hours. The amount of leakage in millimeters for each of the 10 sections was measured on each occasion. A Pearson Product Moment Correlation Coefficient was used to determine the degree of association between the amount of leakage for each right and left measurement for the two occasions. The correlation coefficient indicated a highly significant association in the consistency of evaluating the sections for leakage ($r = .999$, $N = 20$, $p < 0.001$) (Figure 2).

Representative sections from each group are shown in Plates 8-15, demonstrating various depths of microleakage measured in the groups.

CHAPTER V

DISCUSSION

The manufacturer of the KCP 2000 claims that the use of the KCP 2000 to condition enamel prior to sealant placement will alleviate the need for acid etching and thereby reduce sealant placement time. However, the results of this study demonstrate that the percent of dye penetration that occurred in teeth conditioned with the KCP 2000 prior to sealant placement was significantly greater than those conditioned with 37% phosphoric acid ($p < .001$). There was no statistically significant difference in microleakage between the KCP 2000 groups and the untreated control. Additionally, the KCP 2000 groups displayed significant leakage regardless of the cutting speed used. The amount of microleakage found with the KCP 2000 is unacceptable for successful long term sealant retention.

A 20 second etch with 37% phosphoric acid prior to sealant placement has been shown previously to demonstrate little or no leakage (Fuks et al., 1984). The results in this study for the acid etch group were consistent with these previous findings. Thirty three percent of the sections in the acid etch group displayed no leakage at all, and those sections that did exhibit microleakage demonstrated minimal leakage, only approximately 10% of the total sealant-enamel interface. In contrast, 99% of the KCP 2000 sections demonstrated microleakage and the mean percent dye penetration was 96% for the KCP 120 group and 81% for the KCP 160 group.

Studies that have utilized a non-etched control group (Crim and Shay, 1987; Fuks et al., 1984) have demonstrated significant leakage in these teeth. These results were duplicated in this study, with 98% of the untreated control sections demonstrating leakage and a mean percent penetration of 80%.

In the limited research published prior to the onset of this study regarding the KCP 2000, there had been no attempts to evaluate the extent of microleakage that occurs at the tooth-sealant interface. It was anticipated that the microleakage that would be found for the KCP 2000 conditioned teeth would be comparable to acid etch conditioned teeth because previous studies had shown KCP 2000 treated teeth to have enamel prisms affected to the same depth as acid conditioned teeth (Doty, 1994) and also to have shear bond strengths that were similar (Laurell et al., 1993a; Keen et al., 1994). However, this was not the case. Significantly more leakage was found in the KCP 2000 prepared teeth than in the acid etched teeth. The results of this study reveal a mean percent dye penetration for the KCP 2000 group prepared at 160 psi of 81% and a mean percent leakage for the 120 psi group of 96% compared to the 10% leakage of acid etched teeth.

Since the initiation of the present study, there has been one other report in the literature with regard to microleakage with the KCP 2000 and sealants (Eakle et al., 1995). The results of the present study are similar to these recently reported results. In that study which compared the microleakage under fissure sealants and Class I composite restorations conditioned with either the KCP 2000 or acid etch, all of the sealants conditioned with the KCP 2000 leaked. The leakage was severe for 80% of the KCP 2000 conditioned sealants. In contrast, 13 acid etched sealants exhibited no microleakage, and only two had minimal leakage. In addition, all Class I composite restorations prepared with the KCP 2000 leaked to or onto the pulpal floor. This was significantly greater leakage than the restorations that were acid etched.

Another recent report by Keen et al. (1995) compared the microleakage of air abraded (KCP 2000) and bur-prepared Class I and Class V composite restorations. The bur-prepared teeth were etched for 30 seconds with 37% phosphoric acid prior to resin placement. All teeth were thermocycled 100 times and immersed in basic fuchsin dye for 24 hours. Statistical analysis showed that Class I and V restorations which were air abraded or bur-prepared and acid etched experienced similar minimal microleakage. Their results were different from Eakle et al. and the present study because they found microleakage to be minimal in the Class I and Class V composite restorations prepared with the KCP 2000. Because this report exists only in abstract form at the present time, it is difficult to identify where differences in the methodology may have lead to conflicting results.

Since the initiation of the present study, two studies have reexamined the previously promising results with regard to the KCP 2000 and bond strength of composite resins. The results of these new studies have not been supportive of the KCP 2000's replacement of acid etch prior to resin placement. A recently published abstract by Horgesheimer et al. (1995) examined the shear bond strength of composite to air abraded enamel. Three groups received the following different treatment prior to bonding procedures: Group 1- acid etch with 37% phosphoric acid for 30 seconds; Group 2- air-abrasion with the KCP 2000 using 50 micron particle size and 160 psi; Group 3 - air-abrasion (50 microns, 160 psi) followed by acid etch for 30 seconds. Composite cylinders were applied to the prepared surfaces and all restorations thermocycled. Shear bond strengths were measured and the results showed the shear bond strength to enamel surfaces prepared with acid etch (with or without air-abrasion) was statistically greater than that obtained with air-abrasion alone.

Results regarding the effect of air-abrasion on bonding composite resin to dentin were recently reported (Rainey and

Barghi, 1995). This <u>in vitro</u> study examined human molars divided into two groups. The teeth were flattened into dentin and treated as follows: Group 1 - Air abraded (KCP 2000, ADT) with 27 micron size particles and 120 psi pressure; Group 2 - not subject to air-abrasion. Teeth in both groups were acid etched for an unreported length of time and had composite resin cylinders placed. The teeth were stored in 37 degrees celsius water for two weeks and subjected to shear bond strength testing. The results indicated that the use of the KCP 2000 did not improve the shear bond strength of composite resin to dentin.

The dye penetration method to study microleakage was chosen for this project. This method has been shown to be very informative and reliable (Jensen et al., 1978; Powell et al., 1977; Rudolph et al., 1974). Silver nitrate, the most commonly used dye, is stable, inexpensive, and readily available (Barnes et al., 1993).

Thermocycling is commonly used to simulate the thermal changes that take place in the oral cavity over time. However, a few studies indicate that <u>in vitro</u> thermocycling compromises the bond between restorative material and tooth structure, thus creating a potential for microleakage that is even more significant than the oral thermal changes it attempts to mimic (Litkowski et al., 1989; Crim et al., 1985). Litkowski et al. (1989) have reported that thermocycling increases the amount of microleakage that occurs in composite restorations. Barnes et al. (1993) demonstrated in a comparison of microleakage of in vivo and in vitro Class V composite resin restorations that the restorations thermocycled in vitro had significantly more leakage than restorations placed in vivo. Although future research may be necessary to find a design that is more representative of the oral environment, the thermocycling technique is very commonly utilized and is the best method available at this time.

A measurement scale utilizing percentage was chosen by this examiner. Two commonly used measurement scales for microleakage are: 1) an absolute distance measure of dye penetration (in millimeters) or, 2) an ordinal scale as follows:

0 - no dye penetration

1 - dye penetration limited to the outer 1/2 of the sealant

2 - dye penetration extending to the inner 1/2 of the sealant but short of the central fissure

3 - penetration from the periphery to the central fissure.

A third measurement scale, and the one chosen for this study, utilizes a percentage measure of the microleakage. This examiner felt that percentage was a more reliable and sensitive measurement. Use of this ratio measurement scale allowed for utilization of powerful parametric statistical tests to analyze the data. In addition, it allows a more reliable and accurate description of the extent of dye penetration. Misrepresenting the microleakage was avoided by reporting the dye penetration as a percentage of the total length of the sealant in a situation where two separate sections each demonstrated two millimeters of microleakage, but one section (section A) had a total length of six millimeters and the other section (section B) had a total length of two millimeters. In section A, the sealant-enamel interface is six millimeters in length and microleakage occurs that penetrates two millimeters along the interface. This demonstrates a 33% penetration toward the fissure. Section B demonstrates a sealant-enamel interface of two millimeters in length and dye penetration of two millimeters which in this case represents 100% penetration. In this situation, a distance measurement of the microleakage would report an equal score of two millimeters for sections A and B. However, a more accurate description of the microleakage would be 33% for section A and 100% for section B. For these reasons, a ratio scale of percent dye penetration was used for this study.

A pilot study was conducted prior to this project to familiarize the examiner with the mounting process, use of the dye, the sectioning technique, the measurement technique, and to allow the practitioner to become experienced with the KCP 2000. In addition to the experience gained through the pilot study, the practitioner prepared several teeth with the KCP 2000 just prior to conducting this study. As a result of the pilot study changes were made in the methodology, such as using silver nitrate dye in place of basic fuchsin dye, and experience was gained that added to the strength and validity of this project.

The examiner attempted to control as many variables present in this study as was possible with the exception of the test variable of tooth conditioning. A single practitioner conditioned and sealed all of the teeth using a second-hand clock to carefully monitor etch time, rinse time, and polymerization time. All of the teeth were prepared in the same lab during the same time period. The evaluator was blinded and intraexaminer reliability was established.

Occasionally, sections were seen that showed microleakage extending toward the depth of the fissure and also in the center of the fissure, but with an area in between that demonstrated no microleakage. The decision was made to score the interrupted display of dye penetration from the periphery of the sealant to the point of initial interruption (Plate 7). The sections obtained for observation in this study were a two dimensional representation of a three dimensional object. The examiner viewed the secondary dye penetration as being potentially contributed from the mesial or distal direction as opposed to the buccal or lingual periphery of the sealant. The number of sections displaying an irregular pattern were minimal and did not have an influence on the significance of the results.

This project was designed to examine the test groups for a difference in percent dye penetration, and not to identify the cause of these differences. However, several potential explanations can be offered for the results obtained. As well, future research projects can be proposed that may help to explain these results and further examine the usefulness of the KCP 2000.

A contributing factor to the results obtained in this study may be the pattern or quality of etch produced by the KCP 2000. Although the depth of penetration of bonding agent into enamel of teeth conditioned with acid and the KCP 2000 has been shown to be comparable (Doty et al., 1994), the authors did report an irregular etch pattern for the KCP 2000. It is possible that the KCP 2000 may produce an etch with enough micropores of adequate depth to retain a resin with adequate bond strength. However, the irregular etch pattern may leave areas with poor resin-enamel interface and thus avenues for microleakage. A scanning electron microscope study which examines the type and the characteristics of enamel conditioned by the KCP 2000 would help to address this issue.

