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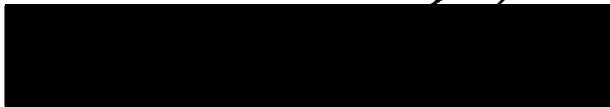
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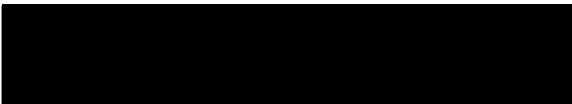
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Shear Bond Strength of a New Resin-modified Glass Ionomer in comparison to Resin-based Composite using Different Bonding Agents.

A Thesis

Presented to the Faculty of the Advanced Education in General Dentistry, Two-Year Program,
United States Army Dental Activity, Fort Hood, Texas

And the Uniformed Services University of the Health Sciences – Post Graduate Dental College

In Partial Fulfillment of the Requirements for the Degree of

Master of Science in Oral Biology

By

Ki Hong Park, CPT USA DC

May 2018

Shear Bond Strength of a New Resin-modified Glass Ionomer in comparison to Resin-based Composite using Different Bonding Agents.

A REPORT ON

Research project investigating the shear bond strength of ACTIVA Bioactive Restorative (Pulpdent, Watertown, MA, USA) and Filtek Supreme Ultra (3M ESPE, St. Paul, MN, USA) among different bonding agents (OptiBond FL, ClearFil SE 2, G-aenial Bond).

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ABSTRACT

Purpose: The purpose of this study is to analyze the shear bond strength of new resin-modified glass ionomer (ACTIVA BioActive Restorative) and resin composite materials (Filtek Supreme Ultra) using different adhesive agents (OptiBond FL, ClearFil SE 2 and G-aenial Bond). The comparisons will be analyzed to determine if a new resin-modified glass ionomer is a possible alternative option in restoring large posterior restorations and open sandwich technique.

Methods: 105 samples were prepared for testing and divided into three groups. Group 1: ACTIVA bonded to ACTIVA, Group 2: Filtek Supreme Ultra bonded to Filtek Supreme Ultra, and Group 3: ACTIVA to Filtek Supreme Ultra without bonding agent. These groups will further divided into three subgroups based on bonding agents. Surfaces of the samples were polished and cleaned with ultrasonic. Adhesive agents were applied according to manufacturers' recommendations. The bonded groups of samples were sheared off in a universal testing machine (MTS). After testing is completed, the samples were analyzed under a light microscope to evaluate method of failure (adhesive, cohesive, mixed).

Results: A total of 105 samples were included in this study (45 samples of two groups and 15 samples of one group). The mean shear bond strength of Group 1 was 3.954 MPa with a standard deviation of 2.173. The mean shear bond strength of Group 2 was 10.552 MPa with a standard deviation of 3.597. The mean shear bond strength of Group 3 was 2.627 MPa with a standard deviation of 1.194. According to the one-way ANOVA and Tukey Kramer HSD tests, there was a statistical significance in shear bond strength between groups ($p < .05$). Adhesive bond failures at the bonding interface were the most common finding in mode of failure. All samples of group 3 exhibited adhesive failures because there was no bonding agent was applied.

Conclusion: ACTIVA BioActive Restorative utilizes patented bioactive resin matrix and glass ionomer, being marketed as true bioactive resin-modified glass ionomer. The manufacturer, Pulpdent Inc., claims superior compressive strength and other more desirable mechanical properties when compared to other RMGIs and comparable to flowable composites. Therefore, this material is indicated for class I, II restorations and core material without using adhesive agents unless retention is in question. In this study, the researcher found statistically significant in shear bond strength of Filtek Supreme Ultra compared to ACTIVA and control: Filtek Supreme Ultra had the highest mean shear bond strength of the three. Thus, based on our study, clinicians should be aware of using ACTIVA on large three or multi surface restorations in conjunction with using composite restoration. However, this study has limitations, and further in vitro studies need to be conducted with tooth structure.

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DISCLAIMER

The opinions or assertions contained herein are the private ones of the author(s) and are not to be construed as official or reflecting the view of the DoD or the USUHS.

