EVALUATION OF MARGINAL INTEGRITY AS A RESULT OF DIFFERENT FINISHING INSTRUMENTATION BASED ON RESTORATIVE MATERIAL AND MARGIN LOCATION

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ABSTRACT

ALEJANDRO J. DELGADO: Evaluation of the Marginal Integrity as a Result of Different Finishing Instruments Based on Restorative Material and Margin Location
(Under the direction of Harald O. Heymann)

Purpose: The purpose of this study was to assess the marginal integrity of composite and glass-ionomer restorations as a function of finishing technique, restorative material and margin location. **Materials and Methods:** Forty extracted third molars free of defects were assigned to four groups (N=10) according to finishing instruments (aluminum oxide discs, fluted carbides, fine diamonds, and coarse diamond). Each specimen received standardized Class V preparations on the facial and lingual surfaces with occlusal margins on enamel and gingival margins on dentin. Each preparation was randomly assigned to be restored with either resin-based composite (RBC) or resin-modified glass ionomer cement (RMGIC). Specimens were finished with standardized pressure at approximately 0.15 N and evaluated at a magnification of 600X using an environmental scanning electron microscope (ESEM). Occlusal and gingival margins were analyzed using an imaging software and means for all measured gaps were calculated. Data were analyzed using a linear regression using generalized estimating model. **Result:** There were no statistically significant differences among the four types of finishing instruments used in the study. . RBC-restored specimens exhibited significantly smaller mean marginal gaps (1.70 µm, 7.56 µm) than RMGI-restored specimens (5.24 µm, 14.24 µm) in enamel and dentin margins, respectively. There was a statistically significant difference between enamel and dentin with regards to marginal gap formation. **Conclusion:** Under the conditions of this study, marginal gap formation was not affected by finishing technique. Resin-based composite margins exhibited significantly less marginal gap than did resin-modified glass ionomer margins, while enamel margins resulted in significantly less marginal gap than did dentin margins.

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LIST OF ABREVIATION

4-META: 4-methacryloxyethyl trimellitate anhydrate

APS: Average particle size

BIS-GMA: Bisphenol A glycidyl methacrylate

BPDM: biphenyl dimethacrylate

DEJ: Dentin-enamel junction

ESEM: Environmental scanning electron microscope

Gpa: Giga pascal

GIC: Glass ionomer cement

HEMA: hydroxyethil methacrylate

kV: Kilovolts

mm: millimeters

Mpa: Mega pascal

N: Newton

PENTA: penta acrylate monophosphate

RBC: Resin-based composite

RMGIC: Resin-modified glass ionomer cement

SEM: Scanning electron microscope

TEGDMA: triethylene glycol dimethacrylate

µm: micrometer

CHAPTER 1: INTRODUCTION

Over the past decades the importance of esthetic dentistry has become more evident. In current clinical treatment many types of restorations are available for the replacement of tooth structure. The introduction of adhesive restorations introduced a new concept in operative dentistry. These tooth-colored materials are not only esthetic, but also, more importantly, are very conservative of tooth structure. Today, adhesive restorations provide numerous potential treatment options to the patients. Moreover, adhesive restorations have become one of the most popular materials for the restoration of both anterior and posterior teeth.

Adhesive restorations are technique sensitive, and many factors can affect their success. Clinicians must take into consideration not only the many steps that these materials require, but also, the substrate to which they plan to bond. It has been proved that enamel bonding is more reliable and durable than dentin bonding. Another important factor is the proper manipulation of adhesive restorations with various finishing instruments, because these can introduce stress to the restoration resulting in a marginal gap formation that can adversely affect the longevity of the restoration and the tooth.

LITERATURE REVIEW

1.1. Enamel

Enamel is a highly mineralized crystalline structure containing 95% to 98% inorganic matter by weight in which hydroxyapatite is the main constituent in the form of crystals (90%-92%). Structurally, enamel is composed of enamel rods and prisms, which vary in number from five million to twelve million depending on the location.[1,2] In general, they are aligned perpendicular to the dentin-enamel junction (DEJ) and they are separated by an interrod substance.[3]

Enamel is the hardest substance in the human body. It is a brittle structure with a high elastic modulus of 40-80 Gpa and low tensile strength. Enamel is relatively translucent; its translucency is related to the degree of mineralization. The color of enamel is primarily a function of its thickness and that of the underlying dentin.[4]

For maximal strength in tooth preparation, all enamel rods should be supported by dentin. Enamel rods not supported by a dentin base are subject to fracture. Due to enamel's inherent brittleness, it relies on a dentin substrate to supply it with toughness.[1,4] Enamel is a non-vital and non-sensitive tissue that cannot repair itself.[1,3,4]

1.2. Dentin

Dentin is a yellowish, elastic, avascular tissue that protects the pulp chamber. It is composed of small apatite crystals embedded in a cross-linked organic matrix of collagen fibrils, containing 45% to 50% inorganic apatite crystals by volume. Unlike enamel, which is a primarily mineralized substrate, dentin is about 30% organic matrix, and 70% of inorganic substance and water.[4] Dentin contains many dentinal tubules extending from the

DEJ to the pulp. The dentinal tubules contain cytoplasmic cell processes from pulpal odontoblasts, known as Tomes fibers. Each dentinal tubule is surrounded by two main types of dentin that are present: (1) Peritubular dentin, which is the mineralized wall of the tubules and (2): Intertubular dentin, is the dentin around and between dentinal tubules and exhibits the greatest surface area at which primary resin/dentin bonding occurs. Because the odontoblasts form dentin while progressing inward towards the pulp, the tubules are forced closer together.[1] The number of tubules at the pulp varies from 45,000/mm^2 to 65,000/mm^2 and decrease to from 15,000/mm^2 to 20,000/mm^2 when approaching to the DEJ.[5]

After the removal of caries by an operative procedure, the majority of odontoblasts die. The remaining odontoblasts can, however, repair the remaining dentin and form reparative dentin. When 1 mm^2 of dentin is exposed, about 30,000 living cells are damaged. It is recommended to subsequently seal the exposed dentin with a non-irritating material. The sensitivity of teeth is widely accepted to be related to the "hydrodynamic theory" of dental pain developed in the 1960's.[6] Brannstrom also stated that bacteria can leak into the dentinal tubules if a gap exists between the tooth and the restoration, causing an insult to the pulpal tissues.

1.3 Adhesion to Enamel and Dentin

The remarkable introduction of the enamel acid-etching technique by Buonocore in 1955 made adhesive dentistry truly possible, and later revolutionized esthetic dentistry. Buonocore's discovery, coupled with the introduction of fluoride-containing restorative materials, has transformed the practice of operative dentistry. It has been well documented that bonding to enamel is a reliable technique, while bonding to dentin represents a greater challenge.[7,8] The reason why dentin bonding is less predictable is mainly because of its organic content and permeability.[9]

1.3.1 Adhesion to Enamel

The success of the acid-etched enamel bond is well established. This technique creates a micro-mechanical bond between the restorative material and the enamel. In his study, Buonocore[10] found that the used of 85% phosphoric acid for 30 seconds on the enamel enhanced the bond strength of acrylic resin to the tooth. It was reported that reducing the concentration and the time did not affect the shear bond strength, and the etched enamel displayed a similar microporosity pattern.[11] An optimal concentration of acid-etchant should produce a minimal loss of enamel surface while creating a strong bond. Acid etching techniques removes about 10 µm of the enamel surface and creates a porous layer ranging from 5-50 µm.[8] There are three patterns in enamel-etching that have been described. *Type I*, is the dissolution of the prism cores without affecting the prism peripheries; *Type II*, is characterized by a predominance of dissolution of prism peripheries while leaving the cores intact; and *Type III*, in which no prism structures are evident, and in some cases the above patterns are resembled.[1,4] Enamel dissolution results in the formation of resin tags; in which the monomer polymerizes into the demineralization pattern of the crystals. Two types have been described, macrotags that are formed circularly between the enamel prism peripheries; and microtags, that are formed at the core of the prisms. Microtags probably contribute most to the bond strength because of a greater quantity and larger surface area.[4]

In vitro shear bond strengths of resin composite to etched enamel have reported average values of 17 to 20 MPa. This bond strength is thought to be sufficient to overcome shrinkage stress, to prevent marginal openings and to overcome shear stress. Thorough etching and bonding techniques are critical to enhance the bond strength. Alternative acids for etching enamel have been studied, reporting a significant decrease in bond strength when weaker etchants are used.[12]

1.3.2 Adhesion to Dentin

Successful bonding to enamel is a predictable procedure achieved with a simple technique, but bonding to dentin has been a more challenging procedure. Dentin is an intrinsically moist organic substrate with a dense network of tubules containing the odontoblastic processes, which communicate with the pulp. Moreover, these tubules become wider and denser close to the pulp. It has been reported that tubules occupy about 22% of the surface closer to the pulp and only about 1% when approaching the DEJ.[13]

The fundamental principle of adhesion to a tooth is mostly based upon an exchange of inorganic substrate for resin. This process involves two phases. The first one consists of removing the organic tissue and exposing microporosities. The second phase is called the hybridization phase that involves the infiltration of a monomer resin within the microporosities. This results in micro-mechanical interlocking. This is believed to be the first step in reliable bonding, with potential benefits from additional chemical interaction.[14]

When tooth structure is removed with an instrument, the debris that forms on the cut surface is called the smear layer. The smear layer is spread out over the surface of dentin and enamel and is composed of mineral, collagen matrix, bacteria, small particles and cutting debris. The thickness of the smear layer varies depending on the cutting instrument and the conditions of the dentin, and is reported to be about 1-5 µm.[15]

Conditioning the dentin can be defined as any chemical alteration of the dentinal surface by acids with the objective of removing the smear layer and simultaneously demineralizing the surface.[4] The smear layer constitutes a barrier; and it must be removed, or made permeable to let the resin monomers penetrate and contact the dentin surface directly. In addition to removing the smear layer and the majority of hydroxyapatite crystals, the substrate exposed by dentin conditioning is a mesh of collagen fibrils that when dried can collapse and shrink because of the loss of inorganic support.[8]

In 1982, Nakabayashi published a classic paper on how resin infiltrates into acid-etched dentin, transforming the surface from being crystalline, acid-sensitive, and hydrophilic to an organic, acid-resistant, and relative hydrophobic surface. This new surface was coined the "hybrid layer". These resins or primers contain hydrophilic monomers dissolved in organic solvents, such as acetone or ethanol. The primer molecules such as hydroxyethil methacrylate (HEMA), biphenyl dimethacrylate (BPDM), penta acrylate monophosphate (PENTA) and 4-methacryloxyethyl trimellitate anhydrate (4-META) contain two functional groups- a hydrophilic group that has affinity for the exposed collagen fibril and the hydrophobic group for copolymerization with the adhesive resin. The primers wet the collagen, increase the surface energy and hence the wettability of the dentinal surface.[8]

After the hybrid layer has been attained, an adhesive resin called dental bonding agent is applied. This resin adhesive consists primarily of hydrophobic monomers, such Bisphenol A glycidyl methacrylate (Bis-GMA) and urethane dimethacrylate (UDMA) or more hydrophilic monomers such as triethylene glycol dimethacrylate (TEG-DMA). The major role of the adhesive resin is to stabilize the hybrid layer and to form resin extensions into dentinal tubes called resin tags.

