MARGINAL INTEGRITY OF GLASS IONOMER AND ALL CERAMIC RESTORATIONS

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CLINICAL RELEVANCE STATEMENT

This study provided useful information for deep margin elevation using glass ionomer (GI) and resin-modified glass ionomer (RMGI).

ABSTRACT

INTRODUCTION: All ceramic restorations (ACRs) are gaining popularity due to excellent physical properties and esthetics. Glass ionomer (GI) and resin-modified glass ionomer (RMGI) provide a tooth-colored restorative option when resin composite is not ideal and a metal restoration is not desired. GI and RMGI provide a slow and continuous release of fluoride and have physical properties similar to natural tooth structure. As the use of ACRs, GI and RMGI increase in dentistry, there will be greater incidence of these restorative materials being used in direct contact with each other at the external cavosurface margin.

OBJECTIVE: This study evaluated the marginal integrity of a ceramic inlay when bonded to a direct GI or RMGI restoration, as compared to bonded to natural tooth structure (enamel or dentin).

MATERIALS & METHODS: Forty, caries-free, non-restored, extracted human third molars were obtained from the National Institute of Dental and Craniofacial Research. Standardized proximal ceramic inlay preparations were made with gingival proximal cavosurface margins separated into the following four groups (n=10): 1) enamel, with margin placed 1 mm above cemento-enamel junction (CEJ); 2) dentin, with margin placed 2 mm below the CEJ; 3) GI and 4) RMGI, with the cavosurface prepared 2 mm below the CEJ, and then GI or RMGI restored to the level of the CEJ. Ceramic inlays were milled from ceramic blocks, and cemented with a dual-cured resin cement. Following thermocycling (10,000 cycles, 5°/55°C), the restorations were examined under a digital microscope for marginal gaps.

RESULTS: No open margins were noted on the 40 samples viewed under the 50x magnification.

CONCLUSIONS: The lack of open margins suggests that ACR bonding to GI or RMGI is comparable to bonding to the natural tooth structure.

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LIST OF ABBREVIATIONS

ACR	All Ceramic Restoration
AMR	All Metal Restoration
ART	Atraumatic Restorative Treatment
DME	Deep Margin Elevation
GI	Glass Ionomer
MCR	Metal Ceramic Restoration
MO	Mesial-Occlusal
RMGI	Resin-modified glass ionomer
NIDCR	National Institute for Dental and Craniofacial Research

CHAPTER I: INTRODUCTION

Metal casting utilizing the lost wax technique probably dates back to ancient China or Egypt. The first use of indirect cast metal dental restorations is generally attributed to Dr. Swasney in 1890.[1] With the introduction of improved casting methods by Taggert and Jamieson in 1907, precision casting of full gold crowns became readily attainable.[2] Since that time, indirect extra-coronal cast metal dental restorations have demonstrated a well-documented history of success.[3, 4] The first indirect cast restorations were typically fabricated out of gold. They exhibited a coefficient of thermal expansion, wear characteristics and strength very similar to natural teeth.[5,6] However, disadvantages included poor esthetics and the high cost of gold.

Ceramics are defined as non-organic, non-metallic materials created by heating minerals at high temperatures. [7] Dental ceramics are composite materials whose structure can vary from amorphous to polycrystalline. A ceramic can be classified by the ratio of glass to crystalline present in its composition. This ratio will determine the microstructure and type of internal structure exhibited by the ceramic. The microstructure of the ceramic will define the characteristics and physical properties of the material.[8]

As the desire for tooth-colored restorations increased, the metal ceramic restoration (MCR) gained popularity.[9] The first MCRs were developed by Weinstein in the 1950's. They were composed of porcelain powders using 11-15% percent K_2O and subjected to temperatures of 700-1200 C°. The MCR appeared more like a natural tooth, while providing the strength necessary to function well under occlusal load.[10] However, the high opacity and occasionally visible metal margins left practitioners searching for a better esthetic option.[11]