Another factor to consider is the possibility of a highly reactive surface left by the acid etch that is not duplicated by the KCP 2000 etch. This idea was set forth as early as Buonocore's original work with phosphoric acid (Buonocore, 1955). He hypothesized that highly polar groups were present on the enamel surface as a result of acid etching and that this could result in a polar bond to the resin. If this is indeed accurate, it is possible that the KCP 2000 etch fails to result in such a charged surface, thus compromising the intimacy of the resin-enamel interface. This theory would be difficult to study.

Another factor which could have influenced the outcome of this study is the practitioner's experience with the KCP 2000. However, to minimize this possibility, a single practitioner, who was trained on the KCP 2000 and gained experience through multiple practice sessions including a pilot study, prepared all the teeth. The practitioner carefully followed the manufacturer's recommendations for conditioning. The manufacturer claims the unit is easy to use and the investigator found that it took minimal practice to achieve consistent results. The effect of practitioner experience with the KCP 2000 as a variable could be examined by repeating the current study using three KCP 2000 operators with varying experience levels to replace the one operator as used in this study. The three different operators with varying experience levels would be (1) a beginner with no experience, (2) an intermediate with training and limited experience, and (3) an "expert" with extensive experience.

Another factor which can contribute to significant microleakage is contamination of the conditioned tooth prior to sealant placement. Numerous studies have shown that moisture contamination of etched enamel will alter the etched surface pattern and disrupt the intimate bond of resin and tooth, thus promoting microleakage (Hormati et al., 1980; Wood and Barkmeier, 1979). However, in this study the same air-water syringe and tip was utilized for all four study groups. If moisture contamination was a factor in this study, the acid etch group would have demonstrated the same significant microleakage as demonstrated in the KCP 2000 groups. But in this study, the etch group displayed significantly less microleakage than the KCP 2000 groups or untreated control group, leading to the conclusion that moisture contamination was not a factor.

The sections were evaluated blindly by one examiner with respect to the type of surface treatment. Intraexaminer reliability was shown to be very high through repeated measures 24 hours apart (Figure 2).

No attempt was made in this study to examine multiple sealant materials. Future studies could focus on this issue. The viscosity of different sealant materials will vary. The penetration coefficient is a measure of a material's ability to flow over a surface and is inversely proportional to the material's viscosity. Perhaps examining multiple sealants with varying penetration coefficients may identify certain materials which best penetrate the micropores produced by the KCP 2000 and better prevent marginal leakage than the sealant used in the present study (Ball, 1986; O'Brien et al., 1978;

Wright and Retief, 1984). However, because the sealant used in this study is unfilled and of low viscosity, it ought to demonstrate as good penetration as any sealant marketed.

Future research might also examine the additive effect on microleakage of widening the fissures and removing incipient decay with the KCP 2000 and then conditioning the surface with phosphoric acid prior to sealant placement. It is possible that this may produce a resin-tooth interface more resistant to leakage than either technique alone because of a deeper, more uniform etched surface with an increase in surface area. As well, it may indicate an even greater reduction in acid etch time is acceptable following preparation with the KCP 2000, which would have a significant clinical effect.

The results of this study have important clinical implications. The significant difference in dye penetration between the etch group and the KCP 2000 groups in this study suggests a poor marginal seal of KCP 2000 treated enamel. Marginal areas have been identified as dynamic microcrevices which contain a busy flow of bacteria, ions, and molecules, and significant microleakage under sealants will lead to their failure (Myers, 1966). The KCP 2000 is highly touted by the manufacturer as an alternative or substitute to acid etching prior to sealant placement. The manufacturer identifies this as a major clinical benefit of the unit, claiming a sealant can be placed in less than 60 seconds using this technique.

However, no study prior to the onset of this study had examined the important concept of microleakage that may take place at the sealant-resin interface when this technique is used.

Microleakage at the tooth-restoration interface of composite resins may lead to staining, postoperative sensitivity, adverse pulpal response, loss of the restoration, or recurrent caries, which could ultimately result in failure of the restoration. Therefore, any technique used to condition a tooth surface prior to resin placement should be examined as to its effectiveness in creating an adequate marginal seal.

The results of this study indicate that the use of the KCP 2000 as an alternative method of tooth conditioning to replace acid etching prior to placement of a sealant can not be recommended due to the significant marginal leakage demonstrated. Further research is necessary in the area of air-abrasion to help explain these microleakage results. The usage of the KCP 2000 to detect and remove decay, remove stain, and widen grooves prior to sealant placement remain advantages to the clinician. However, at this time, acid etching prior to resin placement remains a vital step in the procedure, even with the use of the KCP 2000.

CHAPTER VI

CONCLUSIONS

- The microleakage of teeth conditioned solely with air-abrasion (KCP 2000) is significantly greater than the microleakage seen with enamel conditioned with 37% phosphoric acid.
- The microleakage of teeth conditioned with air-abrasion (KCP 2000) is not significantly different from the microleakage seen with the untreated controls.
- Based on the results of this investigation the use of air-abrasion (KCP 2000) as a substitute for acid etch as a tooth conditioner prior to sealant placement cannot be recommended.