1.4 Resin Composites

The first resin composite was introduced a year after the findings of Buonocore. In 1956, Dr. Rafael Bowen published an article describing the development of a new epoxy resin.[16] This material was developed after the earlier failures of silicates and acrylic resin. Silicates had solubility problems and eroded within few years, while acrylic resins had poor color stability due to water sorption, poor wear resistance, and polymerization shrinkage causing leakage around the margins and compromising the adhesion. Newer materials with improved properties have overcome most of those problems.[17]

The chemical formula for resin composites consist of three main structural components: 1) The resin matrix which is an organic polymer material that forms a continuous phase and binds to the fillers, 2) The inorganic filler particles that reinforce the fibers that are dispersed in the matrix and 3) A coupling agent, that promotes adhesion between the filler particles and the matrix, after being activated with an initiator accelerator.[17] Each of these components is necessary for the mechanical and physical properties of the material.

1.4.1 Resin Matrix

The resin matrix is an organic polymer matrix that is composed of a blend of aromatic and/or aliphatic dimethacrylate monomers. The most popular oligomers found in resin-based composites are Bis-GMA and UDMA. TEG-DMA is also commonly used to increase the depth of cure as well as lower the viscosity for handling purposes. The dimethacrylate monomers also have the advantage of producing extensive cross-linking among polymer chains. This results in a rigid matrix.[17] Unfortunately, the tradeoff is polymerization shrinkage.

1.4.2 Filler Particles

The inorganic filler particles are most commonly produced by finer particles of quartz, glass, silica and more. These particles range in sizes from 0.04 to 100 µm. Depending of the type or particle and how they are processed; their shapes can be spherical or irregular. The above mentioned inorganic particles are added into the matrix to greatly improve the material properties. According to Ralph Phillips, the primary purposes of the fillers are to strengthen a composite and to reduce the amount of matrix. Several other properties are improved, like reinforcement of the matrix, decreased wear, reduction of polymerization shrinkage, and the associated shrinkage stress, reduction of thermal expansion, improved workability, reduction of water sorption and increased radiopacity. The filler particles can only provide reinforcement if they are well bonded to the matrix. Because of the importance of well-bonded filler particles, the use of an effective coupling agent is extremely important to the success of a composite material.

1.4.3 Coupling Agent

The coupling agent is a silane whose role, as previously explained, is to maintain the filler particles and the resin matrix together. The purpose of the well applied coupling agent is to transfer stresses to the higher modulus filler particles to improve physical and mechanical properties and inhibit leaching by preventing water from penetrating the interface.[17]

1.4.4 Classification of Resin Composites

Resin-based composites have been classified according to various characteristics. A useful classification and the most commonly used is by average particle size (APS) and size distribution. Classes of contemporary composites are outlined in Table 1. Composites with a large APS are called macrofills, and composites with small APS are called microfills. Many composites used mixtures of different APSs, and are collectively called “hybrids.” Any resin with fillers from two or more size ranges can, in principle, be considered a hybrid. Nanofilled and nanohybrid resin composites were recently introduced. These composites are highly polishable, provide esthetics, have excellent mechanical properties and present good handling. [18,19] Silorane, a novel composite was developed to reduce polymerization shrinkage and the associated stress. Siloranes use a monomeric system based in openings of cationic rings on radical oxiranes. A 36 month clinical trial reported no statistically significant difference between this new composite compared with a nanohybrid, resulting in a similar performance in the clinical setting.[20] Another study reported similar results when compared with another nanohybrid over a period of 2 years.[21] The advantage of low-shrinkage stress materials, such as this one needs to be further studied and, at this moment, a conclusive statement cannot be drawn from the available data.

1.4.5 Polymerization Shrinkage

Resin-based composites have gone through several changes since their original formulation. Current changes are focused principally on reducing polymerization shrinkage, and perhaps more importantly, reducing and/or counteracting the polymerization shrinkage stress. Recent research has addressed this issue of polymerization shrinkage, which may have a deleterious effect on the interface between tooth and resin composite.[22]

Polymerization shrinkage is the result from the cross-linking reaction that reduces the spaces between the monomer molecules. This reaction depends on the oligomer and the filler particles in the matrix. When more fillers are present, less shrinkage occurs due to a reduced matrix volume. Although shrinkage varies from one composite to another, it ranges from 0.7-5.5 vol% within 24 hours after curing.[17,18]

Stress resultant from polymerization shrinkage can be affected by the cavity preparation size and configuration. In 1987, Albert Feilzer described the Configuration Factor, also known as the C-factor. The C-factor is the ratio of bonded to unbonded surfaces.[4,18] The higher the C-factor, the higher the contraction risk and the potential for bond disruption from polymerization shrinkage stress.

To overcome the problem associated with a material pulling away from the tooth, clinicians must carefully control the insertion technique of the resin composite, appropriate use of the dental bonding agents, control of curing light irradiance and proper isolation. The reality is that the polymerization shrinkage phenomenon cannot be avoided.

Polymerization shrinkage usually results in gap formation at the interface of the restoration and the tooth. The clinical significance of the margin gap is not fully known.

1.5 Glass Ionomer

Glass ionomer cement (GIC) materials are not considered dental adhesives; they represent a class of materials which rely on chemical bonding to tooth structure. GICs consist of acid-soluble aluminosilicate glass, and a polyacrylic acid solution. The Ca^{2+} and the Al^{3+} ions react with the carboxylate groups to cross-link the polymeric acid. The same carboxylate groups react with Ca^{2+} ions of enamel and dentin yielding a calcium chelation bond.[17]

GICs were developed by Wilson and Kent in 1972. Many liquid and powder modifications have been incorporated since the first commercial product emerged, to improve the physical, chemical and mechanical properties. GICs are hydrophilic, and dental composites are hydrophobic, therefore the presence of water makes it difficult to obtain esthetic results as well as mechanical strength with GICs.

1.5.1 Resin-modified glass ionomer cements

Resin-modified glass ionomer cement (RMGIC) was an evolution in glass ionomer technology introduced in the 1980's by Sumita Mitra. It was produced by adding methacrylate resin to polyacrilate acid. RMGICs have the same ion-releasing glass and filler particles used in conventional glass ionomers, but their sizes are smaller. They are light-cured, which is supplementary to the acid-base reaction. The initial setting is triggered by the light, which is followed by the chemical reaction.[23]

Fluoride release from the RMGI is the highest during the first 24 hours. The amount of fluoride released decreases tremendously after 24 hours. The mean concentration for the first 6 hours ranges from 22-65 ppm, which drops to 3-20 ppm after 18-24 hours. Daily release drops from 8-15 ppm on the 1st day to 1-2 ppm on the 7th day.[23]

1.5.2 Volumetric shrinkage in RMGIC

Volumetric changes due to curing shrinkage can form marginal gaps that may affect the longevity of the restoration. This shrinkage is however counteracted by hygroscopic expansion. A study reported that after 24 hours RMGICs exhibit volumetric shrinkage of 3.2 – 4.5%, and after 28 days of water storage the hygroscopic expansion ranged from 0.3 – 10.3%, concluding that curing and water sorption resulted in marked volumetric changes.[24]

It is important to understand the extent of shrinkage, since it can create marginal gaps if the filling material does not have a sufficiently strong bond to the tooth structure.[24,25]

1.6 Finishing and Polishing Adhesives Restorations

Finishing is an extremely important procedure for the longevity of the restoration as well as the tooth.[26-29] A well contoured, finished and polished restoration will promote oral health. Finishing is the gross reduction of the material to obtain the anatomical contour of the restoration, while polishing is making the surface smooth and lustrous.[17] The goal of finishing and polishing are to obtain the desired anatomy, proper occlusion, and reduced roughness.

Appropriate rotatory instruments must be selected according to the specific surface being contoured.[1] Since lack of proper finishing and polishing procedures can compromise the marginal integrity, therefore leading to staining, discoloration of the restoration, gingival irritation and recurrent caries due to plaque accumulation.[26] Proper pressure should be applied during finishing avoiding introduction of stress. This stress can affect the interface creating an opening of the restoration margin that can result in a marginal gap formation that will compromise the restoration.

Instruments for finishing and polishing available to the clinician include fluted carbide burs, diamond burs, stones, coated aluminum oxide discs and strips, polishing pastes, cups and points and wheels impregnated with various abrasive particles. The most studied instruments for contouring a restoration are the fluted carbide burs, diamond burs and coated aluminum oxide discs. All of these finishing and polishing tools are often offered in different degrees of abrasiveness, come in sets and should be used in the proper sequence, working gradually toward the finest grits.[26,27]

It is important to know the effect of polishing direction on the marginal adaptation of the restoration. A study demonstrated that there is a significant difference in the marginal adaptation when polishing is accomplished from resin-composite to tooth structure as opposed to from tooth to resin composite.[30] They used flattened enamel and restored it with a nanofilled composite and a microhybrid composite and used polishing discs and rubber points. The margins were polished from resin- composite to tooth and from tooth to resin composite.

1.7 Margin Integrity

Finishing and polishing procedures can be detrimental to the marginal integrity of the restoration and may lead to microcracks in the enamel.[31] Polymerization shrinkage is also a factor that can initiate a micro gap at the tooth-restoration interface, when the stress of polymerization shrinkage exceeds the cohesive strength of the tooth structure. Marginal gap can result in secondary caries and pulpal irritation.[32] Therefore, it is important for the longevity of the restoration and the vitality of the tooth that the formation of the marginal gaps be prevented or, at the very least, controlled. Finishing and polishing techniques are under the clinician's control, and are essential to achieve good marginal integrity.