CHAPTER II: REVIEW OF THE LITERATURE

Indirect All -Ceramic Restorations

Indirect all-ceramic restorations (ACRs) were introduced independently by Horn, Simonsen, and Calamia in the early 1980s.[12] They appealed to patients who desired a metal-free restoration.[13] The ACR represented a significant esthetic improvement over all-metal and metal-ceramic restorations.[14] Ceramic materials with high aluminosilicate glass, such as feldspathic porcelain, contain fillers such as leucite, nepheline, or albite added to improve their physical properties. These high-glass content ACRs appear very similar to natural teeth. However, due to the irregular microstructure of the glass matrix infused with fillers, they do not possess fracture resistance comparable to natural teeth. This limited ACRs composed primarily of glass to anterior areas.[15]

To improve the physical properties of the ACR, filler particles such as lithium disilicate, alumina, and spinel were added to the glass matrix. This gives greater strength to the restoration.[16] With a high filler content and lower glass content, these ceramics have greater fracture resistance. These improved ceramics can be used in areas with significant lateral and protrusive forces applied to them, but where esthetics is still important.[12]

Most recently, ceramics with a polycrystalline structure have been introduced. Instead of glass, these ceramics are composed of a strong matrix of alumina or zirconia. An additive, known as a dopant, such as yttrium, cerium, and aluminum can be added to the zirconia matrix, while magnesium is added to a matrix composed of alumina.[17] These dopants are added to improve the optical appearance of the well-ordered structure of these ACRs.[18] The polycrystalline structure has a much higher resistance to fracture than the less dense and irregular composition of glass-containing ACRs.[19]

The development of Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) of ceramic restorations has increased the ability of dentists to deliver high quality

ACRs.[19,20] CAD/CAM ceramic restorations can often be made and delivered in one appointment. This eliminates the need to fabricate a physical master impression, stone casts, and provisional restoration.[21] By using the CAD/CAM system, the dentist is able to keep the milling process in-office, bypassing the need for the dental laboratory.[22] The milling process is faster, and more importantly, CAD/CAM restorations have become more accurate in terms of anatomic appearance, and interproximal and occlusal contacts.[23] Research has shown that the long term acceptability and marginal integrity of single crowns fabricated by CAD/CAM technology are similar to single crowns fabricated by traditional laboratory methods over a three-year time period.[24]

Resin Bonding

The ACR has benefited from advances in resin bonding.[25] A considerable advantage of the ACR is that the dentist is able to adjust the shade of the final result by using resin cements.[26] There is an increasing range of shades in resin cements that can be used to modify the shade and value of the restoration. The resin cement can also block out any potential imperfections present in the prepared tooth from being externally visible.[27]

Modern bonding techniques involve treating the prepared tooth with phosphoric acid and a resin bonding agent.[28] The ACR is etched with hydrofluoric acid, which exposes surface area for mechanical retention. The restoration is then treated with silane to act as a coupling agent between the restoration and bonding resin cement.[29] The silane agent forms a covalent hydrogen and chemical bond between the organic matrix of the resin and the exposed hydroxyl group on the surface of the treated ceramic.[30]

The Use of Glass Ionomer in Restorative Dentistry

Glass ionomers (GIs) were developed to combine the favorable physical and esthetic properties of resin composites with the fluoride release of silicate cements.[31] GI is created when a strontium or calcium alumino-flouro-silicate glass powder is mixed with a polyalkenoic acid.[32] The first GIs set using only a chemical reaction initiated by mixing the acid and base.[33] During the setting process, the acid groups are neutralized by the glass powder. GI performs well in the presence of moisture and has low solubility when completely set.[34] Water is the medium that facilitates ionic exchange.[35] This reaction causes the release of fluoride ions. The amount of fluoride released by GI cement into the prepared tooth was found to be statistically greater than the fluoride output of other silicon-phosphate cements.[36]

The addition of a photo-polymerizabale resin to traditional glass ionomer yields resin-modified glass ionomer (RMGI).[37,38] Inclusion of resin in the GI system decreases the setting time. RMGI enhances the cohesive strength of the restorative material while maintaining the tensile and compressive strength of traditional GI.[35,39] A recent improvement in RMGI is the addition of smaller filler particles, leading to the name nano-ionomer.[40] The decreased size of the filler particles results in a GI with high polishability and better esthetic results.[41]