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INTRODUCTION

Resin-modified Glass Ionomers (RMGIs) are hybrid materials of conventional glass ionomers (CGI) with a small addition of light curing resin.¹ Conventional glass ionomers have physiochemical adhesion to tooth structure and release of fluoride ions. Compared to resin-based composites, the glass ionomers possess poor physical properties and are not esthetic.² Due to these reasons, conventional glass ionomers have been widely accepted in the United States as liners, luting agents, and core build-up materials, but their use as restorative materials have been limited.³ Furthermore, they are very sensitive to excessive moisture or desiccation.⁴ In order to overcome these limitations, resin-modified glass ionomers are developed and consider more esthetic and less sensitive to moisture than conventional glass ionomers. It has been known that RMGIs possess the intermediate properties of CGI and resin composite. The mechanical properties of RMGIs show that this group of material is weaker than resin composite but stronger than conventional glass ionomer cement.¹

RMGIs have been developed initially for liner/base materials⁵, and modern RMGIs can be used as restorative materials such as Class V restorations and open sandwich technique.⁶ Particularly, they have found use in pediatric dentistry for restorations in primary teeth and small cavities in permanent teeth.⁷ However, RMGIs are considerably weaker compressive and diametral tensile strengths than resin-based composites. Therefore, RMGIs have been conventionally avoided to be used in not only class I or II restorations but also as a core material.

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The bioactive composite material in dentistry has grown tremendously in recent years. The bioactive dental materials mimic nature and claim to have similar mechanical properties as natural

dentition. They contain water, interact with saliva and tooth structure, release and uptake calcium, phosphate and fluoride ions, and react to pH changes in the oral environment.⁹

ACTIVA BioActive Restoratives is the newest generation of bioactive resin-modified glass ionomers that was introduced in 2014. According to manufacturer's claim, this material was able to be introduced in the market as "bioactive" because it has a patented, moisture-tolerant ionic resin matrix that facilitates release and recharge of calcium, phosphate and fluoride ions.⁹ In addition, this material will enhance the formation of apatite which fuses to dentin across the margin of ACTIVA (Figure 1).

General characteristics of ACTIVA BioActive Restorative are triple cure, water friendly, and fluoride release. ACTIVA Bioactive-enhanced RGMI demonstrated comparable flexural strength (105.4 ± 14.3 MPa) and flexural fatigue (63.7 ± 15.1 MPa) compared to flowable composites and significantly greater than conventional RGMIs and glass ionomers. This in vitro study suggested that the ACTIVA BioActive RGMI material demonstrated flexural strength properties in conformity with and in excess of the minimum requirement of ISO 4049 for occlusal restorations (80 MPa).¹⁰ In previous studies, the resin-modified glass ionomers wore significantly faster than the acid-base setting glass ionomers. Due to unfavorable wear characteristics of RMGI, it cannot be yet recommended for use in high-stress-bearing situations.¹¹ However, ACTIVA demonstrated equivalent wear with Filtek Supreme Ultra and less wear than all other materials.¹² The conventional and resin-modified glass ionomers showed significant fluoride release after 1 day and this fluoride release continued over the entire 10-week testing period.¹³ More recent studies suggested that, at the seven time points tested, the Activa BioActive Restorative has statistically greater fluoride release after recharge at 24 hours, 1 week and 3 weeks compared to the other groups tested (Ketac Nano Lightcuring Glass Ionomer (RGMI) and GC Fuji Triage

(GI)).¹⁴ Resin components can be added to glass ionomers to improve their physical properties and clinical working characteristics.¹⁵ Many studies of light-activated (i.e, resin-modified) glass-ionomers liners have shown that their bond strengths are superior to those of conventional glass ionomers, generally in the range of 6-12 MPa.¹⁶

This study has a great deal of significance with regards to Army dentistry. Military dental care depends heavily on the direct restorative materials and bonding agents and focuses on ensuring that soldiers receive excellent dental care, remain deployable and decrease long-term cost of dental care per soldier. One of the most common findings Defective margins between the restoration and the tooth or between different restorative materials can cause greater problems and is time-consuming for the soldier and the provider. Furthermore, during deployment, many soldiers are not able to access to care for six to nine months in where those defective margins with poor oral hygiene can cause recurrent caries. ACTIVA BioActive-Restorative claims to form the ionic bond between the tooth and the material and have strength to endure the masticatory force with fluoride release and ionic exchanges between the tooth and the material.