No minimum marginal gap has been identified as acceptable for adhesive restorations. The literature is controversial in this regard. A study reported that a gap of less than 1 µm is required to prevent bacterial infiltration, however some toxins can still harm the tooth.[33] There are authors that found that recurrent caries is the result of marginal gaps.[34,35]

1.8 Finishing and Polishing Instrumentation

1.8.1 Impregnated Aluminum Oxide Discs

Impregnated aluminum oxide discs are fabricated by securing abrasive particles of a chemical compound of aluminum and oxygen to a flexible backing material (Mylar or paper). These particles are retained on the disc by a polymeric adhesive coating layer. Aluminum oxide has sufficient hardness (9 on Mohs' hardness scale) for polishing composites and ceramics.[27] The most common examples of impregnated aluminum oxide discs include Sof-Lex discs (3M ESPE, St Paul, MN) and Super Snap discs (Shofu Dental Corp, Menlo Park, CA). Sof-Lex discs, which are coated with aluminum oxide particles (grit 150, 360, 600, 1200) have a four discs sequence that include coarse (100 µm), medium (40 µm), fine (24 µm) and superfine (8 µm) discs.[27] Sof-Lex discs have a great ability to reduce the gross contour with the coarse disc, whereas the medium does it at a much slower rate. These first two discs are used for finishing. Once the ideal anatomy and contour are attained the fine and superfine discs can be used to polish. One of the advantages of Sof-Lex discs is easy access to incisal edges and embrasures due to how thin and flexible the discs re. A major drawback is that they tend to flatten surfaces and cannot be used in concave areas.[26]

1.8.2 Fluted Carbide Finishing Burs

Fluted carbide finishing burs come with 8, 12, 15, 16, 20, 30 and 40 flutes. These burs can be used for resin composite and amalgam restorations. The greater the number of flutes, the less aggressive the instrument is. With carbide burs, 8 or 12 fluted burs are used for contouring but their use does not result in a well-polished surface. The use of 20 or 30 fluted burs will result in a smoother surface.[4,18,26] The most commonly used carbides are the ET series (Brasseler USA, Savannah, GA) and the H48L Spiral-fluted (Brasseler USA), SE trimming and finishing (SS White, Lakewood, NJ) and Trimming and Finishing Taper T-Series (Midwest-Dentsply, York, PA). These burs kit include two or three specific burs and are available in different subcategories as fine, extra-fine and ultra-fine.

1.8.3 Diamond Finishing Burs

Diamond burs consist of a blank surface that is coated with powdered diamond abrasives bonded by a metallic adhesive. Unlike carbides, diamonds rely on the grinding by abrasive particles rather than the cutting action of blades. Diamond particles vary in shapes and sizes. They range from coarse (50-150 µm), medium (40 µm), fine (25-30 µm), extra-fine (15 µm) and super-fine (7-8 µm).[27] The primary intent for diamonds is to contour, adjust, and smooth restorative materials. The clinical performance depends of the size and shape distribution of the particles. The hardness of the diamond particles measures about 10 on Mohs' scale, sufficient for polishing resin composites and ceramics.[17] It is recommended by manufactures to use these instruments with gentle wiping strokes and under water to avoid heat.

The most common diamond finishing burs are the ET Series (Brasseler USA), NTI Diamonds (Axis Dental, Coppell, TX) and Solo Diamond (Premier Dental, Plymouth Meeting, PA). The ET series contain a superfine diamond, whose particles are around 8µm, which is comparable with the superfine Sof-Lex disc.

1.9 Scanning Electron Microscope

The use of organic dyes has been the oldest method to assess the sealing effectiveness of the margin. The main problem with this methodology is the different molecules size of the dies being too small, and is a qualitative evaluation method.[14]

The measurement of sealing effectiveness should be semi-quantitative by using scanning electron microscope (SEM). This publication describes a method to quantify the quality of dental restorations.[33] The restoration margins are traced on the SEM screen with a digitizer and an interface to measure the margin's length. Simultaneously the margin quality is assessed and assigned to the corresponding lengths.[36] There have been many studies evaluating marginal gaps with SEM *in vitro.* [2,36-38] This method assumes that the stress induced by the polymerization shrinkage and the thermal-mechanical strain exceeds the bond strength and observable gaps will form.[14]

1.9.1 Environmental Scanning Electron Microscope

A environmental scaning elctron microscope (ESEM) is used to observe specimens without much preparation. This microscope has the capability of elemental analysis and x-ray mapping along with the conventional SEM imaging. The microscope works with secondary and back scattered electron detectors. The instrument can be operated at variable pressure modes and hydrated specimens can be viewed without much sample preparation, thus preserving the integrity of the viewed surfaces. This quality represents a big advantage over traditional SEM analyses, where samples can attain artifacts simply due to dehydration effects encountered during preparation of the samples.

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CHAPTER 2: MANUSCRIPT

Evaluation of the Margin Integrity as a Result of Different Finishing Instrumentation Based on Restorative Material and Margin Location

2.1 Introduction

Over the past several decades an impressive improvement in adhesive technology has occurred. Adhesive restorations have gained considerable importance due to increasing demand for conservative and esthetic dentistry. However, adhesive restorations are technique sensitive, and achieving an ideal restoration can be challenging. Multiple factors can affect the marginal integrity and the longevity of direct restorations, including the margin location and geometry, restorative material, quality of isolation, polymerization variables, C-factor, insertion technique, finishing technique, and polishing technique. From these, the finishing and polishing techniques are critical steps that are under the clinician's control, and are essential to achieve marginal integrity. Some finishing procedures may affect negatively the margin integrity, creating a gap between the restorative material and the tooth.[1-3] Finishing is the process used to obtain the anatomical contour of the restoration, while polishing is the procedure employed to make surface smooth and lustrous.[4] Thorough finishing and polishing contribute to restoration longevity and esthetics.[2,5,6]

Selecting the appropriate finishing instrumentation can be confusing because of the wide range of commercially available products. Other factors that affect the finishing efficiency include the hardness of the abrasive and the composition of the substrate, the size and shape of the abrasive instrument, the pressure applied, the speed, the polishing condition, and direction.[7] Proper finishing and polishing techniques should be applied for avoiding introduction of stress. This stress can adversely affect the interface creating disruption at the interface between the restoration and the tooth that can result in a marginal gap formation that will compromise the restoration and the tooth. Proper finishing and polishing of adhesive restorations enhance the esthetic outcome and longevity of the tooth.[5,8] Clinically, the main cause of failure of adhesive restorations is related to marginal leakage, which eventually leads to secondary caries, and/or subsequent loss of retention. [9-15]

There are many different types of finishing techniques and instruments, and if they are not carefully used they may lead to gap or crevice formation and poor marginal adaptation.[15] As noted in Chapter 1, instruments for finishing and polishing include carbide burs, diamonds, rubber cups, points, abrasive discs, stones, strips and pastes.[4,10] Fluted carbides burs, fine diamonds and aluminum oxide discs are the most popular instrumentation for finishing and contouring.

Although finishing and polishing procedures for adhesive materials are well documented, there are not many studies reporting the effectiveness of the various finishing instruments regarding the quantitative evaluation of the marginal integrity.

Effective and efficient finishing procedures achieve the objective of producing restorations similar in surface texture to natural tooth structure.[16] Unfortunately, there are not many studies reporting quantitative information on marginal gaps. One such study reported that the best results were achieved with the 30 fluted carbide finishing bur.[1] Another study presented that carbide finishing burs exhibit the greatest incidence in marginal gap formation.[3] A more recent study reported the largest gaps were obtained with regular coarse diamonds, and the smallest gaps with fine diamonds.[12] To date, there is not a predictable approach for finishing adhesive restorations that maintains marginal integrity and reduces gap formation. Therefore, *the purpose of this study was to compare the effect of different finishing techniques on the marginal integrity of resin-based composite (RBC) and resin-modified glass ionomer cement (RMGIC) restorations in vitro.*

2.2 Materials and Methods

2.2.1 Specimens preparation

Forty extracted fresh human third molars free of defects were collected, and stored in 0.5% Thymol for disinfection. Each specimen received two standardized Class V preparations (approximately 3 mm x 2 mm x 2 mm; mesiodistally, incisogingivally, and depth wise respectively), one on the facial surface and one on the lingual surface. Each preparation had an occlusal margin in enamel and a gingival margin in dentin (Figure 1). Each preparation was done with a new No. 271 carbide bur (H26M Brasseler USA) using a water-cooled high-speed handpiece. The dimensions of all preparations were verified with a digital caliper.

The preparations were restored with two different materials, either a nanofilled resin-based composite (RBC) (Filtek Supreme Ultra, 3M ESPE) or a resin modified glass ionomer cement (RMGIC) (Ketac Nano, 3M ESPE) (Figure

2). Both materials were used following manufacturer's recommendations. For the RBC, the preparation was etched with 35% phosphoric acid (Scotchbond Etchand Plus, 3M ESPE) for 15 seconds and then thoroughly rinsed with water for 15 seconds. An ethanol and water based dental adhesive agent was used (Adper Single Bond, 3M ESPE) and applied with a microbrush and rubbed for 15 seconds, slightly dried to evaporate the solvent and then coated again and repeated the same protocol as before and then was light cured for 20 seconds.

The RBC was inserted by two increments; the first increment was placed from the axial wall to the gingival margin and the second increment from the first increment to the occlusal margin. Each increment was light-polymerized with a light-curing unit (LED Demetron A.2, Kerr Corporation, Orange, CA) for 20 seconds. The average of the curing intensity of the light curing unit was 1150 mW/cm^2.

The preparations restored with RMGIC were first coated with the primer Ketac Nano Glass Ionomer Primer (3M ESPE) for 15 seconds to prepared semi-dry enamel and dentin surfaces, then the primer was slightly dried with air for 10 seconds, and after drying, the primed surfaces were light cured for 10 seconds. After the surfaces were primed and polymerized the RMGIC was placed using the Quick Mix Capsule after mixing the pastes. The material was dispensed directly into the preparation, and the tip was kept immersed into the material to avoid air entrapment. Material was shaped anatomically using a mini 3 spatula (Hu-Friedy Mgf. Co, Chicago, IL). The material was light polymerized for 30 seconds with the light-curing unit described above. The restorations were finished and polished under moist conditions immediately after curing.

After polymerization, the specimens (n=10) were assigned randomly to one of the four experimental groups (Figure 3) according to the finishing technique. *Group 1*, was finished with impregnated aluminum oxide discs (Sof-Lex, 3M ESPE), *Group 2* was finished with long flame spiral fluted carbide bur series (H48L Brasseler USA,), *Group 3* was finished with fine diamonds series (DET 9 Brasseler USA), and *Group 4* served as a negative control, which was finished with regular coarse diamond (888 Brasseler USA).