Decreasing the base-to-acid ratio will yield a GI that can be used as luting cement. GI has been used successfully as luting cement for many years,[42, 43] especially for pediatric patients in need for the delivery of stainless steel crowns and orthodontic bands.[37] Another useful application of GI is as a liner under direct restorations.[44] GI liners have positive clinical performance when used to cover dentin prior to the acid etching step when placing direct composite restorations.[45] GI can also be an excellent choice as a liner when a restoration is close to the pulp of the tooth.[46,47] The low modulus of elasticity, and potential for self-repair following the inevitable micro-fractures seen in the setting process, make GI an excellent layer between tooth structure and a more brittle direct restorative materials.[48]

Unlike resin composites, which rely on acid etching and micromechanical retention, GI bonds chemically to tooth structure via chelation.[49] In this process, calcium ions chelate carboxyl groups on polyacrylic acid to form cross-linked chains of polymers. Carboxyl groups present on the polymer chains bond with ions on the surface of tooth structure and the alumino-silicate powder.[50] Over the first 2-3 days, calcium ions are substituted for aluminum ions, forming an even tighter polymer chain. Over the next month, available silicate ions react with water to create covalent bonds, increasing the strength of the tooth-to-GI bond.[51]

The ability of GI to provide extended fluoride release is a great advantage.[52] The slow and continuous release of fluoride by GI has an anti-cariogenic effect adjacent to the margins of indirect restorations.[53] Recurrent caries is a major cause of failure of dental restorations.[54,55] This occurs when cariogenic bacteria colonize the area between restoration and tooth surface. The acid released by these bacteria causes a drop in the local pH, which demineralizes tooth structure.[56] Fluoride-releasing dental materials inhibit the drop in pH at the cavosurface margin.[57]

The positive performance of GI makes it a frequently used restorative material.[58] GI has a coefficient of thermal expansion similar to enamel and dentin.[59,60] A similar coefficient of thermal expansion decreases microleakage and postoperative sensitivity.[61]

GI's ability to bond to tooth structure through chelation makes it very effective when there is minimal enamel left for bonding.[52] In areas of buccal or lingual cervical recession, GI provides a tooth colored restoration with good marginal adaptation,[62] when resin-based composite is not clinically ideal, but an amalgam or gold restoration is not desired.

The fluoride releasing properties of GI make it an excellent choice for patients with high caries risk. Patients with extensive treatment needs often require multi-phased treatment plans. GI can provide an esthetic and functional restoration in the disease control phase of treatment, prior to initiation of the corrective phase. Similarly, GI is the most commonly utilized restorative material in atraumatic restorative treatment (ART). [63,64] This technique consists of removing gross decay and placing a restoration to protect the tooth and inhibit further decay.[65] ART is often used in low-income areas, and in countries where modern dental treatment may not be affordable or available.[63]

Research indicates that Class II resin-based composite and GI restorations have the highest success rate when the cervical margins are placed in enamel due to the presence of more enamel rods available for bonding.[66,67] However, the success rate of Class II restoration decreases when the cervical margins are placed on dentin. [68]

To improve the longevity of restoration, the sandwich technique was developed to use GI as a base under a resin composite restoration.[69] The technique can improve the marginal adaptation of Class II resin composite restorations when gingival margins are located in dentin.[68] The "closed sandwich" technique uses GI as the restorative material on the internal aspect of the preparation, and maintains resin-based composite as the restorative material at the entire cavosurface margin. The "open sandwich" variation utilizes GI at the external cavosurface margin in the cervical area.[70,71]

Marginal Integrity in Dental Restorations

The success of indirect dental restorations is directly related to the marginal adaptation. Open margins collect plaque and have increased leakage and failure rates.[72] Marginal integrity is expressed as the micrometer gap between dental restoration and fixed margin of the tooth.[73] The margins of dental restorations can be evaluated clinically using radiographs and tactile examination.[74] Marginal integrity is often measured in the laboratory using dye penetration and electron microscopy.[75]

The margins of an AMR made from gold have been found to reach 7 to 65 micrometers.[76] The marginal integrity of the MCR has been found to range from 6 to 34 micrometers.[77] Variance in marginal integrity in MCR can depend on the type of metal used to fabricate the coping. Initially, the ACR did not have the ability to completely cover the margin. Instead of the crown fitting perfectly, the early ACR relied upon the luting cement to seal the cavosurface margin. When the CAD/CAM ACR entered into use, initial marginal integrity left room for improvement, with marginal integrity ranging from 63-161 micrometers.[78] Over time the scanning and milling technology has improved. Current marginal integrity of ACR's has been reported to range from 40 to 60 micrometers.[79]