APPENDICES

APPENDIX A

Plate I. KCP 2000

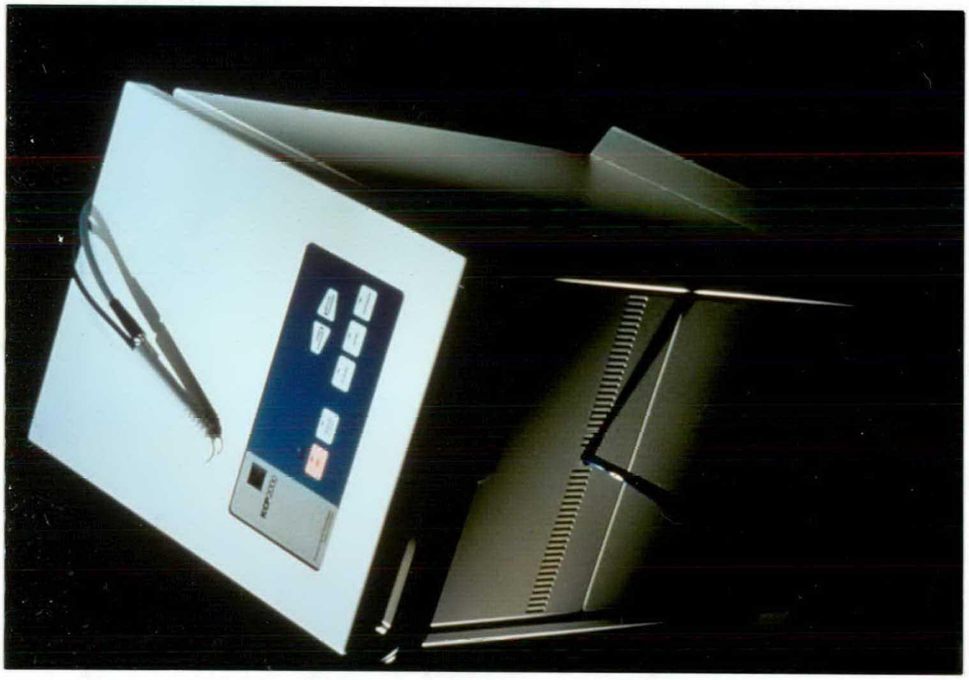

Plate II. Mounting Process I

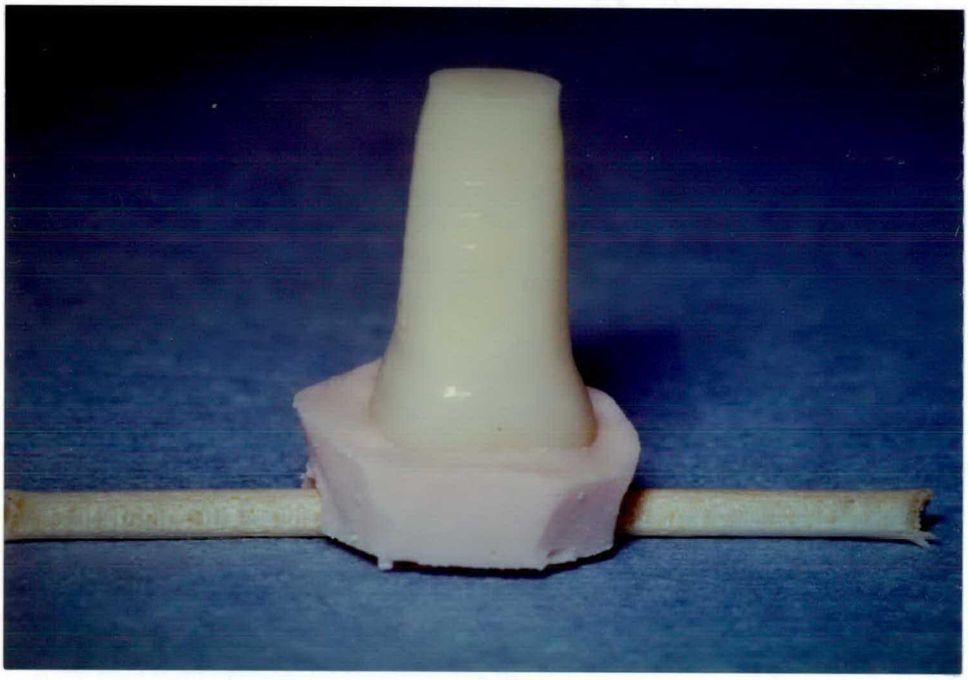

Plate III. Mounting Process II

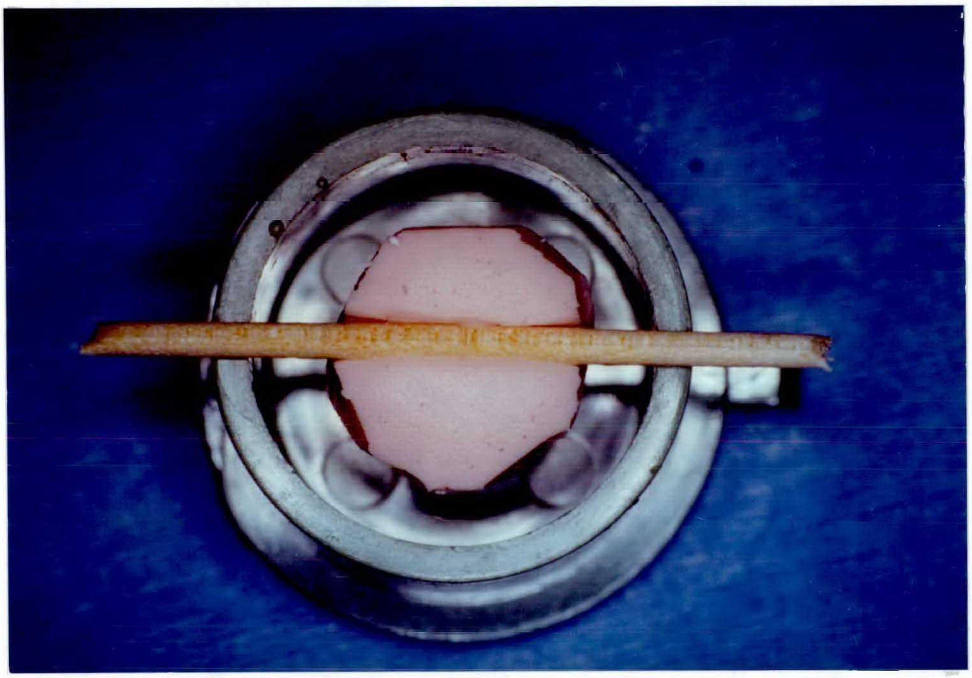

Plate IV. Sealant Applicator

Plate V. Thermocycling Unit

Plate VI. Digital Image Analyzer

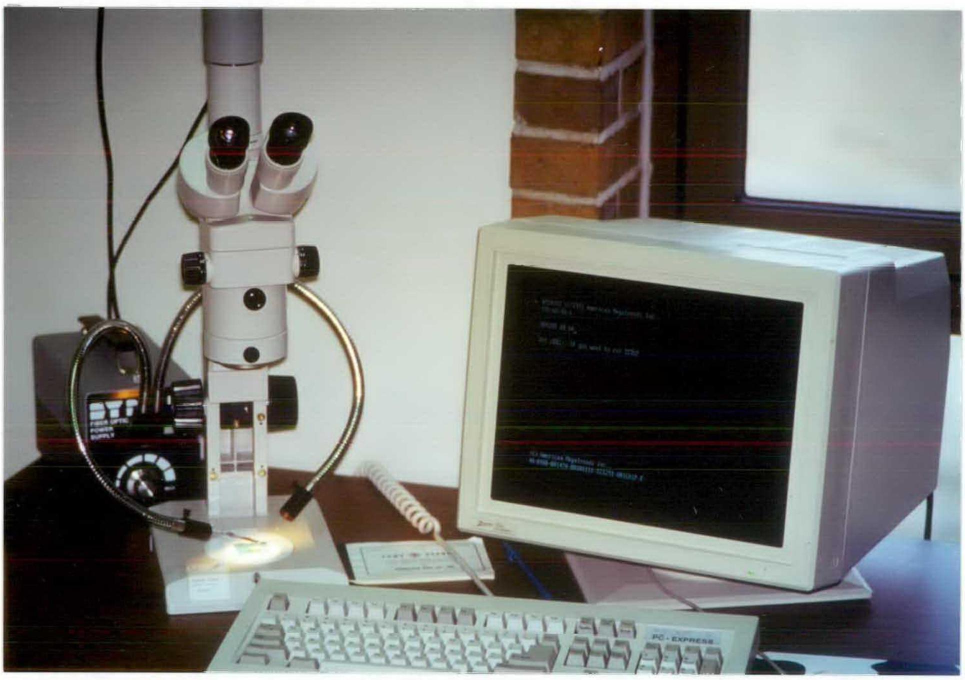

Plate VII. Interrupted Microleakage

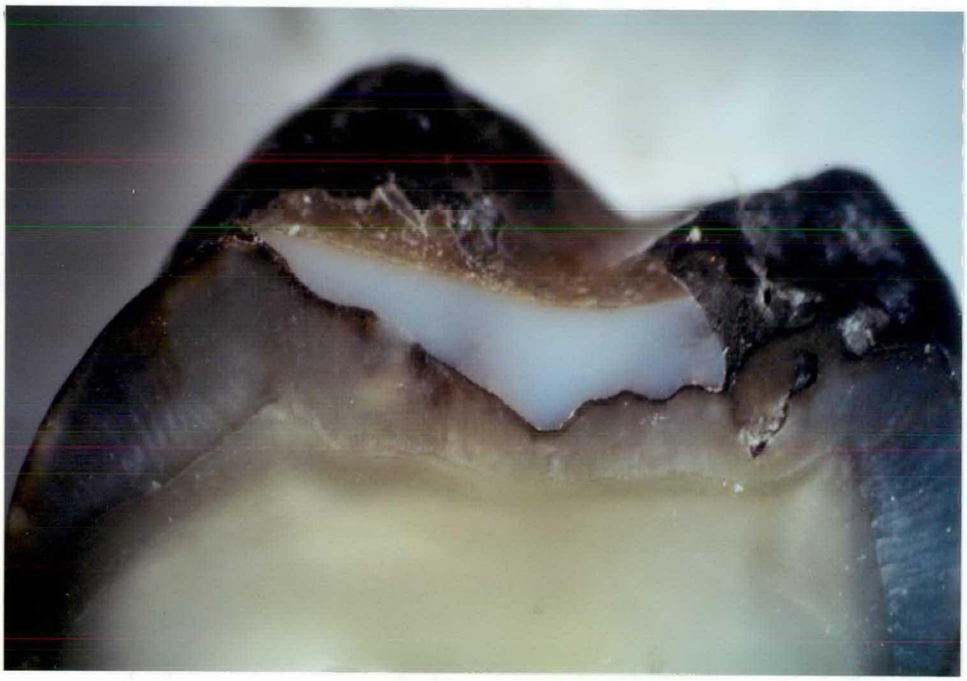

Plate VIII. Control Group I

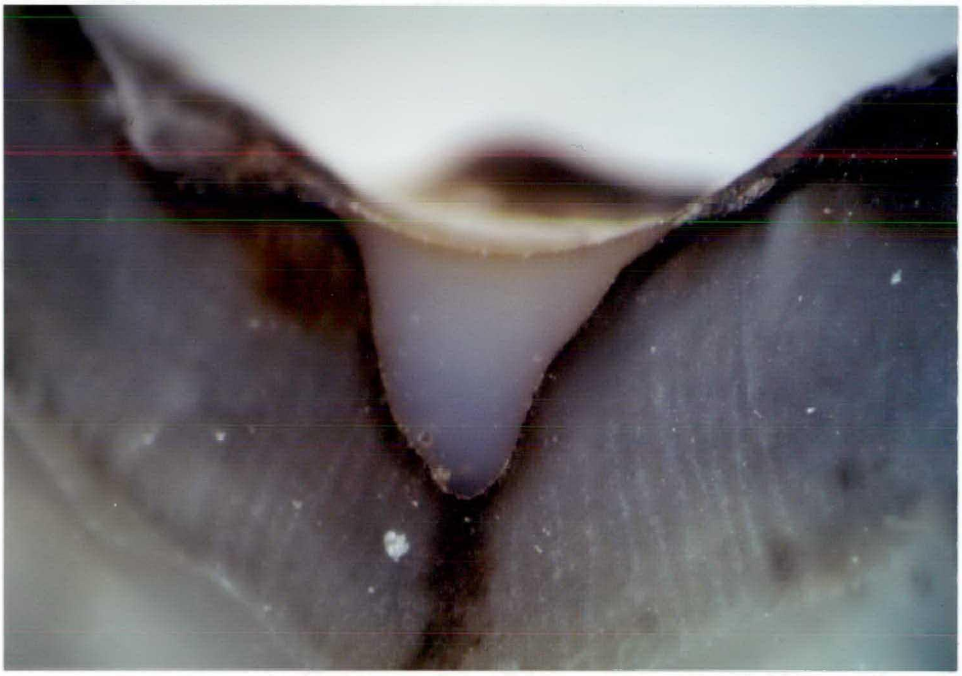

Plate IX. Control Group II

Plate X. Acid Etch Group I

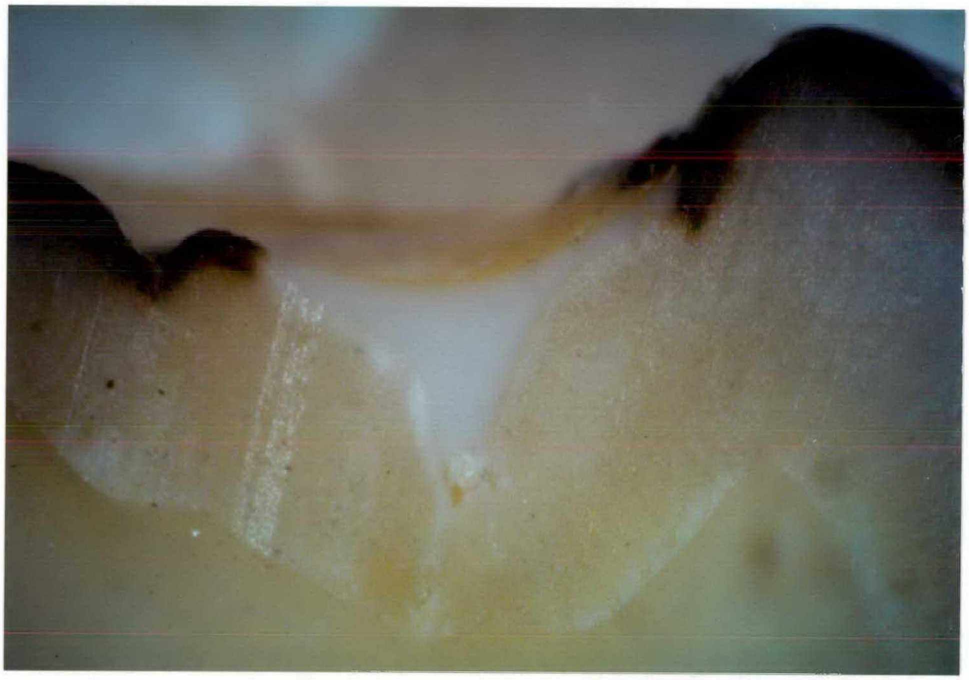

Plate XI. Acid Etch Group II

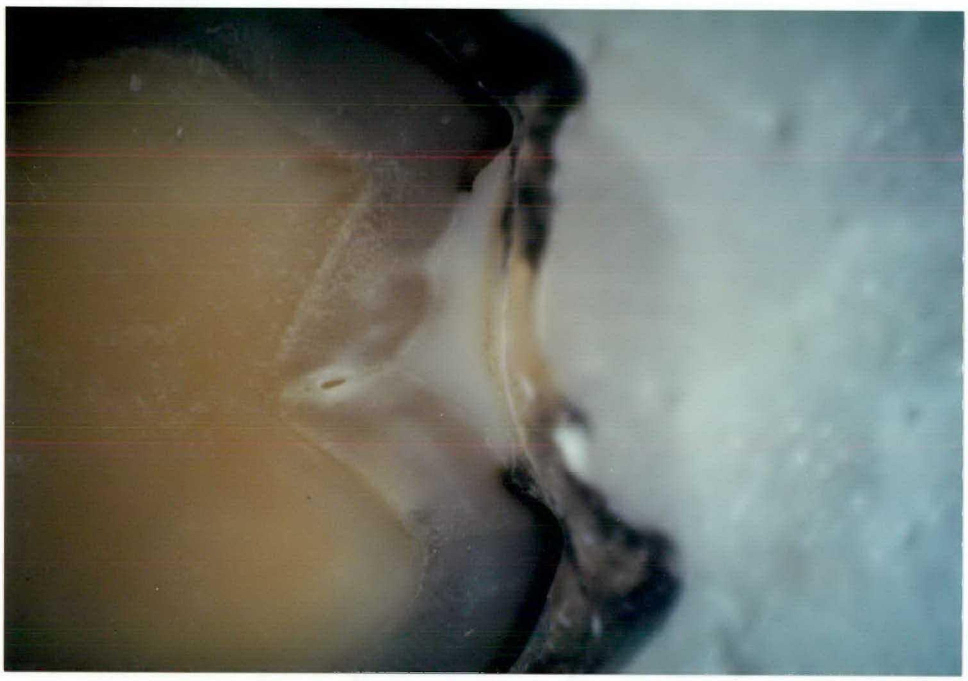

Plate XII. KCP 160 Group I

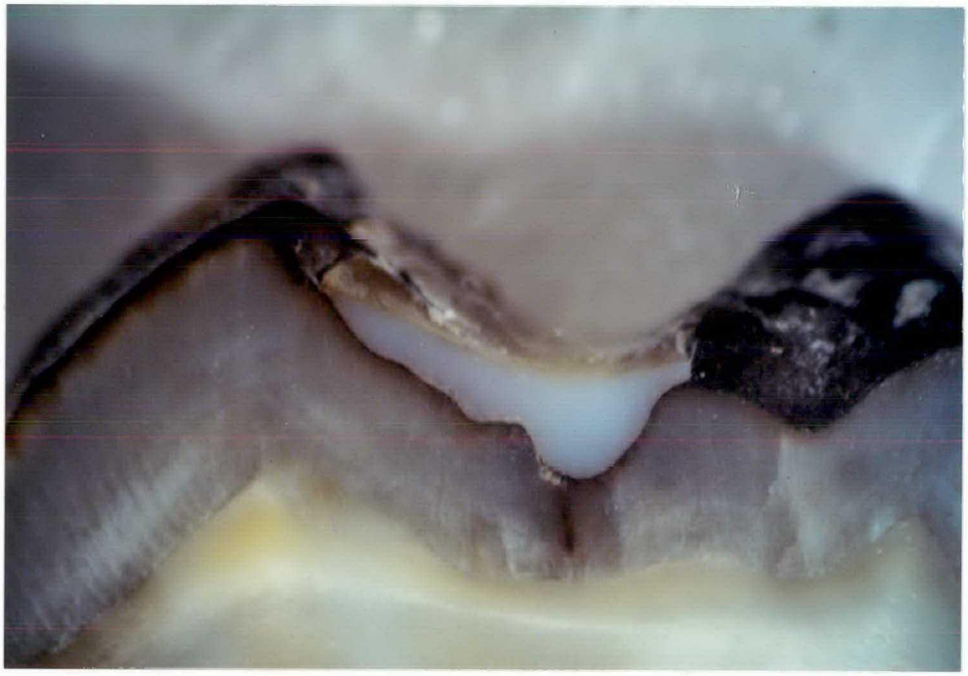

Plate XIII. KCP 160 Group II

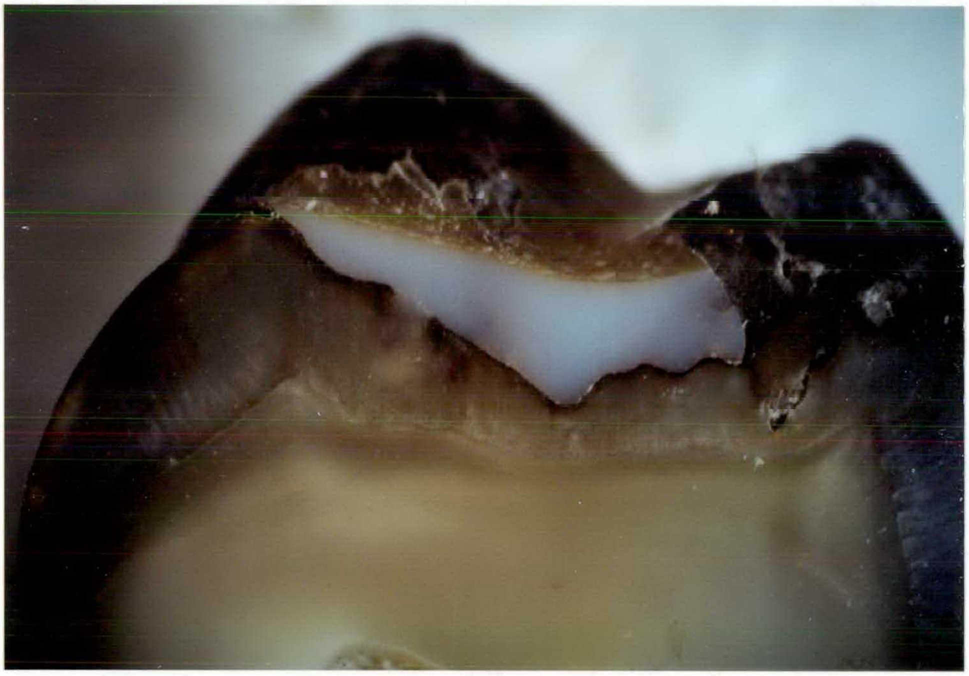

Plate XIV. KCP 120 Group I

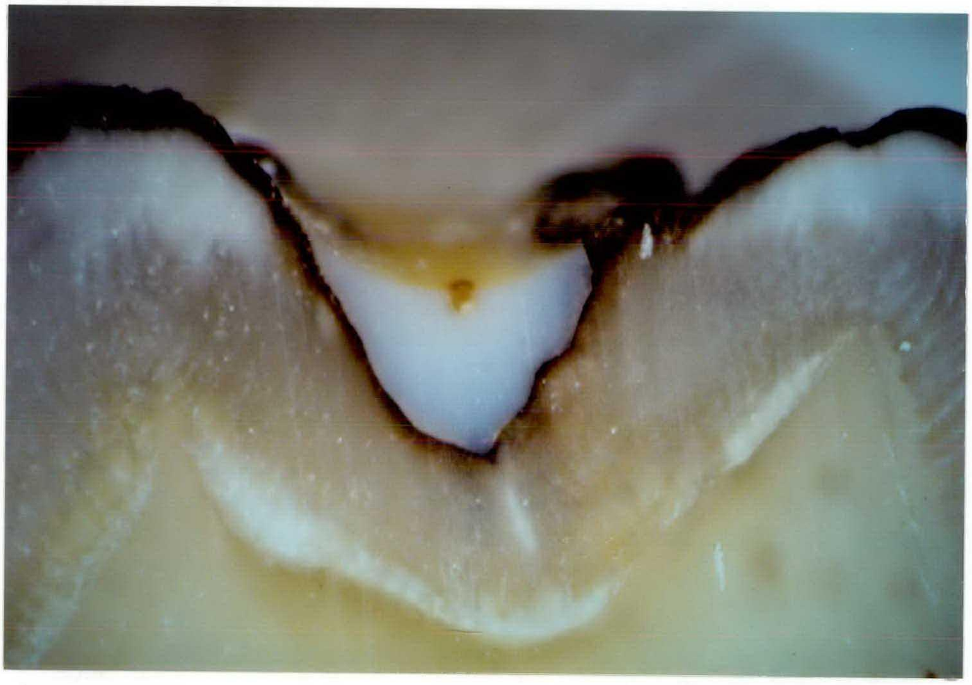

Plate XV. KCP 120 Group II

APPENDIX B

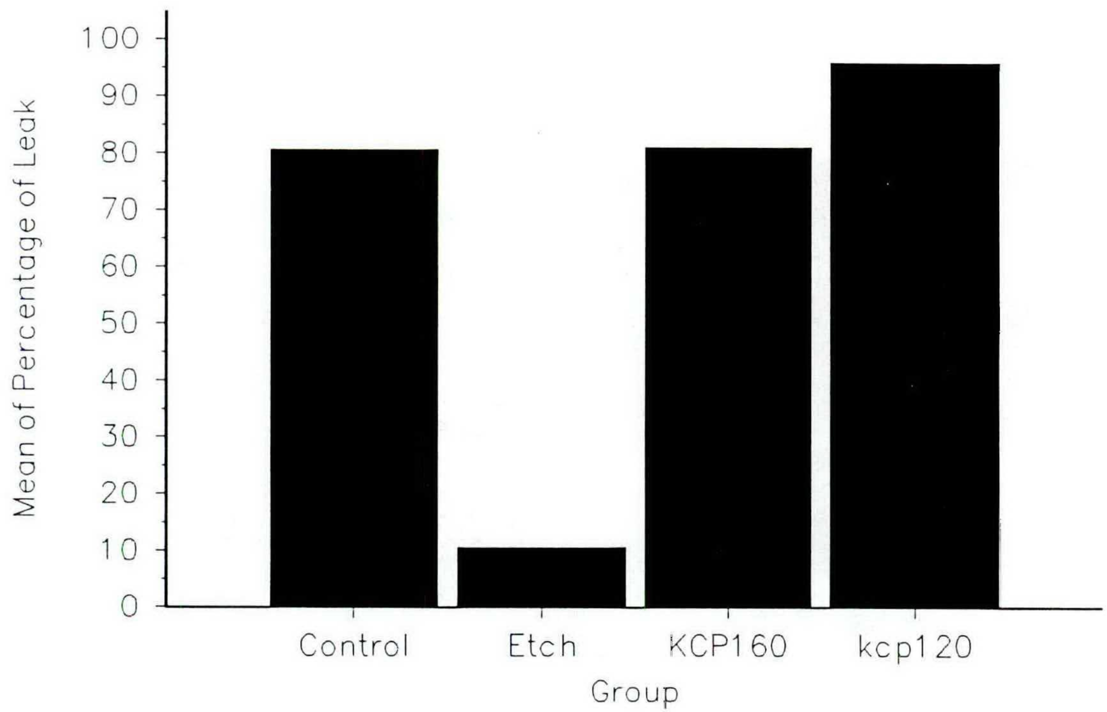

Figure 1. Mean % Penetration as a Function of Occlusal Conditioning

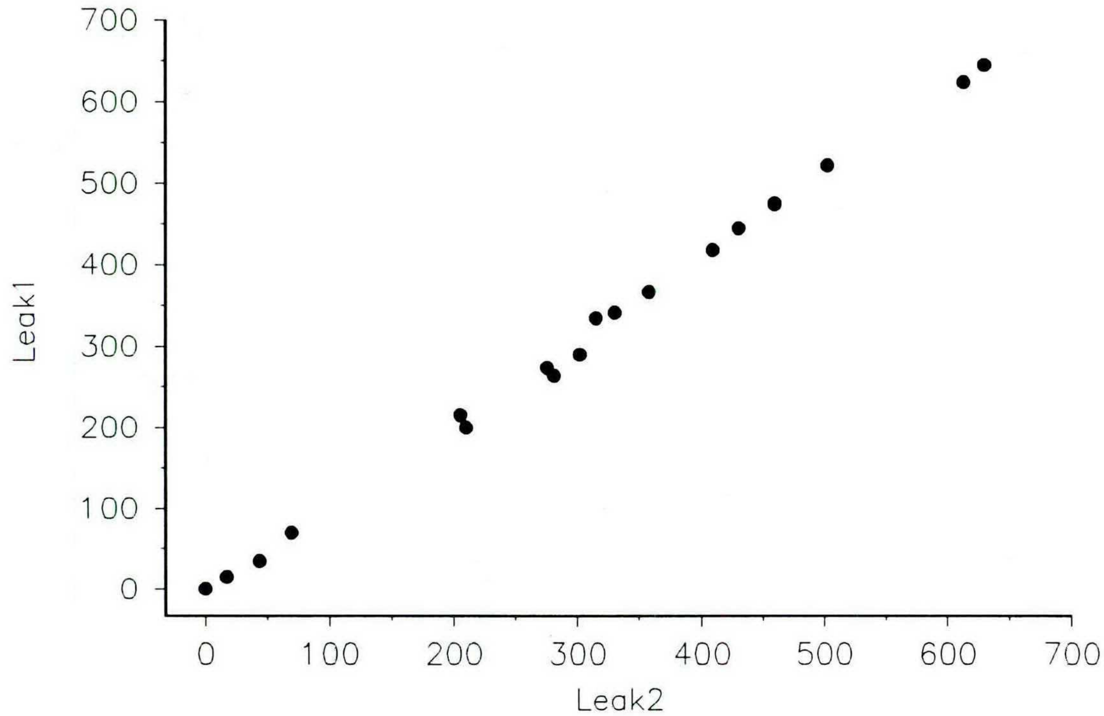

Figure 2. Scattergraph Demonstrating Intra-Examiner Reliability

APPENDIX C

Table 1. Mean % Penetration and Leakage in Millimeters Evaluated as a Function of Group

Group	% Penetration	Leak in mm
Etch	10.4 ± 15.2	0.28 ± 0.4
Control	80.4 ± 30.5	1.72 ± 0.9
KCP 160	81.0 ± 32.9	2.50 ± 1.5
KCP 120	96.0 ± 11.8	2.22 ± 1.2

Table 2. One-Way ANOVA for % Penetration and Leakage in Millimeters as a Function of Group.

Variable	F	d.f.	p
% Penetration	99.03	3	0.001
Leakage in MM	31.2	3	0.001

Table 3. A 2-Factor ANOVA of the % Penetration as a Function of Right and Left Slope and Groups.

Variable	F	d.f.	p
Group	96.78	3	0.001
Slope	0.193	1	0.611
Grp X Slope Interaction	0.103	3	0.958

APPENDIX D

RAW DATA

GROUP	SECTION	% PENETRATION
1	5R	100
1	5L	84
1	6R	100
1	6L	100
1	14R	91
1	14L	18
1	17R	100(lost)
1	17L	100(lost)
1	21R	100
1	21L	100
1	23R	100(lost)
1	23L	100(lost)
1	28R	100
1	28L	72
1	32R	10
1	32L	9
1	36R	71
1	36L	80
1	38R	78
1	38L	74
1	41R	88
1	41L	84