2.2.2 Specimens Finishing and Polishing

The specimens assigned to one of four finishing techniques were finished following the respective manufacturer's recommended sequence. The finishing sequence and the particle sizes (grits) are expressed in Table 2 for each group.

The finishing according to the groups was done at a standardized pressure approximated to 0.15N (Figure 4) using a customized pressure/abrasion device developed at the UNC School of Dentistry. This device monitors the pressure applied during the instrumentation to help create a standardized pressure in the finishing of all the specimens. The pressure device consists of a load cell, a bridge amplifier, and a data acquisition unit connected to an IBM compatible PC through a USB port. The device measured the pressure applied by the hand while finishing the tooth specimen. The software collected the data of the pressure values in Newtons (N) and exported the date to a Microsoft Excel spreadsheet (Microsoft, Redmont, WA). A single input value was saved in the spreadsheet for every second, for the total of the 12 seconds finishing cycle. Therefore, a total of twelve values per sample were acquired. Also, the pressure value for each second was the result of the average of pressure release for every second during the entire cycle. The specimens were fixed to the device by using polyvinyl siloxane bite registration material (Regisil PB Bite Registration, Dentsply Caulk, Milford, DE).

2.2.3 Scanning Electron Microscope Evaluation

After the finishing procedure, all specimens were stored in a moist environment for 24 hours to avoid dehydration before the evaluation of the marginal integrity. An environmental scanning electron microscope (ESEM) (Fei Quanta 200 ESEM Hillsboro, OR) was used to observe the specimens (Figures 5.1 and 5.2). This microscope has the capability of imaging uncoated (Low vacuum mode) and nearly wet (Environmental mode) specimens, along with the conventional high vacuum Scanning Electron Microscope (SEM) imaging. The microscope has secondary and back scattered electron detectors, and a cooling stage. The instrument can be operated at variable pressure modes and hydrated specimens can be viewed without much preparation. It was used at the low vacuum mode with a 10.00 kV accelerating voltage, a working distance between 10-12 mm. and a chamber pressure of 0.4 Torr.

The specimen was affixed to an aluminum planchet with a copper tape and viewed without conductive coating (Figure 6). In a low vacuum mode a small amount of humidity is introduced into the chamber. As the electron beam passes through the chamber, the water vapor ionizes providing a source of ions to passivate the sample surfaces, thereby reducing beam induced charging effects.

The specimens were observed at 25 X magnification to localize the entire restoration. Then the enamel and dentin margins were divided in three equal parts to assess three different areas on each margin (Figure 7). The image was zoomed at 300X to examine the entire periphery and locate the largest gap in each subdivision. An image of the three largest gaps in both margins was acquired at a magnification of 600X (Figures 8 and 9). The margin gap obtained in the photograph was measured by using an imaging software (ImageJ 1.34 software, NIH, Bethesda, MD) to measure from the substrate to the restorative material from each subdivision.

Three measurements obtained from every margin were recorded, totaling six measurements per restoration, twelve measurements per specimen. A total of 480 marginal sites were evaluated and the gap measurements were averaged for each specimen. The mean was obtained by averaging the three greatest observed values for each margin (Figure 10).

2.3 Statistical Analysis

The main purpose of the statistical analysis was to assess whether the outcomes were significantly affected by the instrument, material used or margin location (enamel vs. dentin). Material and surface variables were assessed within subject tooth (facial and lingual, n=40). Finishing instruments were assessed independently between subject variable. Since each tooth has multiple observations there is an expectation of correlation among these observations. For this reason, a linear regression using Generalized Estimating Equations with an unstructured working correlation was used separately for each outcome to specify both the within and between subject variation. All the possible two way interactions were included in the initial model and removed from the final model if not statistically significant present.

2.4 Results

2.4.1 Inter-examiner reliability

One hundred and sixty margins, representing 480 measurements were included in the study. An inter-examiner reliability test was analyzed to determine the concordance among examiners. The inter-examiner reliability was computed with correlation coefficients of 0.99, indicating a strong agreement between the two examiners (Table 3).

2.4.2 Descriptive Statistics for Margin Integrity

The mean value for each marginal gap was calculated individually and presented in Table 4. When observing the enamel margin there was statistically significant difference between the means of the restorative materials (Figure 11). There is no statistically significance difference among the mean values of the four instruments controlling for material or surface. Regarding the dentin marginal gaps, there were no statistically significant differences among the mean values for the 4 instruments evaluated (Figure 12). There was a statistically significant difference in the mean values of the two restorative materials adjusted for instrument. The final model and the analysis of estimation for both enamel and dentin are expressed in Table 5 and 6.

2.4.3 Average of Finishing Pressure

The average of pressure used throughout the study is showed in Table 7. All the restorations were finished and polished using the pressure/abrasion device and values recorded by the computer software. The mean average of the pressure applied was 0.16N.

2.5 Discussion

The longevity of the restoration and the tooth depends on many factors such as material, operator, substrate/tooth and patient. The main cause of failure of adhesive restorations is related to the occurrence of marginal leakage, which eventually lead to marginal staining, secondary caries, and subsequent loss of retention.

Three variables related to the marginal integrity were investigated in this study: the finishing instrumentation technique used, the restorative material placed and the margin location on the tooth.

Regarding the first variable, selecting the appropriate finishing instrumentation can be challenging because of the wide range of commercial products. Also, there is not a well-documented, predictable approach for finishing adhesive restorations that may maintain marginal integrity and reduce gap formation. One similar in-*vitro* study recommended superfine diamond (8 µm) and 40 fluted carbide as finishing instruments, because they resulted in less finishing-line destruction than with other instruments.[15] Another study suggested that finishing diamonds were best suited for gross removal and contouring due to their high cutting efficiency, while carbide finishing burs were best suited for smoothing and finishing as a result of their low cutting efficiency.[17] A microleakage study comparing fluted carbides with diamonds and finishing discs used in different substrates (enamel and dentin) demonstrated no microleakage occurred in the enamel. Therefore, there was a significant difference when the margin was placed in dentin/cementum. A 30-fluted reported no microleakage involving dentin margins.[1]

A more recent study demonstrated that a sequence of finishing diamond burs generated the smallest marginal gap when compared with fluted carbides.[12] These results are in accordance with previous studies that showed that the margin integrity of the restoration was significantly superior when diamond burs were used.[11] A different study comparing several finishing instruments from scalpel blade, carbide burs, diamonds, impregnated aluminum oxide discs, stones, rubber points and abrasive pastes reported that a sequence of discs produced the smoothest surface than individual instruments.[18] The problem with this article and most of the finishing and polishing studies is the dissimilar approach regarding finishing instruments. It is not appropriate to compare instruments with different abrasive particle sizes, grits or blade resulting in bias to the reader.

Another study stated that finishing with burs alone produced a rougher surface and therefore recommended using subsequent finishing instruments to improve the surface quality.[19] They concluded that degree of the generation of enamel damage induced during instrumentation can be influenced by the type of bur. Finishing with fine diamond burs was effective in crack removals. This conclusion supports the fact that clinicians should always finish with a fine instrument.[20]

The findings of the present study demonstrated that after using a sequence of finishing instruments as a system in a defined series, there is no statistical significant difference on the marginal integrity. In other words, most studies evaluate individual instruments and often inappropriately compare results to other instruments used in series. That is akin to comparing “apples to oranges.” In this thesis study, instruments were evaluated as they were recommended: as a system or series of finishing instruments. Under these conditions, as noted above, no statistically significant differences were noted with regards to their potential to generate marginal gaps.

Another important point is the *pressure* applied on the instruments during the finishing procedures. It seems that most of the studies did not standardize the pressure applied when testing finishing and polishing instruments. As noted earlier, his thesis study standardized the pressure applied 0.16 N by using a pressure/abrasion device that monitors every second and recorded the pressure in Newton on a computer software. A previous study also used the same device with 0.5 N when polishing composite.[12] Additionally, yet another study used a device that held the handpiece and regulated the speed while polishing, and maintained a pressure of 0.2- 0.3 N.[21]

One manufacturer recommended 0.3-0.6 N for proper use of their discs sequence. A reason for the lack of recording or standardizing finishing procedures is because manufacturers' recommendations are not clear to the clinician. Light strokes, light touch, or light pressure are some of the recommendations that you find in the instructions or technical guides of the manufactures. The question is *how light is light?* Such ambiguous recommendations can result in widely different clinical applications and results.

Selection of restorative materials also can affect the gap formation owing to wide differences in potential polymerization shrinkage and hygroscopic expansion. In the present study, a standardized class V preparation was used. It is well-known that these restorations have a C-factor of approximately 5, which means 5 bonded surfaces over 1 unbonded surface. Therefore, polymerization shrinkage for the resin composite is at much less risk of bond disruption.[10] It is universally recognized that all adhesive materials shrink during polymerization, an unfortunate physical property that these materials possess. However, it was hoped that the relatively shallow depth of the preparations employed, and the use of incremental additions for the resin composite samples would mitigate the effects of polymerization shrinkage.