Challenging Restorative Conditions

Full coverage indirect restorations are often indicated after teeth have been treated with a series of direct restorations. Often these restorations have increased in size and depth at each dental encounter.[80] By the time an indirect restoration is indicated, the margin is often sub-gingival. The ideal location of an ACR is one with ample enamel present to bond with the resin cement.[81] As the margin of the ACR extends toward the CEJ, there is decreasing enamel available. If ideal bonding cannot be achieved on the external cavosurface margin, the longevity of the restoration may be compromised.[82] Dental restorations have the highest success rate when they are placed above the CEJ.[83,84,85] However, there are many situations when it is not possible to place restorations above the CEJ.

When the margin of a restoration approaches the alveolar bone, the biologic width is violated.[86,87] The biological width is the area of the gingival tissue connected to the tooth above the height of the alveolar bone.[88] Restorations should allow for at least 2-3mm of biologic width.[89] If biologic width is violated, periodontal bone loss and gingival inflammation can occur.[90] Corrective Crown Lengthening (CCL) is a surgical procedure to remove hard and soft periodontal tissue for a more accessible margin. This procedure involves gaining access and surgically removing supporting bone to allow for a more supragingival margin and reestablishing biologic width.[88] Although this is a proven technique, there are some disadvantages. Surgical complications such as post-operative bleeding and bacterial infection can occur. Post-operative sensitivity and decreased ability to perform oral hygiene at the surgical site immediately following the operation has been noted.[91] Poor gingival esthetic results and gingival recession can occur, resulting in a "black triangle" surrounding the restored area.[92]

Margins that are placed with cavosurface above the gingiva are believed to have higher success rates. One study found that subgingival margins with restorative overhangs lead to changes in the types of bacteria found in the adjacent periodontium.[93] A supragingival margin makes the impression taking process easier and more accurate and makes it easier to verify proper fit of the restoration. Removing excess cement and polishing the margins of the indirect restoration are also better accomplished when the margin is in accessible location.[92]

Recently, non-surgical techniques have been developed to place restorative margins in a more ideal location. Deep margin elevation (DME), also termed proximal box elevation (PBE), involves placing a resin-based composite to relocate the gingival margin in a more coronal location.[94] With the gingival margin more accessible, it can be isolated with a rubber dam. This allows the the dentist better access and moisture control.[95]

The PBE technique has been used to raise proximal dentin margins prior to scanning for indirect dental restorations. Using this composite placement technique, PBE could be used as an alternative to other restorative techniques, such as placing the margin of the direct restoration in a deep subgingival location.[96] PBE has been shown to provide marginal integrity comparable to when ceramic restorations are placed in dentin.[97] However, by placing a layer of direct restorative material at the cavosurface margin prior to an indirect restoration, the practitioner introduces another restorative interface with the potential for leakage. When using techniques such as PBE, there are concerns that there will be an increase in failure between the additional layer of restorative material.[96]

CHAPTER III: MATERIALS AND METHODS

This *in vitro* study quantified and compared the marginal integrity of all-ceramic inlays when bonded to a direct GI or RMGI restoration, as compared to bonding to natural tooth structure (enamel or dentin). The independent variables were: (1) margin depth (two levels: enamel and cementum); and (2) restorative material for margin elevation (GI and RMGI). The dependent, or outcome, variable was marginal integrity, measured as the percentage of gingival cavosurface margin visibly closed when viewed at 50x magnification.

Sample Size Determination. We used a sample size calculator developed by the University of British Columbia Department of Statistics[98] with the following assumptions:

α (Type I error):	0.05
Sigma (common S.D.):	15% of the mean
Power:	0.80
Two-sided Test	

The sample size needed to detect a 20% difference between mean values was calculated to be n = 9. For ease in statistical calculations, we elected to increase the sample size to n = 10.