Additionally, it is claimed to be hydrophillic and to have lower polymerization shrinkage which contributes to greater marginal seal. It also does not require the bonding agent between the tooth and the material due to ionic bonding. If those claims are shown to be accurate, we may experience less debonding and less recurrent carious lesions at the tooth-restorative margins, especially on military population whose hygiene may not be ideal due to deployments and operational considerations. We can therefore expect the long-term cost of dental care per soldier to decline as less intervention may be required for one's restoration. If the new resin-modified glass ionomer, ACTIVA BioActive Restorative exhibits good bond strengths to resin-based

composite in our study, then this could be an indication to start purchasing this new material for military dental clinics.

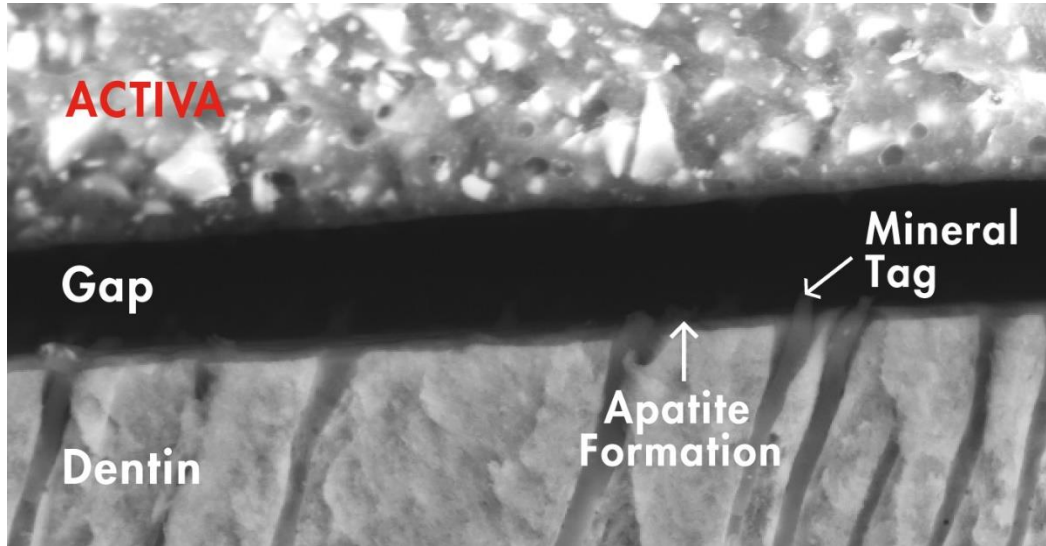


Figure 1: Scanning Electron Microscope (SEM) and Energy-dispersive X-ray spectroscopy (EDS) of apatite formation and fusion on dentin to ACTIVA (ACTIVA BioActive brochure)

Composition				
Chemical characterization of the preparation:		Bioactive ionic resin with reactive glass filler		
Hazardous ingredients				
CAS Number	Name of the Ingredient	Concentration	Classification per 67/548/EEC	Classification per Regulation (EC) No.1272/2008 (CLP).
Proprietary	Blend of diurethane and other methacrylates with modified polyacrylic acid	44.6%	Irritant; Xi R 3637//38 - 43	Eye irritation, 2 STOT SE 3 Skin irritation, 2 Skin sensitization, 1
112945-52-5	Silica, amorphous	6.7%	Irritant; Xi, R 36/37/38	Eye irritation, 2 STOT SE 3 Skin irritation, 2
7681-49-4	Sodium fluoride	0.75%	Harmful (Xn); R22-36/38	Acute toxicity, 4 Skin irritation, 2 Eye irritation, 2

Figure 2: Chemical composition of ACTIVA BioActive Restorative, based on MSDS

PURPOSE

The purpose of this study is to analyze the shear bond strength of one resin composite material to RGMI (Activa BioActive Restorative) under using different adhesive systems (OptiBond FL, Clearfil SE 2, and G-aenial Bond). The comparisons will be analyzed to determine if the newest bioactive resin-reinforced glass ionomer has comparable and competitive to a nanohybrid resin-based composite material.