Similar to resin composites, RMGICs go through curing shrinkage and volumetric changes. These volumetric changes can create marginal gaps that may contribute to the failure of the restoration.[4,7] An *in-vitro* study that measured the volumetric changes on RMGIC blocks demonstrated that curing and water storage of RMGIC resulted in marked volumetric changes. Moreover, they also expressed that these materials might behave differently if they are bonded to cavity walls, but further studies are needed.[22]

Resin composites also retain water and that can influence the physical and mechanical properties of the material. A study showed that different types of resin composites can react particularly to the filler size and matrix. The authors compared the water sorption and solubility of 10 discs of a nanofill, microhybrid and microfill, and concluded that there was a significant difference in low solubility of nanofill than microhybrid and microfill[23]. Hygroscopic expansion causes swelling of the resin composite and may improve the marginal seal.[24,25]

It is not completely true that the margin gap is formed as a consequence only from the trauma induced by various finishing and polishing instrumentation. Some materials have demonstrated a preference for certain polishing methods.[7,9] A study reported no significant difference in microleakage of enamel margins with various types of materials (nanofill, nanohybrid and microhybrid) and polishing systems (Super-Snap disks, Astropol/Astrobrush polishing system).[26] Dentin margins, however, showed significant differences with more leakage occurring in the microhybrids followed by the nanohybrids and then the nanofills.[26] An *in-vitro* study examined the effect of diamond burs and carbides with two types of composites (microfilled and mycrohybrid), and found that carbides for finishing and trimming microhybrid are contraindicated, but showed a non-disrupted surface. Diamonds operated at low speed did not disrupt the margin of microfilled and microhybrids. The study concluded that rotary instruments for finishing composite resin must be selected in accordance with the type of composite resin used.[27]

Another study using the same methodology of the present study in regards to the tooth preparation compared the marginal sealing ability of two types of composites a microfilled and microhybrid with two finishing protocols (immediate or delay) and two different finishing and polishing systems (aluminum oxide discs and diamonds finishing burs). The results revealed that significantly lower leakage scores were recorded for teeth restored with microfilled resins in delay mode.[28]

Also, there is a study that suggested placing a thin layer of low viscosity, low elastic modulus flowable resin composite between the adhesive layer and the composite to diminish the negative effects of the polymerization shrinkage. They evaluated 4 different groups: 1) enamel/RBC, 2) enamel/flowable /RBC, 3) dentin/RBC and 4) dentin/flowable/RBC and measured the margin gap with SEM. Their results showed that in the enamel groups it is not necessary to use this layer, but in the radicular dentin the use of a flowable layer reduced the marginal gap in 77%.[29] It seems that resin composite placed in root dentin, cannot guarantee an ideal marginal seal in the cementum. A study that evaluated the microleakage on RMGIC with two different materials, with margin in enamel and dentin and polishing with Sof-Lex disc (wet/dry) reported that was a significant less leakage in enamel than dentin with RMGIC.[30] Polymerization shrinkage usually does not significantly affect the margin when preparations are in enamel.

In this present study, a quantitative margin analysis was chosen instead of microleakage because of the possibility to quantify margin gaps. Moreover, the ESEM method used in the present study is non-destructive, and microleakage tests could be biased because the sizes of the molecules dye are small and it might over-leak.[31,32] The restoration margins are measured on the SEM screen with a digitizer and an interface to measure the margin's length.[32,33] Also this method has been proved to be reliable in intra-examiner reliability as was proved in the present study.

Regarding the third variable, it is scientifically proved in the literature that bonding to enamel is stronger and more reliable that bonding to dentin. [9,10,13,14,34-41] It has been showed that deep dentin and radicular dentin have more dentinal tubules and the sizes of those tubules are bigger in diameter. This increase in size and number of tubules leaves minimum surface area for intertubular dentin bonding to occur. This study reported a significant difference between the substrates. Enamel resulted in less marginal gaps than dentin/cementum.

2.6 Limitations

This *in vitro* study included some manipulations that are not normally performed in a clinical situation. For this study, only Filtek Supreme Ultra and Ketac Nano were evaluated. Results should be interpreted with caution and may not apply to other materials. Individual instrumentation for each technique was not assessed independently. Finally, only margin integrity was assessed; no attempts were made do evaluate surface roughness of the materials which can also be affected by finishing techniques.

2.7 Conclusions

Under the conditions of this study:

- Finishing instruments generated comparable results with regards to marginal gap formation.

- Resin-based composite margins exhibited significantly less marginal gap than resin-modified glass ionomer margins.
- Enamel margins resulted in significantly less marginal gap than dentin/cementum margins.

Table 1. Classification of resin-based composites according to the average particle size (APS).

Composite type	APS (µm)	Filled (% wt)	Clinical use
Macrofil	10-100	75	n/a
Hybrids	0.1-10	75-80	Moderate to high stress areas
Microfil	0.01-0.1	40-70	Low stress areas, class V
Nanohybrids/ Nanofil	0.005-0.1	72-78	Anterior and posteriors
Packables	15-80	65-85	Class I and II
Flowables	0.6-1	40-60	Class II (difficult areas), repairs
Siloranes	0.4-0.7	76	Posteriors
Bulk Fill		64-84	Posteriors, dentin replacements

Table 2. Finishing and polishing instruments by group.

Group	Instruments	Specifications (µm) particle size
1 Sof-Lex Discs	Coarse	100 µm / 150 grit
	Medium	40 µm / 360 grit
	Fine	24 µm / 600 grit
	Extra Fine	8 µm /1200 grit
2 H48 Fluted Carbide Finishing Burs	Fine	12 flutes blade
	Extra Fine	20 flutes blade
	Ultra Fine	30 flutes blade
3 ET Fine Diamond Finishing Burs	Fine	30 µm
	Extra Fine	15 µm
	Super Fine	8 µm
4 Regular Coarse Diamond	Coarse	60 µm

Table 3. Intraclass correlation coefficient (reliability) showing a concordance of 0.99.

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                  Marginal Integrity: Inter-examiner Reliability - Alex Delgado
             INTRACLASS CORRELATION COEFFICIENT (RELIABILITY) AND MULTIPLE RSQUARE
                                                                  09:04 Tuesday, August 27, 2013

    Obs   NAME    DFE    SSE      MSE    SOURCE DFS    SSR      MSS    SIGMAS2  RELIAB times RSQUARE

     2  measure   12 1.1986 0.099883 trial    11 1898.99 172.636 86.2679 0.99884   2    0.99937

Intraclass correlation (ICC) - between examiner concordance = 0.99

                                        Paired T-Tests

                                      The MEANS Procedure

                                  Analysis Variable : measdif

                    N            Mean         Std Dev     t Value     Pr > |t|
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                   12       0.1133333       0.4515697       0.87       0.4032
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Table 4. Mean gaps values for each finishing technique per type of material and margin location.

Instrument		Material	Enamel		Dentin		Dentin-Enamel	
			Mean (µm)	SD	Mean (µm)	SD	Mean (µm)	SD
1	SofLex	RBC	2.03	2.83	8.09	7.07	6.06	6.45
		RMGIC	6.09	4.77	12.42	6.98	6.33	6.30
2	Carbide	RBC	1.56	1.34	7.22	3.89	5.66	3.79
		RMGIC	4.12	5.20	16.56	8.93	12.44	5.49
3	Diamond	RBC	2.19	1.93	7.67	6.44	5.49	6.42
		RMGIC	3.53	4.82	12.90	9.43	9.37	9.27
4	Corse	RBC	1.05	0.98	7.29	3.84	6.23	3.08
		RMGIC	7.24	5.60	15.11	13.35	7.87	13.33

RMGIC (resin-modified glass ionomer), RBC (resin-based composite). Dentin-Enamel: is the dentin mean minus the enamel mean.

Table 5. Analysis of the Generalized Estimation Equation parameter and final model for the enamel.

Analysis Of GEE Parameter Estimates							
Empirical Standard Error Estimates							
Parameter		**Estimate**	**Standard Error**	**95% Confidence Limits**		**Z**	**Pr > |Z|**
Intercept		2.2935	0.6453	1.0287	3.5583	3.55	0.0004
Material	glass ionomer	3.5390	0.8746	1.8249	5.2531	4.05	<.0001*
Instr	Carbide	-1.2215	1.0245	-3.2294	0.7864	-1.19	0.2331
Instr	Corse	0.0840	1.0359	-1.9463	2.1143	0.08	0.9354
Instr	Diamond	-1.2055	1.1303	-3.4209	1.0099	-1.07	0.2862

* Statistically significant difference $p < 0.001$

$$Enamel = \beta_0 + \beta_1 \times I(material = RC) + \beta_2 \times I(instr = Carbide) + \beta_3 \times I(instr = Corse) + \beta_4 \times I(instr = Diamond) + \beta_5$$

Table 6. Analysis of the Generalized Estimation Equation parameter and final model for the dentin.

Analysis Of GEE Parameter Estimates							
Empirical Standard Error Estimates							
Parameter		**Estimate**	**Standard Error**	**95% Confidence Limits**		**Z**	**Pr > |Z|**
Intercept		6.9176	1.8410	3.3093	10.5259	3.76	0.0002
Material	glass ionomer	6.6788	1.7966	3.1575	10.2000	3.72	0.0002*
Instr	Carbide	1.6315	2.0751	-2.4356	5.6986	0.79	0.4317
Instr	Corse	0.9400	2.6524	-4.2585	6.1385	0.35	0.7230
Instr	Diamond	0.0270	2.1325	-4.1527	4.2067	0.01	0.9899

* Statistically significant difference $p < 0.001$

$$Dentin = \beta_0 + \beta_1 \times I(material = RC) + \beta_2 \times I(instr = Carbide) + \beta_3 \times I(instr = Corse) + \beta_4 \times I(instr = Diamond) + \beta_5$$

Table 7. Mean pressure (in N) applied for individual instruments, series and complete study reporting 0.16 N.

	Sof-Lex Discs				**Fluted Carbide**			**Fine Diamond**			**Coarse**
	C	M	F	EF	12	20	30	F	EF	SF	C
Individual Mean	.16	.16	.16	.17	.16	.15	.15	.16	.16	.16	.16
Series Mean		.16				.15			.16		.16
Study Mean						.16					

C (coarse), M (medium), F (fine), EF (Extra-fine), SF (Super-Fine)

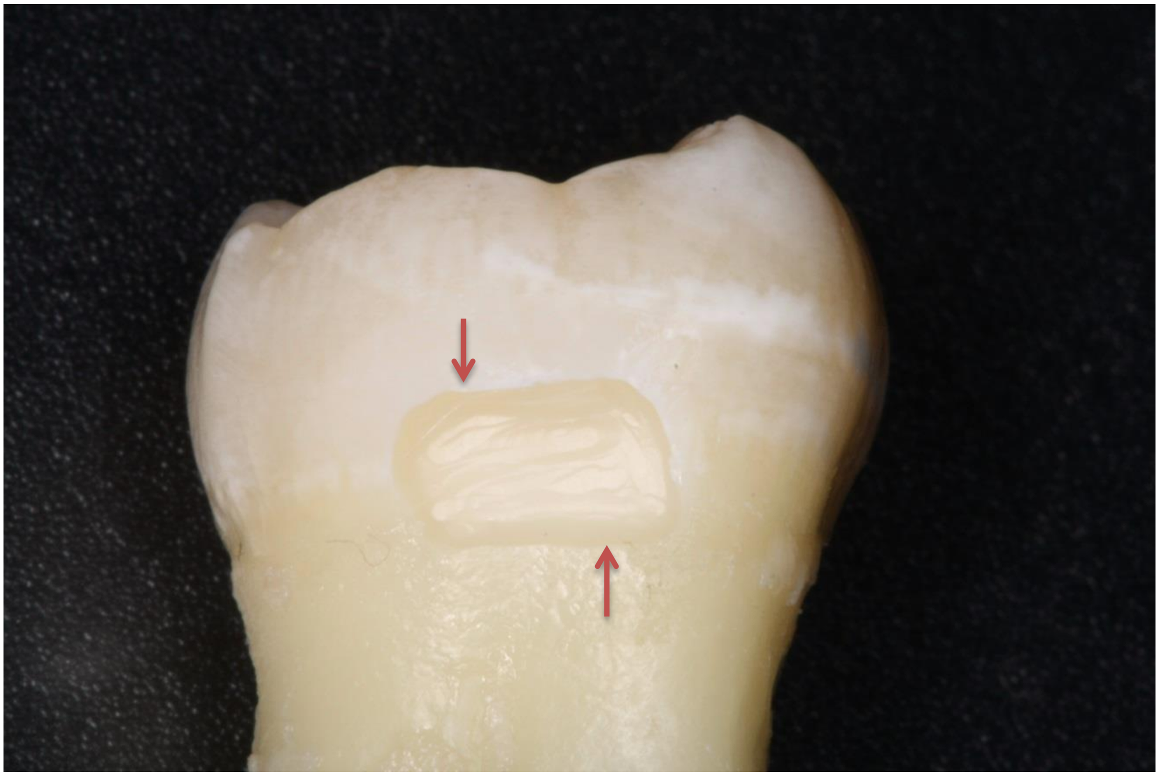


Figure 1. Standarized class V preparation with occlusal margin on enamel and gingival margin on dentin.