1	45R	100
1	45L	100
1	49R	100
1	49L	100
1	52R	47
1	52L	68
1	56R	81
1	56L	100
1	58R	0
1	58L	13
1	60R	100
1	60L	100
1	67R	78
1	67L	100
1	72R	100
1	72L	100
1	75R	100
1	75L	100
2	2R	23
2	2L	6
2	4R	6
2	4L	24
2	9R	5
2	9L	0
2	13R	7

2	13L	0
2	15R	5
2	15L	0
2	20R	13
2	20L	6
2	26R	0
2	26L	0
2	29R	6
2	29L	35
2	31R	9
2	31L	0
2	39R	8
2	39L	0
2	42R	14
2	42L	20
2	44R	15
2	44L	0
2	46R	42
2	46L	8
2	51R	4
2	51L	0
2	62R	0
2	62L	5
2	63R	9
2	63L	36
2	65R	0
2	65L	6
2	70R	11
2	70L	0
2	74R	10
2	74L	78
2	77R	7
2	77L	0
3	1R	100
3	1L	84
3	8R	100
3	8L	25
3	11R	100
3	11L	81
3	18R	2
3	18L	100
3	22R	100
3	22L	100
3	25R	100
3	25L	100
3	27R	17
3	27L	100
3	30R	100
3	30L	100
3	34R	100
3	34L	14
3	35R	100

3	35L	100
3	47R	0
3	47L	8
3	50R	100
3	50L	44
3	54R	95
3	54L	82
3	57R	100
3	57L	100
3	59R	76
3	59L	100
3	66R	100
3	66L	100
3	68R	100
3	68L	100
3	71R	64
3	71L	100
3	73R	100
3	73L	100
3	78R	49
3	78L	100
4	3R	100
4	3L	100
4	7R	100
4	7L	93
4	10R	100
4	10L	100
4	12R	43
4	12L	91
4	16R	100
4	16L	100
4	19R	64
4	19L	100
4	24R	100
4	24L	100
4	33R	100
4	33L	100
4	37R	100
4	37L	100
4	40R	100
4	40L	100
4	43R	100
4	43L	100
4	48R	100
4	48L	84
4	53R	100
4	53L	100
4	55R	100
4	55L	100
4	61R	66
4	61L	100
4	64R	100

4	64L	100
4	69R	100
4	69L	100
4	76R	100
4	76L	100
4	79R	100(lost)
4	79L	100(lost)
4	80R	100(lost)
4	80L	100(lost)

LIST OF REFERENCES

Ball IA: An update on fissure sealants. Prev Dent. 1:380-388, 1986.

Barkmeier WW, Gwinnett AJ, Shaffer SE: Effects of enamel etching time on bond strength and morphology. J Clin Ortho. 19:36-38, 1985.

Barkmeier WW, Shaffer SE, Gwinnett AJ: Effects of 15 versus 60 seconds enamel acid conditioning on adhesion and morphology. Oper Dent. 11:111-116, 1986.

Barnes DM, Blank LW, Thompson VP, McDonald NJ: Microleakage of class 5 composite resin restorations: A comparison between in vivo and in vitro. Oper Dent. 18:237-245, 1993.

Berry EA, Berry LL, Powers JM: Bonding of hybrid ionomer to air-abraded enamel and dentin. J Dent Res. 73:183, Abstract 654, 1994.

Black R: Technique for nonmechanical preparation of cavities and prophylaxis. JADA. 32:953-965, 1945.