Specimen Preparation. Forty caries-free, non-restored, extracted human third molars were obtained from the National Institute for Dental and Craniofacial Research (NIDCR) (approved Material Transfer Agreement). The teeth were cleaned of any contaminants or biologic debris and stored in 0.5% chloramine T at 4° C for up to twelve months until ready for use. Twenty-four hours before beginning the study, all specimens are transferred to deionized water at 4° C. .

Specimens were assigned to four treatment groups (n=10): 1) enamel, with margin placed 1 mm above the CEJ; 2) dentin, with margin placed 2 mm below the CEJ; 3) GI and 4) RMGI, with the cavosurface prepared 2 mm below the CEJ, and then GI or RMGI restored to the level of the CEJ (Table 1).

Standardized proximal ceramic inlay preparations were made (33% of overall width at bucco-lingual dimension of isthmus, 33% of overall width at bucco-lingual dimension of proximal box, 33% of overall occlusal depth, extended to the central groove mesio-distally, and 2 mm mesio-distally of depth in the proximal box at the cervical margin). For the control group, the cervical margin was placed 1 mm above the CEJ in enamel (Figure 1). In the remaining three groups, the cervical margin was placed 2mm below the CEJ in cementum (Figure 2). Twenty teeth had 2 mm DME restored to the level of the CEJ using either a self-cured GI (Fuji IX, GC America, Alsip, Illinois) or light-cured RMGI (Fuji II LC, GC America, Alsip, Illinois) (Figure 3). Each of the forty preparations were scanned by the CEREC Omnicam (Sirona, Charlotte, North Carolina). Forty feldspathic porcelain inlays were milled from CEREC Blocks, and milled by CEREC inLab MC XL system (Figure 4). Following milling, the intaglio surface of the inlays were treated using 5% hydrofluoric acid for 60 seconds, rinsed with water for 60 seconds, and treated with a silanating agent for 60 seconds. The restorations were cemented to the respective samples using Nexus NX3 resin cement (Kerr, Orange, California) followed by polishing, according to the manufacturer's instructions (Figures 5, 6, 7).

The study proposal was approved by the Walter Reed National Military Medical Center Department of Research Programs in September 2014. The funding for the project was allocated in May 2015. Tooth preparation was completed in January 2016, and the 40 samples were thermocycled in February 2016, after which the samples were examined under the HiRox KH-1300 digital microscope (Hirox, Hackensack, New Jersey).

Following 24 hours storage in distilled water at room temperature, the specimens were subjected to thermal cycling (10,000 cycles; 5° C / 55° C; 30 seconds each). After thermocycling, the samples were examined under a digital microscope (HiRox) at 50x magnification.

The interface between the ACR and the GI, RMGI, cementum or enamel composing the terminal margin of the tooth was examined. Each interface was classified as either possessing a closed or open margin, measured as the percentage of gingival cavosurface margin visibly closed. A closed margin was defined as having complete continuity between restorative materials, or between restorative material and tooth structure. An open margin would indicate there was a gap between restorative materials. The null hypothesis was that there was no difference in the marginal integrity of ceramic inlays cemented to GI or tooth structure.

CHAPTER IV: RESULTS

In this study, all 40 margins were closed with no discrepancies. There were no clinically relevant differences between the four sample groups. Figures 8-11 show representative results with closed margins on the samples. Each of the ten samples within the four groups with cervical margins placed in enamel, cementum, GI or RMGI had no marginal gaps.

Upon first examination under the microscope, some flash was noted that was covering up the ACR to GI, RMGI, enamel or cementum margins. The samples were re-polished in order to remove this flash and better visualize the margin.

Following re-polishing, the lack of open margins on all samples was confirmed under 50x digital magnification with the HiRox microscope. Marginal integrity appears to be as good between ceramic restorations and GI or RMGI as between ceramic restorations and natural tooth structure.

CHAPTER V: DISCUSSION

In modern dentistry the ACR is gaining popularity due to its esthetic and structural qualities. It has an appearance very similar to natural tooth structure.[99] Advances in the science of dental materials are resulting in improved and stronger ACRs that can be placed in areas with significant occlusal forces applied to them. CAD/CAM technology allows creation of a strong and esthetic ACR in one visit.[100] Both patients and providers can appreciate the convenience of the CAD/CAM ACR treatment option.