Figure 2. Restorative materials resin-based composite (RBC) and resin-modified glass ionomer (RMGIC).

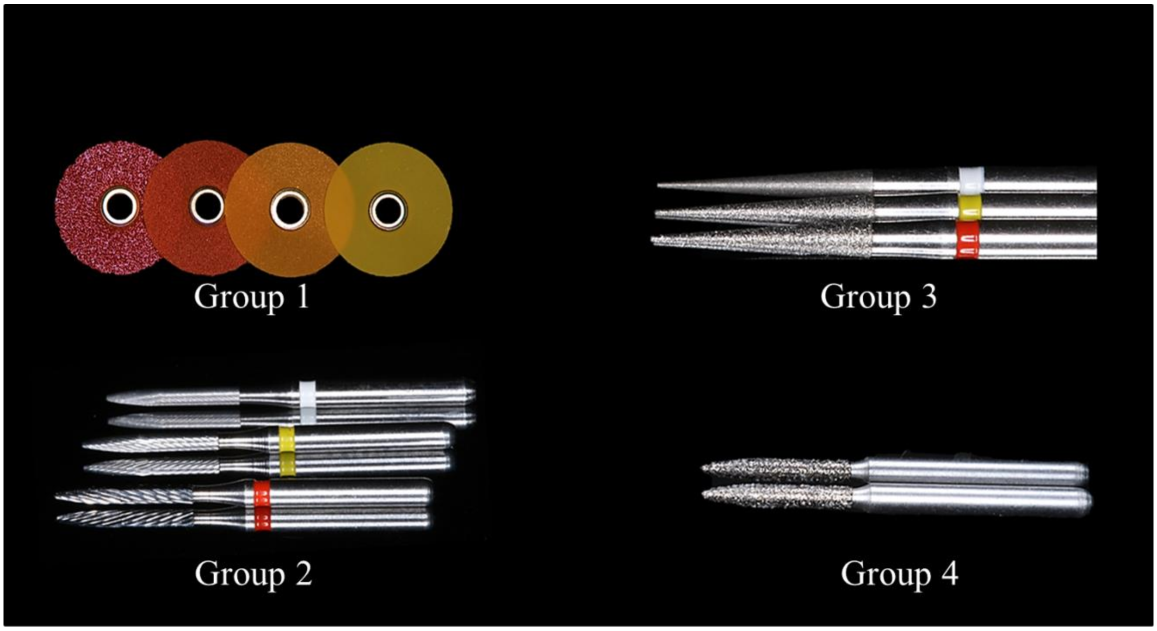


Figure 3. Finishing and polishing instrument by groups. Group 1: Sof-Lex discs, Group 2: Fluted carbide finishing burs, Group 3: Fine diamond finishing burs and Group 4: Regular coarse diamond.

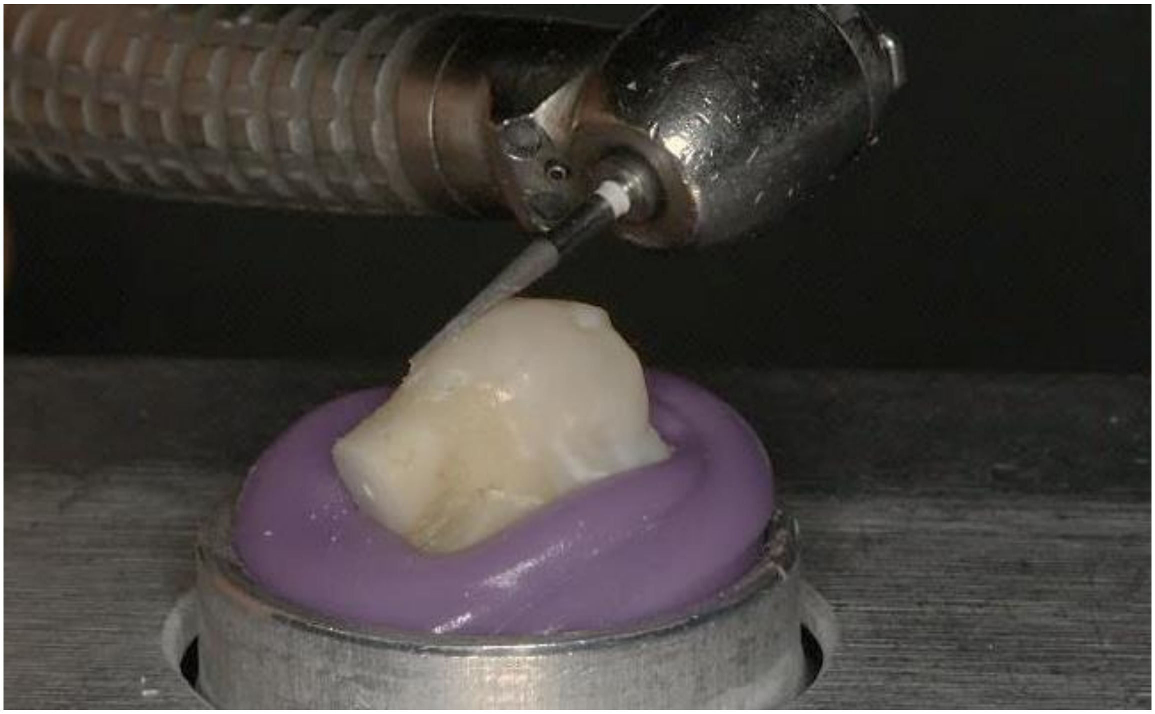
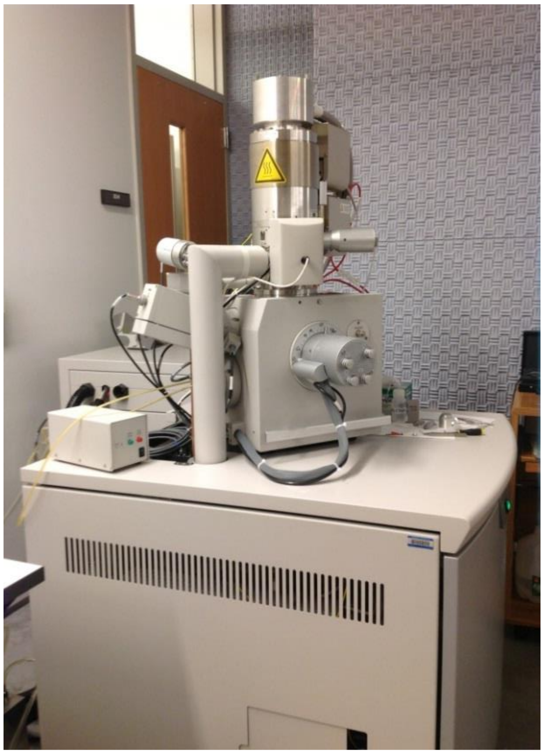


Figure 4. Finishing procedure using pressure device at approximadetely 0.15 N.

Figures 5.1 and 5.2. Environmental Scanning Electron Microscopy at the Chapel Hill Analytical and Nanofabrication Laboratory.

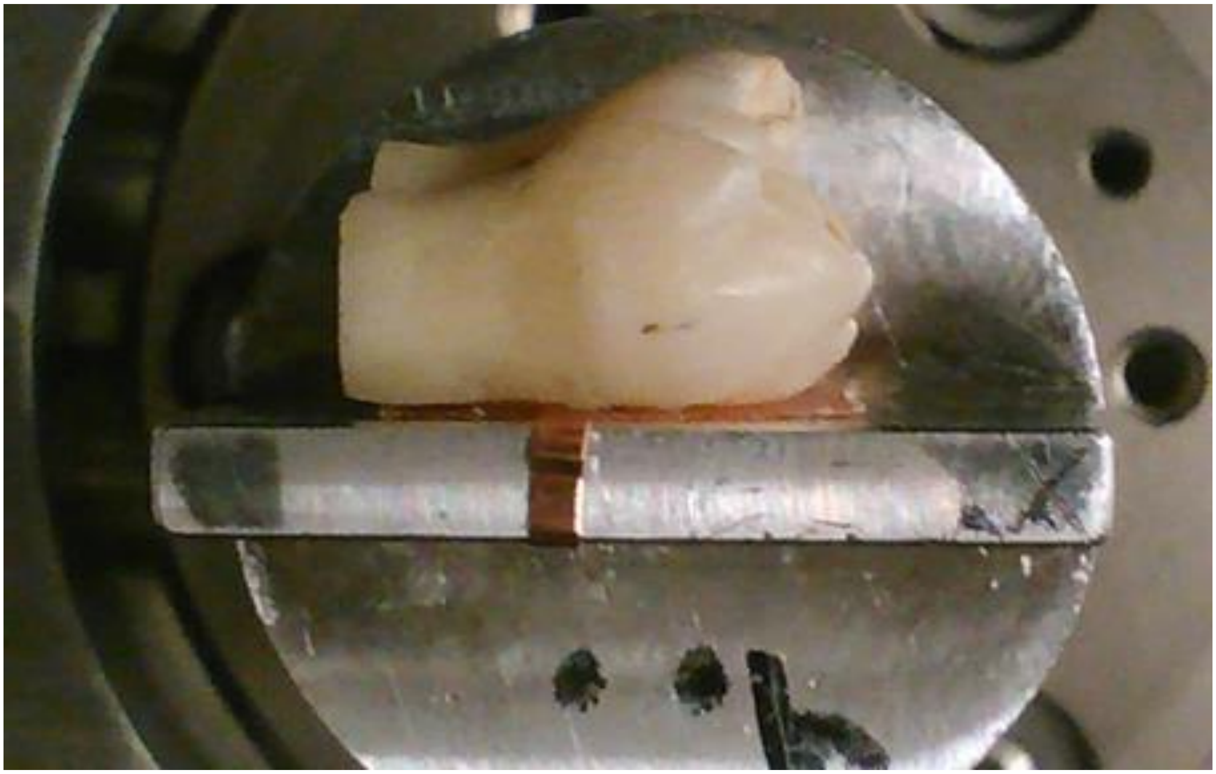


Figure 6. The sample was affixed to an aluminum planchet and held it with a copper tape for evaluation on environmental scanning electron microscopy.