Black R: Application and reevaluation of air abrasive technique. JADA. 50: 408-413, 1955.

Blankenau RJ, Kelsey WP, Powell GL: Degree of composite resin polymerization with visible light and argon laser. Am J Dent 4:40, 1991.

Bodecker CF: The eradication of enamel fissures. Dent Items Int. 51:859-63, 1929.

Boksman L, Gratton DR, McCutcheon E, Plotzke OB: Clinical evaluation of a glass ionomer cement as a fissure sealant. Quint Int. 18:707-709, 1987.

Bowen RL: Dental filling materials comprising vinyl silane treated fused silica and a binder consisting of the reaction product of bisphenol and glycidyl acrylate, U.S. Patent 3; 066, 112, 1962.

Bowen RL: Properties of a silica-reinforced polymer for dental restorations. JADA. 66:57, 1963.

Bowen RL: Composite and sealant resins- past, present, and future. Pediatr Dent. 4: 10-15, 1982.

Bruer GM, Termini DJ: Bonding of bovine enamel to restorative resin: Effects of pretreatment of enamel. J Dent Res. 34: 151-160, 1972.

Buonocore MG: A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res. 34:849-54, 1955

Charbeneau GT: Pit and fissure sealants. J Dent. 32:315, 1982.

Charlton DG, Moore BK: in vitro evaluation of two microleakage detection tests. J Dent. 20:55-58, 1992.

Conlon DJ, Silverstone LM: A comparison of the effect of etching all five tooth surfaces of single teeth in vitro. J Dent Res. 61 (Special Issue A): Abstract # 87; 244, 1982.

Cooley RL, McCourt JW, Huddleston AM: Evaluation of a fluoride-containing sealant by SEM, microleakage, and fluoride release. Pediatr Dent. 12:38, 1990.

Council on Dental Materials and Devices. Nuva Seal Pit-And-Fissure Sealant Classified as Provisionally Accepted. JADA. 84:1109, 1972.

Crim GA, Garcia-Godoy F: Microleakage: The effect of storage and cycling duration. J Prosth Dent. 57:574-576, 1987.

Crim GA, Shay JS: Effect of etchant time on microleakage. J Dent Child. 54:339-340, 1987.

Crim GA, Swartz ML, Phillips RW: A comparison of four thermocycling techniques. J Prosth Dent. 53:50-53, 1985.