The use of GI has increased since the 1970s.[31,56] GI physical properties and bonding capabilities make it a good choice for restoration when extensive tooth structure has been lost.[52] It has been used to successfully repair and extend the longevity of indirect restorations.[101] Fluoride released from GI can help remineralize teeth.[102] Techniques such as the open sandwich restoration have demonstrated the success of GI when used at the cervical margin.[70]

Direct and indirect restorations are most successful when placed in a supragingival location with sufficient enamel at the cavosurface margin.[103] Recent techniques such as DME and PBE have involved the use of resin-based composites to place cavosurface margins in a more accessible, coronal location. Repairing existing direct and indirect restorations with direct restorative materials can be successful.[104]

The ACR and GI are often used in conjunction. GI is frequently used as a liner and base to support an ACR.[105] As the use of both GI and ACRs increases in dentistry, the incidence of these restorative materials being used in direct contact will increase. There are documented situations when there is consistent marginal failure when two different direct restorative materials are joined together.[106] However, there is not sufficient research present to evaluate the performance of GI when it is in direct contact with an ACR, and simultaneously exposed to the oral environment as an external cavosurface margin. Therefore, purpose of this study was to evaluate the marginal leakage of a ceramic inlay when bonded to a direct GI or RMGI restoration, as compared to that of a ceramic inlay bonded to enamel or cementum.

In this study, all 40 margins were closed with no discrepancies. There were no clinically significant differences between the four groups. The results resembled similar studies that saw no difference in marginal integrity of indirect restorations cemented to direct restorative material, when compared with dentin and cementum.[96,107] It is generally assumed that a bonded ACR will be most successful when cemented to an enamel margin with perfect isolation.[66,67] However, in clinical practice there are many situations when it is not possible to place the cavosurface margin on enamel. This study examined placing the cavosurface margin on enamel, cementum, GI or RMGI restoration. Marginal integrity appears to be as good between ceramic restorations and GI or RMGI as ceramic restorations and natural tooth structure.

No significant difference in samples could result from a number of factors. It is possible that there were not enough samples in the study. In this case, a sample size calculator was used from the University of British Columbia Department of Statistics [98] that anticipated detecting a 20% difference between mean values to determine the sample size of n = 9. It was rounded to n = 10 for ease in statistical calculations.

Another limitation influencing the results was the fact that *in vitro* conditions are unrepresentative of the oral environment. For example, no chewing or mechanical cycling was performed, which might otherwise place stresses on the tooth and restoration interface. Teeth were thermocycled in distilled water instead of saliva. Saliva has a rich chemical composition that might interact with the resin cement differently than distilled water. There were also no acid insults that would be expected with daily food and beverage intake. And no toothbrush or flossing abrasion occurred. Future studies could incorporate conditions closer mimicking the oral environment.

Finally, restorations were cemented with no adjacent tooth present, allowing ease of placement and finishing. This is consistent with clinical placement of an ACR on a class V GI or RMGI restoration, but when the restoration is interproximal, the finishing and polishing of the margin become more difficult. The likelihood of more voids trapped between an interproximal matrix increases. Perhaps a future study could examine restorations placed interproximally in multiple teeth mounted adjacently.

Despite the shortcomings of this study, based on the findings it appears that bonding ACRs to GI should have similar clinical success as bonding ACRs to natural tooth structure. More research is indicated to evaluate this bonding success under wear, occlusal loading, and erosive and abrasive conditions.

CHAPTER VI: CONCLUSION

This *in vitro* study evaluated the marginal integrity of a ceramic inlay when bonded to a direct GI or RMGI restoration, as compared to bonding to enamel or cementum. There were no clinical differences across the four categories examined at 50x magnification. Sound margins were found on ceramic restorations bonded to enamel, dentin, GI, and RMGI. This suggests that placing a ceramic restoration on a GI or RMGI restoration using DME is a viable clinical option.

CHAPTER VII: REFERENCES

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CHAPTER VIII: TABLE

Table 1. Treatment groups (n = 10 restorations).

Group	Margin Placement	Deep Margin Elevation	DME Material
1 (Positive Control)	Enamel	--	None
2 (Negative Control)	Cementum	--	None
3	Cementum	Yes	Fuji II LC
4	Cementum	Yes	Fuji IX

CHAPTER IX: FIGURES

Captions

Figure 1: Tooth preparation in enamel with margin 1mm above the CEJ.