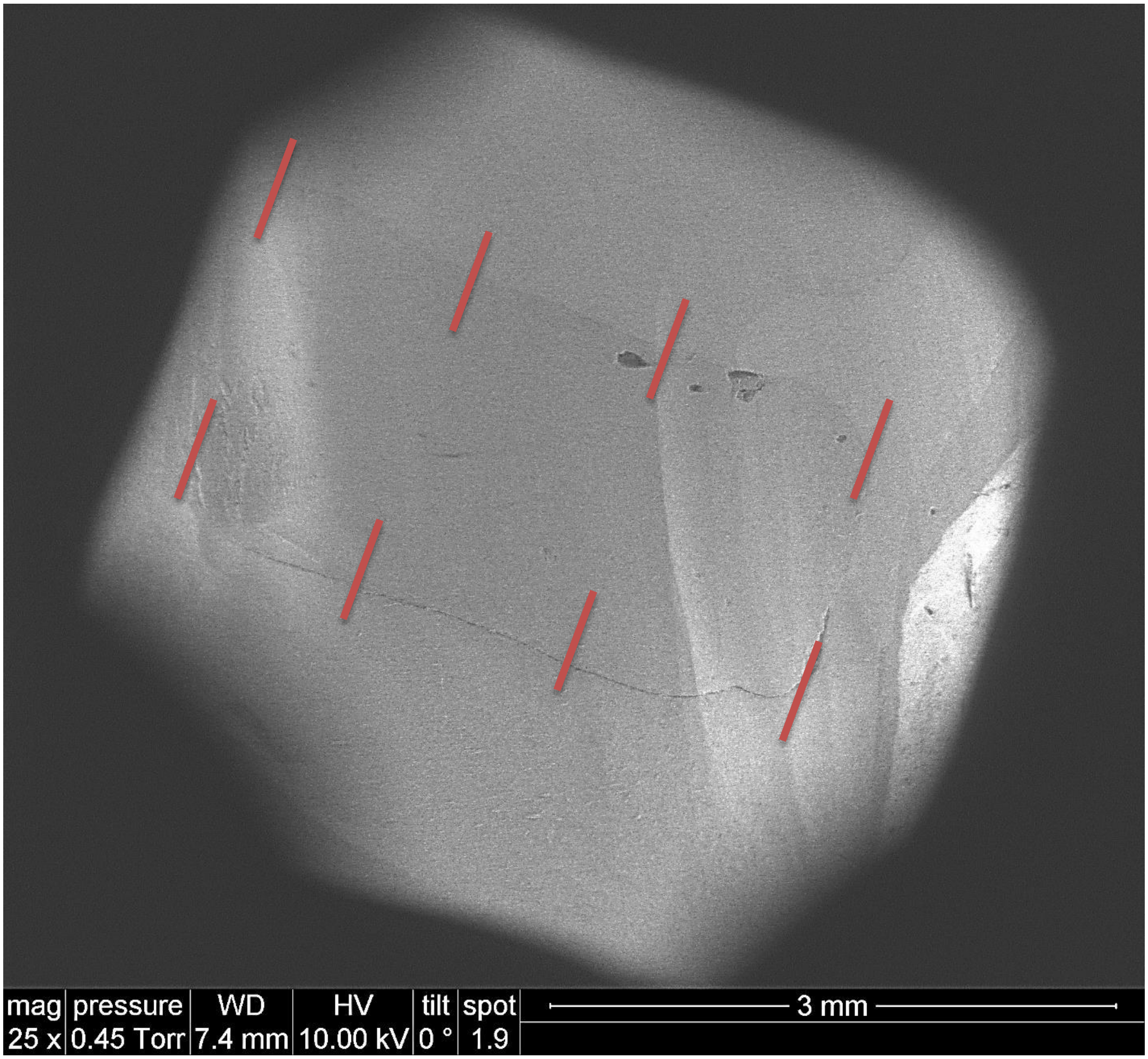


Figure 7. Image at 25X magnification to localize restoration and subdivisions of occlusal and gingival margin.

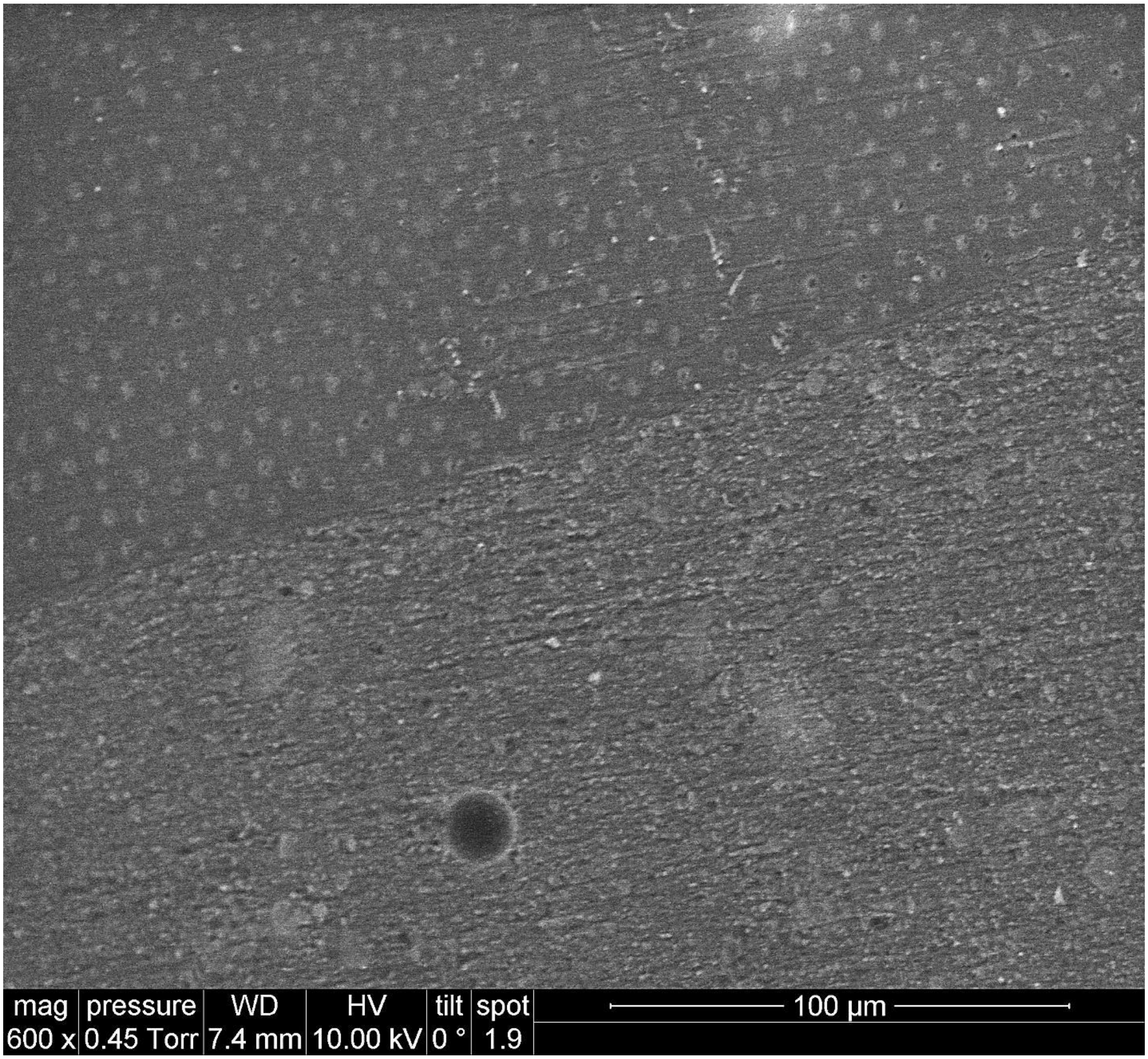


Figure 8. Enamel margin at 600 X magnification showing no gap formation between restoration and substrate.