Cueto EI, Buonocore MG: Sealing of pits and fissures with an adhesive resin: Its use in caries prevention. JADA. 75:121-128, 1967.

Doty WD, Pettey D, Holder R, Phillips S: KCP 2000 enamel etching abilities tested. J Dent Res. 73:411, Abstract 2474, 1994.

Eakle WS, Goodis HE, White JM, Do HK: Effect of microabrasion on dentin permeability and bond strength. J Dent Res. 73:131, Abstract 239, 1994.

Eakle WS, Wong J, Huang H: Microleakage with microabrasion versus acid etched enamel and dentin. J Dent Res. 74:31, Abstract 160, 1995.

Edelstein B, Tinanoff N: Screening preschool children for dental caries using a microbial test. Pediatr Dent. 11:129-132, 1989.

Eidelman E, Shapira J, Houpt M: The retention of fissure sealants using 20 second etching time: three year follow-up. J Dent Child. 5:119, 1988.

Ekstrand K, Quist V, Thylstrup A: Light microscope study of the effect of probing in occlusal surfaces. Caries Res. 21:368-74, 1987.

Flaitz CM, Hicks MJ, Silverstone LM: Radiographic, histological, and electronic comparison of occlusal caries: an in vitro study. Pediatr Dent, 8:24-27, 1986.

Forss H, Saarni U-M, Seppa L: Comparison of glass-ionomer and resin-based fissure sealants: A two year clinical trial. Community Dent Oral Epidemiol. 22:21-24, 1994.

Fuks A, Grajower R, Shapira J: in vitro assessment of marginal leakage of sealants placed in permanent molars with different etching times. J Dent Child. 51:425-427, 1984.

Galil KA: Scanning and transmission electron microscope examination of occlusal plaque following tooth brushing. J Can Dent Assoc. 41:499-504, 1975.

Gottlieb EW, Retief DH, Bradley EL: An optimum concentration of phosphoric acid as an etching agent. Part I: Tensile bond strength studies. J Prosth Dent. 48:48-51, 1982.

Gross JD, Retief DH, Bradley EL: An optimum concentration of phosphoric acid as an etching agent. Part II: Microleakage studies. J Prosth Dent. 52:786-789, 1984.

Gwinnett AJ, Buonocore MG: Adhesive and caries prevention: A preliminary report. Br Dent J. 119:77-80, 1965.

Gwinnett AJ, Ripa LW: Penetration of pit and fissure sealants into conditioned human enamel in vivo. Arch Oral Biol. 18:435-441, 1973.

Hicks MJ, Flaitz CM: Epidemiology of dental caries in the pediatric and adolescent population: A review of past and current trends. J Clin Ped Dent. 18: 43-47, 1993.

Hicks MJ, Flaitz CM, Silverstone LM: The current status of dental caries in the pediatric population. J Pedodont. 10:57-62, 1985.

Hicks MJ, Flaitz CM, Silverstone LM: Secondary caries formation in vitro around glass ionomer restorations. Quint Int. 17:527, 1986.

Horgesheimer JJ, Haws SM, Kanellis MJ, Vargas MA: Composite shear bond strength to air-abraded enamel. J Dent Res. 74:32, Abstract 162, 1995.

Hormati AA, Fuller JL, Denehy GE: Effects of contamination and mechanical disturbance of the quality of acid etched enamel. JADA. 100(1):34, 1980.

Houpt M, Fuks A, Eidelman E: Measuring the stickiness of pits and fissures in enamel. Clin Prev Dent. 7:28, 1985.

Houpt M, Shey Z: The effectiveness of a fissure sealant after 6 years. Ped Dent. 5:104-106, 1983.

Hyatt TP: Prophylactic odontotomy: The cutting into the tooth for prevention of disease. Dent Cosmos. 17:234-39, 1923.

Jensen OE, Handelman SL: in vitro assessment of marginal leakage of six enamel sealants. J Prosth Dent. 39:304-306, 1978.

Keen DS, Parkins FM, Crim GA: Microleakage of composite restorations prepared with air-abrasive technique. J Dent Res. 74:36, Abstract 199, 1995.

Keen DS, von Fraunhofer JA, Parkins FM: Air- abrasive "etching": Composite bond strengths. J Dent Res. 73:131, Abstract 238, 1994.

Laurell K, Carpenter W, Beck M: Pulpal effects of airbrasion cavity preparation in dogs. J Dent Res. 72:273, Abstract 1360, 1993b.

Laurell K, Carpenter W, Beck M: Pulpal effects of composite and amalgam removal with airbrasion. J Dent Res. 73:318, Abstract 1730, 1994b.

Laurell KA, Fisher TE, Johnston W: Airbrasion effects on dentin permeability. J Dent Res. 73:215, Abstract 907, 1994a.

Laurell K, Lord W, Beck M: Kinetic cavity preparation effects on bonding to enamel and dentin. J Dent Res. 72:283, Abstract 1437, 1993a.

Litkowski LJ, McDonald NJ, Swierczewski M: A comparison of thermocycling methods for evaluating microleakage. J Dent Res. 68:207, Abstract 208, 1989.

Lussi A: Validity of diagnostic and treatment decision of fissure caries. Caries Res. 25: 296-303, 1991.

Manson-Rahemtulla B, Retief DH, Jamison HC: Effect of concentrations of phosphoric acid on enamel dissolution. J Prosth Dent. 51: 495-498, 1984.

McKnight-Hanes C, Myers DR, Salama FS, Thompson WO, Barenie JT: Comparing treatment options for occlusal surfaces utilizing an invasive index. Pediatr Dent. 12:241-245, 1990.

Milgrom P, Weinstein P: Dental fear in general practice: New guidelines for assessment and treatment. Int Dent J. 43:288-293, 1993.

Morrison AH, Berman L: Evaluation of the airdent unit: Preliminary report. JADA. 46:298-303, 1953.

Myers HM: Dental Pharmacology, in Shapiro M (ed): The Scientific Bases In Dentistry. Philadelphia, WB Saunders Co, 1966, p 285.

National Center for Health Statistics: Decayed, Missing and Filled Teeth Among Children: United States. Vital and Health Statistics, Series 11, No 106. DHEW Publication No. (HSM) 72-1003. Washington, D.C., U.S. Government Printing Office, 1971.

National Center for Health Statistics: Decayed, Missing and Filled Teeth Among Youths 12-17 Years: United States. Vital and Health Statistics, Series 11, No 144. DHEW Pub. NO. (HRA) 75-1626. Washington, D.C., U.S. Government Printing Office, 1974.

National Institute of Dental Research, National Caries Program: The Prevalence of Dental Caries in U. S. Children, 1979-1980. NIH Pub. No. 82-2245. Bethesda, MD, National Institutes of Health, 1981.

National Institute of Dental Research, National Caries Program: Epidemiology and Oral Disease Prevention Program: Oral Health of U. S. School Children: The National Survey of Dental Caries in U. S. School Children: 1986-1987. NIH Pub. No. 89-2247, Bethesda, MD, National Institutes of Health, 1989.

O'Brien WJ, Fan PL, Apostolidis A: Penetrativity of sealants and glazes. Oper Dent. 3:51, 1978.

Oshawa T: Studies on solubility and adhesion of the enamel in pretreatment for caries preventing sealing. Bull Tokyo dent Coll. 13: 65-82, 1972.

Powell BP, Johnston JD, Hembre JH: Microleakage around a pit and fissure sealant. J Dent Child. 44:298-301, 1977.

Rainey JT, Barghi N: Effect of micro-abrasion on bonding to dentin. J Dent Res. 74:30, Abstract 147, 1995.

Retief DH, Bischoff J, van der Merwe E: Pyruvic acid as an etchant agent. J Oral Rehab. 3: 245-265, 1976.

Ripa L: Occlusal sealing: Rationale of the technique and historical review. JASPD. 1:32-39 1973.

Ripa L: Occlusal sealants: Rationale and review of clinical trials. Int Dent J. 30:127-139,1980.

Ripa LW: Sealants revisited: An update of the effectiveness of pit and fissure sealants. Caries Res. 27 (suppl. 1), 77-82, 1993.

Ripa LW, Cole WW: Occlusal sealing and caries prevention: Results 12 months after a single application of adhesive resin. J Dent Res. 49: 171-173, 1970.

Roeder LB, Berry EA, You C, Powers JM: Bond strength of composite to air-abraded enamel and dentin. J Dent Res. 73:131, Abstract 237, 1994.

Rohr M, Makinson OF, Burrow MF: Pit and fissures: Morphology. J Dent Child. 58:97, 1991.

Rudolph JJ, Phillips RW, Swartz ML: <u>in vitro</u> assessment of microleakage of pit and fissure sealants. J Prosth Dent. 32:62-65, 1974.

Schulein TM, Chan DC, Reinhardt JW: Rinsing times for a gel etchant related to enamel/composite bond strength. Gen Dent. 4:296-298, 1986.

Silverstone LM: Fissure Sealants: Laboratory Studies. Caries Res. 8: 2-26, 1974.

Silverstone LM: The acid etch technique: <u>in vitro</u> studies with special reference to the enamel surface and the enamel resin interface. Proc. Int. Symp. Acid Etch Tech. L. M. Silverstone and I. L. Dogon, Eds. St. Paul: No. Central Publication Co., 13-35, 1975a.

Silverstone LM: State of the art on sealant research and priorities for further research. J Dent Ed. 48:No 2 (Supplement), 107-118, 1984.

Silverstone LM, Saxton CA, Dogon IL, Fejerskov O: Variations in the pattern of acid etching of human enamel examined by SEM. Caries Res. 9:373-387, 1975b.

Simonsen, RJ: The clinical effectiveness of a colored sealant at 24 months. Ped Dent. 2:10-16, 1980.

Simonsen, RJ: The clinical effectiveness of a colored sealant at 36 months. JADA. 100:34-38, 1981.

Simonsen RJ: Retention and effectiveness of a single application of white sealant after 10 years. JADA. 115:31, 1987.

Simonsen RJ: Retention and effectiveness of dental sealants after 15 years. JADA. 122:34, 1991.

Stephen KW, Kirkwood M, Main C, Gillespie FC, Campbell D: Retention of a filled fissure sealant using reduced etch time. Brit Dent J. 153: 232-233, 1982.

Stephen KW, Strang R: Fissure sealants: A review. Community Dental Health. 2:149-156, 1985.