Figure 2: Tooth preparation in cementum with margin 2mm below the CEJ.

Figure 3: DME restored with GI or RMGI to level of the CEJ. Figure 4: Milled Cerec ACR inlay prior to cementation.

Figure 5: ACR inlay bonded to enamel after excess cement removed and polished.

Figure 6: ACR inlay bonded to cementum after excess cement removed and polished.

Figure 7: ACR inlay bonded to GI or RMGI after excess cement removed and polished.

Figure 8: View at 50x digital magnification of ACR inlay bonded to enamel. Cement completely fills the margin and no voids are present.

Figure 9: View at 50x digital magnification of ACR inlay bonded to Cementum. Cement completely fills the margin and no voids are present.

Figure 10: View at 50x digital magnification of ACR inlay bonded to GI. Cement completely fills the margin and no voids are present.

Figure 11: View at 50x digital magnification of ACR inlay bonded to RMGI. Cement completely fills the margin and no voids are present.

Figure 1

Figure 2

Figure 3

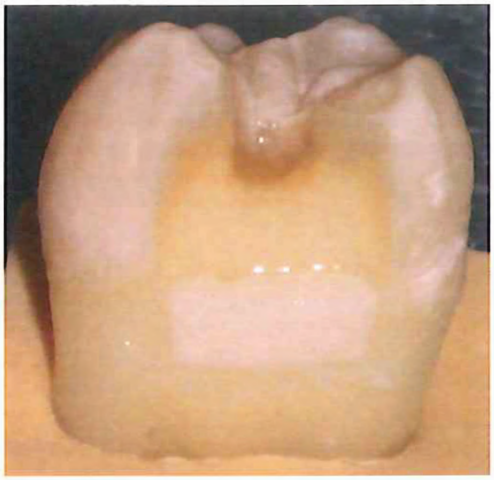

Figure 4

Figure 5

Figure 6

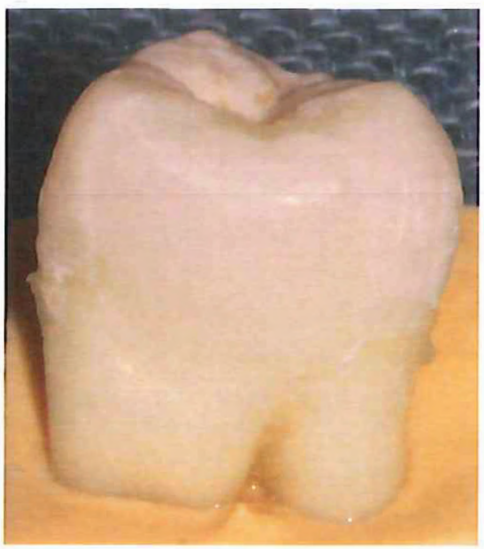

Figure 7

Figure 8

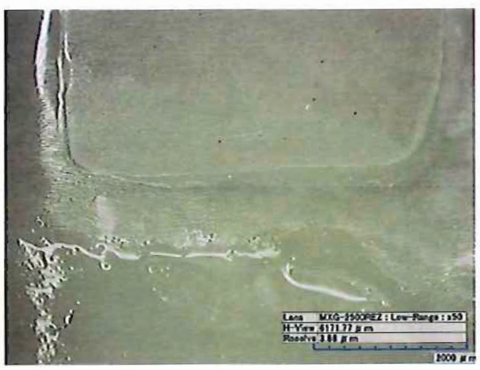

Figure 9

Figure 10

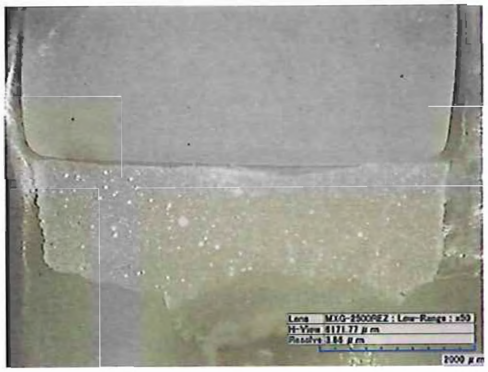

Figure 11