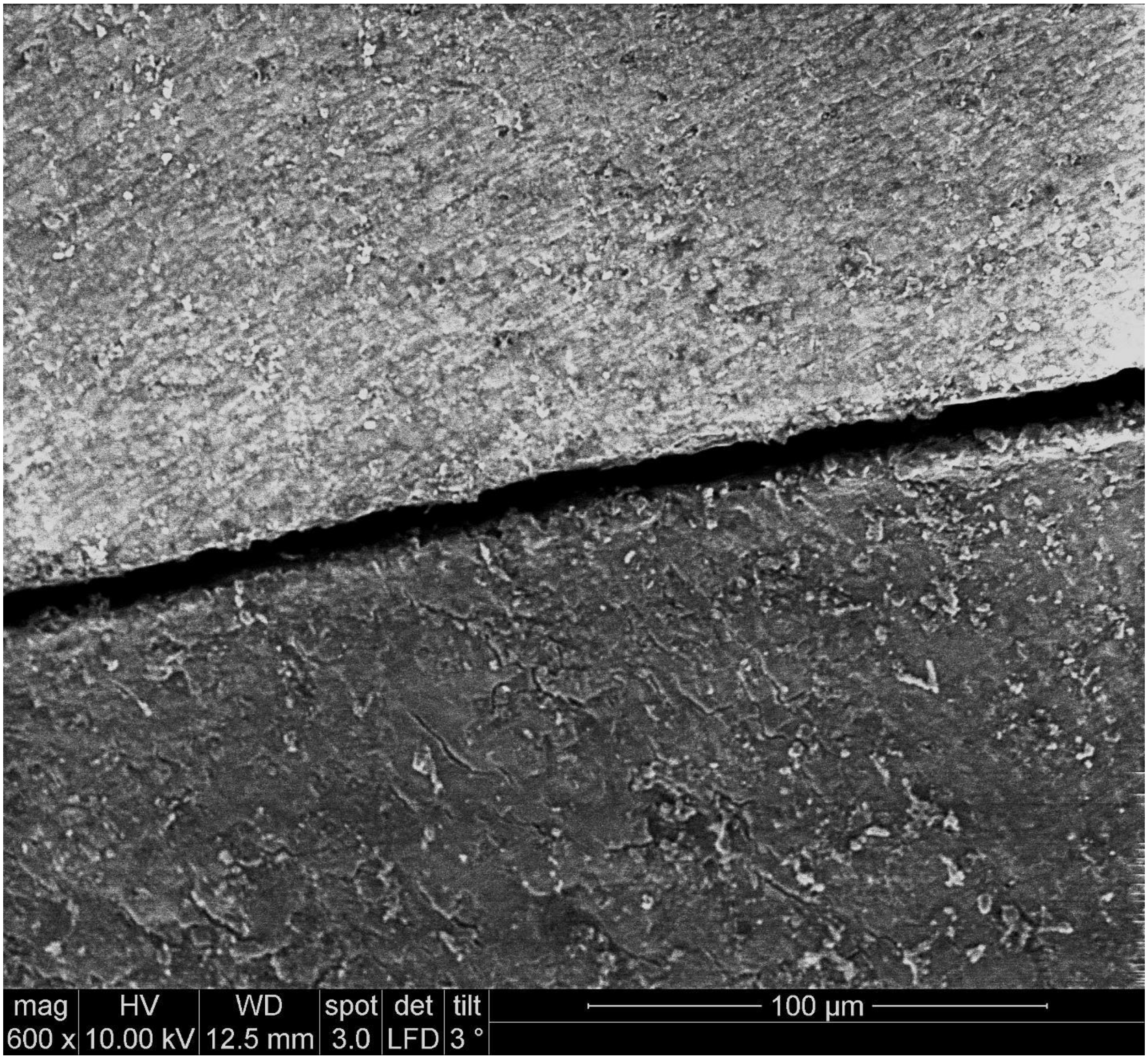


Figure 9. Dentin margin showing marginal gap formation.

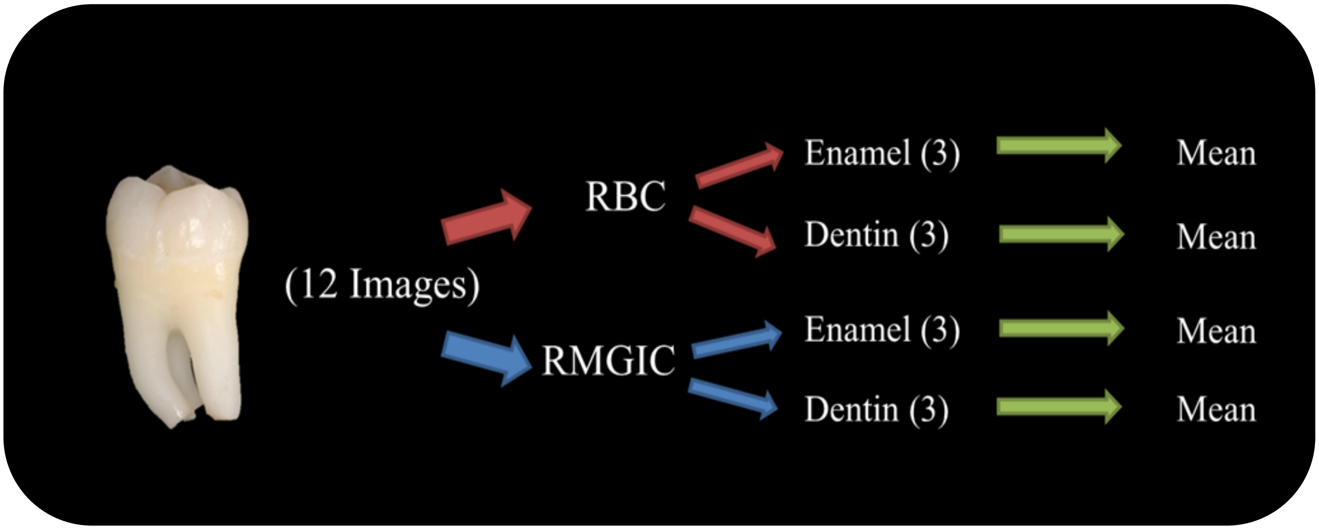


Figure 10. 12 images per tooth, totaling 480 images for the study were evaluated.

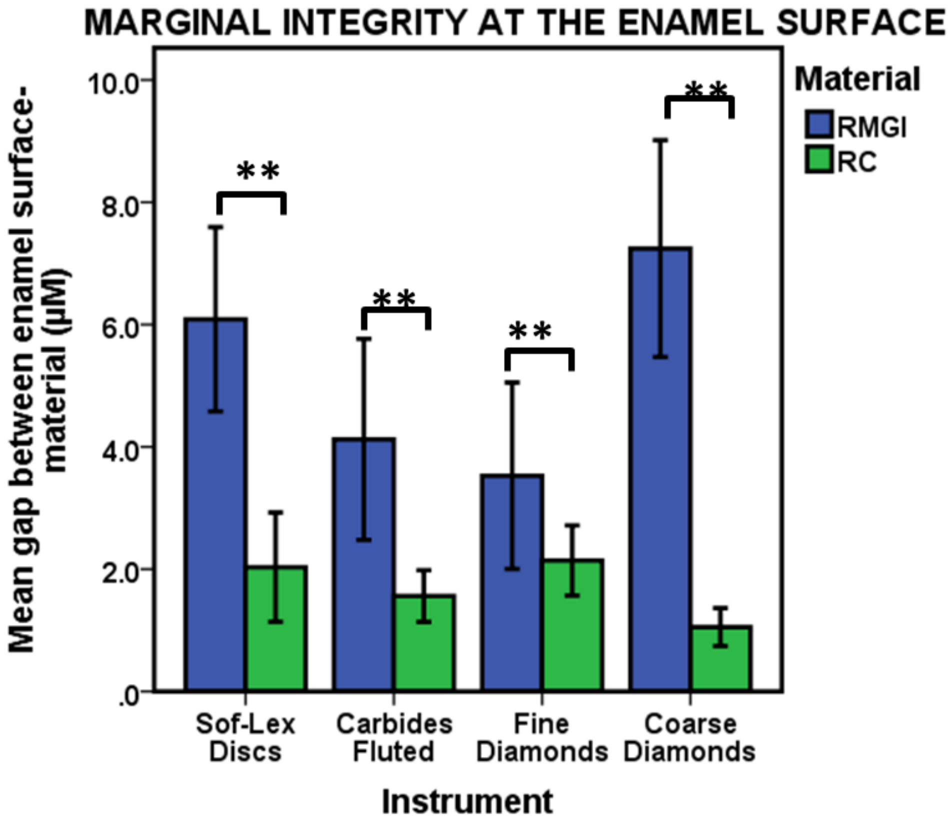


Figure 11. Marginal integrity at the enamel showed statistically significant difference between restorative materials, but not significant difference between instruments. (** *p*-value< 0.005)

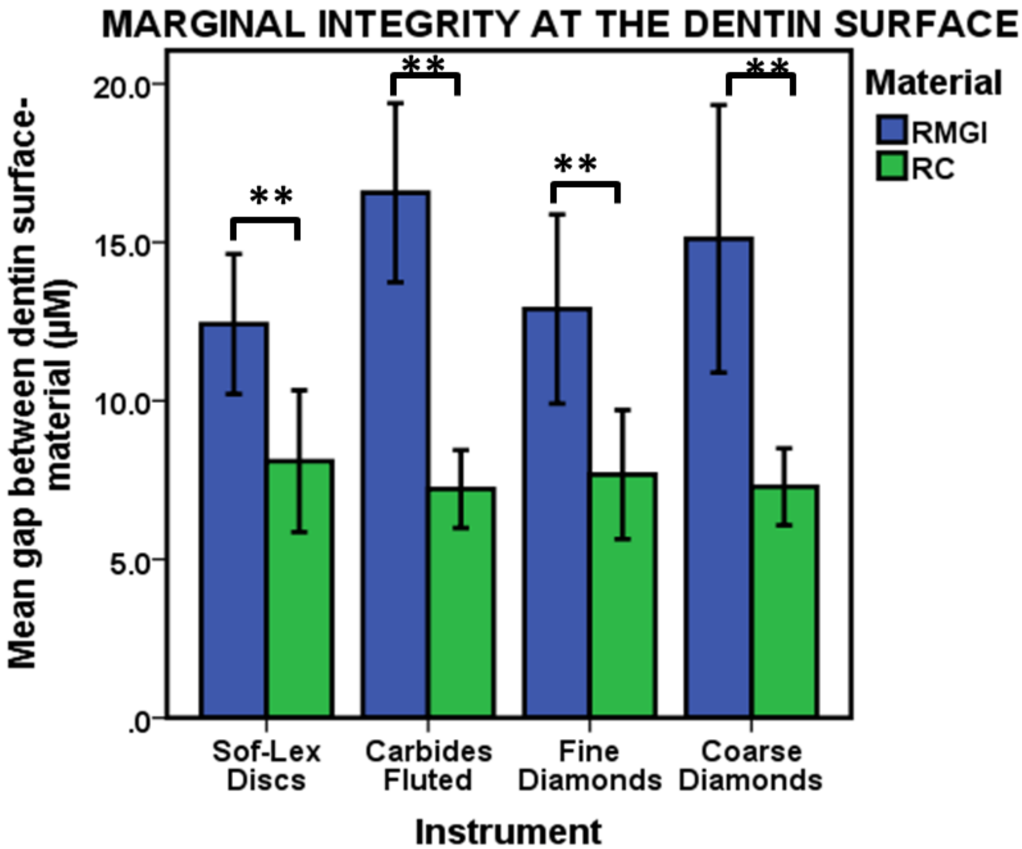


Figure 12. Marginal integrity at the dentin resulted in statistically significant difference between RMGI and RC. No statistically significant difference between instruments was observed. (** *p*-value< 0.005)

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