Straffon LH, Dennison JB: Clinical evaluation comparing sealant and amalgam after 7 years. Final report. JADA. 117:751, 1988.

Summitt JB, Chen DCN, Burgess JO, Dutton FB: Effect of air/water rinse versus water only and of five rinse times on resin to etched enamel shear bond strength. Oper Dent. 17:142-151, 1992.

Tandon S, Kumari R, Udupa S: The effect of etch time on the bond strength of a sealant and on the etch pattern in primary and permanent enamel: An evaluation. J Dent Child. 56: 186-190, 1989.

Trowbridge HO: Model systems for determining biological effects of microleakage. Oper Dent. 12:164-172, 1987.

Van Amerongen JP, Penning C, Kidd EAM, ten Cate JM: An in vitro assessment of the extent of caries under small occlusal cavities. Caries Res. 26:89-93, 1992.

Wang WN, Lu TC: Bond strength with various etching times on young permanent teeth. Am J Ortho. 100: 72-79, 1991.

Westerman G, Hicks MJ, Flaitz CM: Argon laser-cured sealant and caries-like lesions formation. J Dent Res. 70: 493, 1991.

Wood LW, Barkmeier WW: The effect of salivary contamination on the retention of acid-etched retained composite resin. J Nebraska Dent Assoc. 56(2):14-18, 1979.

Wright TJ, Retief DH: Laboratory evaluation of eight pit and fissure sealants. Ped Dent. 6:36-40, 1984.

Young KC, Hussey M, Gillespie FC: The performance of ultraviolet lights used to polymerize fissure sealants. J Oral Rehab. 2:181-191, 1977.

Young KC, Main C, Gillespie FC: Ultraviolet absorption by two ultraviolet activated sealants. J Oral Rehab. 5:207-213, 1978.

APPENDIX B

APPENDIX C

Table 1. Mean % Penetration and Leakage in Millimeters Evaluated as a Function of Group

Group	% Penetration	Leak in mm
Etch	10.4 ± 15.2	0.28 ± 0.4
Control	80.4 ± 30.5	1.72 ± 0.9
KCP 160	81.0 ± 32.9	2.50 ± 1.5
KCP 120	96.0 ± 11.8	2.22 ± 1.2

Table 2. One-Way ANOVA for % Penetration and Leakage in Millimeters as a Function of Group.

Variable	F	d.f.	p
% Penetration	99.03	3	0.001
Leakage in MM	31.2	3	0.001

Table 3. A 2-Factor ANOVA of the % Penetration as a Function of Right and Left Slope and Groups.

Variable	F	d.f.	p
Group	96.78	3	0.001
Slope	0.193	1	0.611
Grp X Slope Interaction	0.103	3	0.958

APPENDIX D

RAW DATA

GROUP	SECTION	% PENETRATION
1	5R	100
1	5L	84
1	6R	100
1	6L	100
1	14R	91
1	14L	18
1	17R	100(lost)
1	17L	100(lost)
1	21R	100
1	21L	100
1	23R	100(lost)
1	23L	100(lost)
1	28R	100
1	28L	72
1	32R	10
1	32L	9
1	36R	71
1	36L	80
1	38R	78
1	38L	74
1	41R	88
1	41L	84
1	45R	100
1	45L	100
1	49R	100
1	49L	100
1	52R	47
1	52L	68
1	56R	81
1	56L	100
1	58R	0
1	58L	13
1	60R	100
1	60L	100
1	67R	78
1	67L	100
1	72R	100
1	72L	100
1	75R	100
1	75L	100
2	2R	23
2	2L	6
2	4R	6
2	4L	24
2	9R	5
2	9L	0
2	13R	7

2	13L	0
2	15R	5
2	15L	0
2	20R	13
2	20L	6
2	26R	0
2	26L	0
2	29R	6
2	29L	35
2	31R	9
2	31L	0
2	39R	8
2	39L	0
2	42R	14
2	42L	20
2	44R	15
2	44L	0
2	46R	42
2	46L	8
2	51R	4
2	51L	0
2	62R	0
2	62L	5
2	63R	9
2	63L	36
2	65R	0
2	65L	6
2	70R	11
2	70L	0
2	74R	10
2	74L	78
2	77R	7
2	77L	0
3	1R	100
3	1L	84
3	8R	100
3	8L	25
3	11R	100
3	11L	81
3	18R	2
3	18L	100
3	22R	100
3	22L	100
3	25R	100
3	25L	100
3	27R	17
3	27L	100
3	30R	100
3	30L	100
3	34R	100
3	34L	14
3	35R	100

3	35L	100
3	47R	0
3	47L	8
3	50R	100
3	50L	44
3	54R	95
3	54L	82
3	57R	100
3	57L	100
3	59R	76
3	59L	100
3	66R	100
3	66L	100
3	68R	100
3	68L	100
3	71R	64
3	71L	100
3	73R	100
3	73L	100
3	78R	49
3	78L	100
4	3R	100
4	3L	100
4	7R	100
4	7L	93
4	10R	100
4	10L	100
4	12R	43
4	12L	91
4	16R	100
4	16L	100
4	19R	64
4	19L	100
4	24R	100
4	24L	100
4	33R	100
4	33L	100
4	37R	100
4	37L	100
4	40R	100
4	40L	100
4	43R	100
4	43L	100
4	48R	100
4	48L	84
4	53R	100
4	53L	100
4	55R	100
4	55L	100
4	61R	66
4	61L	100
4	64R	100

4	64L	100
4	69R	100
4	69L	100
4	76R	100
4	76L	100
4	79R	100(lost)
4	79L	100(lost)
4	80R	100(lost)
4	80L	100(lost)

LIST OF REFERENCES

Ball IA: An update on fissure sealants. Prev Dent. 1:380-388, 1986.

Barkmeier WW, Gwinnett AJ, Shaffer SE: Effects of enamel etching time on bond strength and morphology. J Clin Ortho. 19:36-38, 1985.

Barkmeier WW, Shaffer SE, Gwinnett AJ: Effects of 15 versus 60 seconds enamel acid conditioning on adhesion and morphology. Oper Dent. 11:111-116, 1986.

Barnes DM, Blank LW, Thompson VP, McDonald NJ: Microleakage of class 5 composite resin restorations: A comparison between in vivo and in vitro. Oper Dent. 18:237-245, 1993.

Berry EA, Berry LL, Powers JM: Bonding of hybrid ionomer to air-abraded enamel and dentin. J Dent Res. 73:183, Abstract 654, 1994.

Black R: Technique for nonmechanical preparation of cavities and prophylaxis. JADA. 32:953-965, 1945.

Black R: Application and reevaluation of air abrasive technique. JADA. 50: 408-413, 1955.

Blankenau RJ, Kelsey WP, Powell GL: Degree of composite resin polymerization with visible light and argon laser. Am J Dent 4:40, 1991.

Bodecker CF: The eradication of enamel fissures. Dent Items Int. 51:859-63, 1929.

Boksman L, Gratton DR, McCutcheon E, Plotzke OB: Clinical evaluation of a glass ionomer cement as a fissure sealant. Quint Int. 18:707-709, 1987.

Bowen RL: Dental filling materials comprising vinyl silane treated fused silica and a binder consisting of the reaction product of bisphenol and glycidyl acrylate, U.S. Patent 3; 066, 112, 1962.

Bowen RL: Properties of a silica-reinforced polymer for dental restorations. JADA. 66:57, 1963.

Bowen RL: Composite and sealant resins- past, present, and future. Pediatr Dent. 4: 10-15, 1982.

Bruer GM, Termini DJ: Bonding of bovine enamel to restorative resin: Effects of pretreatment of enamel. J Dent Res. 34: 151-160, 1972.

Buonocore MG: A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res. 34:849-54, 1955

Charbeneau GT: Pit and fissure sealants. J Dent. 32:315, 1982.

Charlton DG, Moore BK: in vitro evaluation of two microleakage detection tests. J Dent. 20:55-58, 1992.

Conlon DJ, Silverstone LM: A comparison of the effect of etching all five tooth surfaces of single teeth in vitro. J Dent Res. 61 (Special Issue A): Abstract # 87; 244, 1982.

Cooley RL, McCourt JW, Huddleston AM: Evaluation of a fluoride-containing sealant by SEM, microleakage, and fluoride release. Pediatr Dent. 12:38, 1990.

Council on Dental Materials and Devices. Nuva Seal Pit-And-Fissure Sealant Classified as Provisionally Accepted. JADA. 84:1109, 1972.

Crim GA, Garcia-Godoy F: Microleakage: The effect of storage and cycling duration. J Prosth Dent. 57:574-576, 1987.

Crim GA, Shay JS: Effect of etchant time on microleakage. J Dent Child. 54:339-340, 1987.

Crim GA, Swartz ML, Phillips RW: A comparison of four thermocycling techniques. J Prosth Dent. 53:50-53, 1985.

Cueto EI, Buonocore MG: Sealing of pits and fissures with an adhesive resin: Its use in caries prevention. JADA. 75:121-128, 1967.

Doty WD, Pettey D, Holder R, Phillips S: KCP 2000 enamel etching abilities tested. J Dent Res. 73:411, Abstract 2474, 1994.

Eakle WS, Goodis HE, White JM, Do HK: Effect of microabrasion on dentin permeability and bond strength. J Dent Res. 73:131, Abstract 239, 1994.

Eakle WS, Wong J, Huang H: Microleakage with microabrasion versus acid etched enamel and dentin. J Dent Res. 74:31, Abstract 160, 1995.

Edelstein B, Tinanoff N: Screening preschool children for dental caries using a microbial test. Pediatr Dent. 11:129-132, 1989.

Eidelman E, Shapira J, Houpt M: The retention of fissure sealants using 20 second etching time: three year follow-up. J Dent Child. 5:119, 1988.

Ekstrand K, Quist V, Thylstrup A: Light microscope study of the effect of probing in occlusal surfaces. Caries Res. 21:368-74, 1987.

Flaitz CM, Hicks MJ, Silverstone LM: Radiographic, histological, and electronic comparison of occlusal caries: an in vitro study. Pediatr Dent, 8:24-27, 1986.

Forss H, Saarni U-M, Seppa L: Comparison of glass-ionomer and resin-based fissure sealants: A two year clinical trial. Community Dent Oral Epidemiol. 22:21-24, 1994.

Fuks A, Grajower R, Shapira J: in vitro assessment of marginal leakage of sealants placed in permanent molars with different etching times. J Dent Child. 51:425-427, 1984.

Galil KA: Scanning and transmission electron microscope examination of occlusal plaque following tooth brushing. J Can Dent Assoc. 41:499-504, 1975.

Gottlieb EW, Retief DH, Bradley EL: An optimum concentration of phosphoric acid as an etching agent. Part I: Tensile bond strength studies. J Prosth Dent. 48:48-51, 1982.

Gross JD, Retief DH, Bradley EL: An optimum concentration of phosphoric acid as an etching agent. Part II: Microleakage studies. J Prosth Dent. 52:786-789, 1984.

Gwinnett AJ, Buonocore MG: Adhesive and caries prevention: A preliminary report. Br Dent J. 119:77-80, 1965.

Gwinnett AJ, Ripa LW: Penetration of pit and fissure sealants into conditioned human enamel in vivo. Arch Oral Biol. 18:435-441, 1973.

Hicks MJ, Flaitz CM: Epidemiology of dental caries in the pediatric and adolescent population: A review of past and current trends. J Clin Ped Dent. 18: 43-47, 1993.

Hicks MJ, Flaitz CM, Silverstone LM: The current status of dental caries in the pediatric population. J Pedodont. 10:57-62, 1985.

Hicks MJ, Flaitz CM, Silverstone LM: Secondary caries formation in vitro around glass ionomer restorations. Quint Int. 17:527, 1986.

Horgesheimer JJ, Haws SM, Kanellis MJ, Vargas MA: Composite shear bond strength to air-abraded enamel. J Dent Res. 74:32, Abstract 162, 1995.

Hormati AA, Fuller JL, Denehy GE: Effects of contamination and mechanical disturbance of the quality of acid etched enamel. JADA. 100(1):34, 1980.

Houpt M, Fuks A, Eidelman E: Measuring the stickiness of pits and fissures in enamel. Clin Prev Dent. 7:28, 1985.

Houpt M, Shey Z: The effectiveness of a fissure sealant after 6 years. Ped Dent. 5:104-106, 1983.

Hyatt TP: Prophylactic odontotomy: The cutting into the tooth for prevention of disease. Dent Cosmos. 17:234-39, 1923.

Jensen OE, Handelman SL: in vitro assessment of marginal leakage of six enamel sealants. J Prosth Dent. 39:304-306, 1978.

Keen DS, Parkins FM, Crim GA: Microleakage of composite restorations prepared with air-abrasive technique. J Dent Res. 74:36, Abstract 199, 1995.

Keen DS, von Fraunhofer JA, Parkins FM: Air- abrasive "etching": Composite bond strengths. J Dent Res. 73:131, Abstract 238, 1994.

Laurell K, Carpenter W, Beck M: Pulpal effects of airbrasion cavity preparation in dogs. J Dent Res. 72:273, Abstract 1360, 1993b.

Laurell K, Carpenter W, Beck M: Pulpal effects of composite and amalgam removal with airbrasion. J Dent Res. 73:318, Abstract 1730, 1994b.

Laurell KA, Fisher TE, Johnston W: Airbrasion effects on dentin permeability. J Dent Res. 73:215, Abstract 907, 1994a.

Laurell K, Lord W, Beck M: Kinetic cavity preparation effects on bonding to enamel and dentin. J Dent Res. 72:283, Abstract 1437, 1993a.

Litkowski LJ, McDonald NJ, Swierczewski M: A comparison of thermocycling methods for evaluating microleakage. J Dent Res. 68:207, Abstract 208, 1989.

Lussi A: Validity of diagnostic and treatment decision of fissure caries. Caries Res. 25: 296-303, 1991.

Manson-Rahemtulla B, Retief DH, Jamison HC: Effect of concentrations of phosphoric acid on enamel dissolution. J Prosth Dent. 51: 495-498, 1984.

McKnight-Hanes C, Myers DR, Salama FS, Thompson WO, Barenie JT: Comparing treatment options for occlusal surfaces utilizing an invasive index. Pediatr Dent. 12:241-245, 1990.

Milgrom P, Weinstein P: Dental fear in general practice: New guidelines for assessment and treatment. Int Dent J. 43:288-293, 1993.

Morrison AH, Berman L: Evaluation of the airdent unit: Preliminary report. JADA. 46:298-303, 1953.

Myers HM: Dental Pharmacology, in Shapiro M (ed): The Scientific Bases In Dentistry. Philadelphia, WB Saunders Co, 1966, p 285.

National Center for Health Statistics: Decayed, Missing and Filled Teeth Among Children: United States. Vital and Health Statistics, Series 11, No 106. DHEW Publication No. (HSM) 72-1003. Washington, D.C., U.S. Government Printing Office, 1971.

National Center for Health Statistics: Decayed, Missing and Filled Teeth Among Youths 12-17 Years: United States. Vital and Health Statistics, Series 11, No 144. DHEW Pub. NO. (HRA) 75-1626. Washington, D.C., U.S. Government Printing Office, 1974.

National Institute of Dental Research, National Caries Program: The Prevalence of Dental Caries in U. S. Children, 1979-1980. NIH Pub. No. 82-2245. Bethesda, MD, National Institutes of Health, 1981.

National Institute of Dental Research, National Caries Program: Epidemiology and Oral Disease Prevention Program: Oral Health of U. S. School Children: The National Survey of Dental Caries in U. S. School Children: 1986-1987. NIH Pub. No. 89-2247, Bethesda, MD, National Institutes of Health, 1989.

O'Brien WJ, Fan PL, Apostolidis A: Penetrativity of sealants and glazes. Oper Dent. 3:51, 1978.

Oshawa T: Studies on solubility and adhesion of the enamel in pretreatment for caries preventing sealing. Bull Tokyo dent Coll. 13: 65-82, 1972.

Powell BP, Johnston JD, Hembre JH: Microleakage around a pit and fissure sealant. J Dent Child. 44:298-301, 1977.

Rainey JT, Barghi N: Effect of micro-abrasion on bonding to dentin. J Dent Res. 74:30, Abstract 147, 1995.

Retief DH, Bischoff J, van der Merwe E: Pyruvic acid as an etchant agent. J Oral Rehab. 3: 245-265, 1976.

Ripa L: Occlusal sealing: Rationale of the technique and historical review. JASPD. 1:32-39 1973.

Ripa L: Occlusal sealants: Rationale and review of clinical trials. Int Dent J. 30:127-139,1980.

Ripa LW: Sealants revisited: An update of the effectiveness of pit and fissure sealants. Caries Res. 27 (suppl. 1), 77-82, 1993.

Ripa LW, Cole WW: Occlusal sealing and caries prevention: Results 12 months after a single application of adhesive resin. J Dent Res. 49: 171-173, 1970.

Roeder LB, Berry EA, You C, Powers JM: Bond strength of composite to air-abraded enamel and dentin. J Dent Res. 73:131, Abstract 237, 1994.

Rohr M, Makinson OF, Burrow MF: Pit and fissures: Morphology. J Dent Child. 58:97, 1991.

Rudolph JJ, Phillips RW, Swartz ML: in vitro assessment of microleakage of pit and fissure sealants. J Prosth Dent. 32:62-65, 1974.

Schulein TM, Chan DC, Reinhardt JW: Rinsing times for a gel etchant related to enamel/composite bond strength. Gen Dent. 4:296-298, 1986.

Silverstone LM: Fissure Sealants: Laboratory Studies. Caries Res. 8: 2-26, 1974.

Silverstone LM: The acid etch technique: in vitro studies with special reference to the enamel surface and the enamel resin interface. Proc. Int. Symp. Acid Etch Tech. L. M. Silverstone and I. L. Dogon, Eds. St. Paul: No. Central Publication Co., 13-35, 1975a.

Silverstone LM: State of the art on sealant research and priorities for further research. J Dent Ed. 48:No 2 (Supplement), 107-118, 1984.

Silverstone LM, Saxton CA, Dogon IL, Fejerskov O: Variations in the pattern of acid etching of human enamel examined by SEM. Caries Res. 9:373-387, 1975b.

Simonsen, RJ: The clinical effectiveness of a colored sealant at 24 months. Ped Dent. 2:10-16, 1980.

Simonsen, RJ: The clinical effectiveness of a colored sealant at 36 months. JADA. 100:34-38, 1981.

Simonsen RJ: Retention and effectiveness of a single application of white sealant after 10 years. JADA. 115:31, 1987.

Simonsen RJ: Retention and effectiveness of dental sealants after 15 years. JADA. 122:34, 1991.

Stephen KW, Kirkwood M, Main C, Gillespie FC, Campbell D: Retention of a filled fissure sealant using reduced etch time. Brit Dent J. 153: 232-233, 1982.

Stephen KW, Strang R: Fissure sealants: A review. Community Dental Health. 2:149-156, 1985.

Straffon LH, Dennison JB: Clinical evaluation comparing sealant and amalgam after 7 years. Final report. JADA. 117:751, 1988.

Summitt JB, Chen DCN, Burgess JO, Dutton FB: Effect of air/water rinse versus water only and of five rinse times on resin to etched enamel shear bond strength. Oper Dent. 17:142-151, 1992.

Tandon S, Kumari R, Udupa S: The effect of etch time on the bond strength of a sealant and on the etch pattern in primary and permanent enamel: An evaluation. J Dent Child. 56: 186-190, 1989.

Trowbridge HO: Model systems for determining biological effects of microleakage. Oper Dent. 12:164-172, 1987.

Van Amerongen JP, Penning C, Kidd EAM, ten Cate JM: An in vitro assessment of the extent of caries under small occlusal cavities. Caries Res. 26:89-93, 1992.

Wang WN, Lu TC: Bond strength with various etching times on young permanent teeth. Am J Ortho. 100: 72-79, 1991.

Westerman G, Hicks MJ, Flaitz CM: Argon laser-cured sealant and caries-like lesions formation. J Dent Res. 70: 493, 1991.

Wood LW, Barkmeier WW: The effect of salivary contamination on the retention of acid-etched retained composite resin. J Nebraska Dent Assoc. 56(2):14-18, 1979.

Wright TJ, Retief DH: Laboratory evaluation of eight pit and fissure sealants. Ped Dent. 6:36-40, 1984.

Young KC, Hussey M, Gillespie FC: The performance of ultraviolet lights used to polymerize fissure sealants. J Oral Rehab. 2:181-191, 1977.

Young KC, Main C, Gillespie FC: Ultraviolet absorption by two ultraviolet activated sealants. J Oral Rehab. 5:207-213, 1978.