HYPOTHESES

Research questions: Will there be a significant difference in shear bond strength of Activa BioActive Restorative when compared to nanohybrid resin-based composite? Will there be any significant differences among different adhesive systems?

Null hypothesis #1: There will be no significant difference in shear bond strength of Active BioActive Restorative to Filtek Supreme Ultra.

Null hypothesis #2: There will be no significant relationship between bond strengths of the composites based on adhesive systems.

MATERIALS AND METHODS

A total of 60 capsules of Filtek Supreme Ultra A2 shade (3M ESPE Dental Products, St. Paul, MN) and 4 tubes of ACTIVA BioActive Restorative (Pulpdent, Watertown, MA) were used in this study (Picture 1a and 1b). Prior to surface preparation, the round black ring was filled with Maxitemp. After Maxitemp was filled inside of the round black ring, the round carbide lab bur was used to make three circular preparation for those materials can be placed. After preparation is finished, 45 samples of Filtek Supreme Ultra and 60 samples of ACTIVA BioActive Restorative were placed into preparations (Picture 2).



Picture 1a, 1b: ACTIVA Bioactive Restorative (a) and Filtek Supreme Ultra (b) were tested.



Picture 2: Initial sample preparation into black rings.

Three preparations of each round black ring served as bonding surfaces (105 total surfaces). All bonding surfaces followed a standard surface preparation as described: The samples were then polished (6 rings at a time) using the Buehler Automet 3 Powerhead and Ecomet 6 Variable Speed Polisher. CarbiMet SiC Abrasive paper was used starting with a 320 grit (30-080320), then 600 grit (30-08-0400), and finishing with a 800 grit (30-08-0600, Picture 3). On each grit, the samples were run through two cycles at 200 rpm using five pounds of pressure. The direction of the motor would change direction for each cycle. Each sample was then evaluated under a microscope to verify that all the resin bonding surface was smooth and polished. Samples that had roughness or scratches were run through another polishing cycle using all grits. After all surfaces were evenly polished, these samples underwent ultrasonic machine for 20 minutes for clean bonding surfaces. On each round black ring, the back of it was labeled 1, 2, or 3, corresponding to the following groups: Group 1 – 45 samples of Activa BioActive Composite, Group 2 – 45 samples of Filtek Supreme Ultra, and Group 3 – 15 samples of Activa BioActive Composite.

After finishing and polishing the preparation for bases, these groups were divided further depending on the usage of bonding agents. There were three adhesive systems were used: 1. OptiBond FL 2. Clearfil SE 2 3. G-aenial bond. Further groups were sub-divided as follows: Group 1-1 15 samples of Activa BioActive Restoratives, OptiBond FL; 1-2 15 samples of Activa BioActive Restoratives, Clearfil SE 2; 1-3 15 samples of Activa BioActive Restoratives, G-aenial bond; Group 2-1 15 samples of Filtek Supreme Ultra, OptiBond FL; 2-2 15 samples of Filtek Supreme Ultra, Clearfil SE 2; 2-3 15 samples of Filtek Supreme Ultra, G-aenial bond; Group 3 Activa BioActive Restoratives, no adhesive system.

First 15 bonding surfaces were treated as follow: 1) 37% phosphoric acid etch for 15 seconds and then rinsed with water and air dried. 2) OptiBond FL primer (Kerr Dental, Orange, CA) applied with microbrush for 15 seconds and gentle air dried for 5 seconds. 3) OptiBond FL adhesive (Kerr Dental, Orange, CA) applied with microbrush for 15 seconds and gentle air dried for 5 seconds. 4) Light cured with an LED curing light, Valo Cordless (Ultradent, South Jordan, UT) for 20 seconds.

Second 15 bonding surfaces were treated as follow: 1) ClearFil SE 2 primer (Kuraray Noritake Dental Inc., Okayama, Japan) applied with microbrush for 20 seconds and gentle air dried for 5 seconds. 2) Clearfil SE 2 adhesive (Kuraray Noritake Dental Inc., Okayama, Japan) applied with microbrush for 15 seconds and gentle air dried for 5 seconds. 4) Light cured with an LED curing light, Valo Cordless (Ultradent, South Jordan, UT) for 10 seconds.

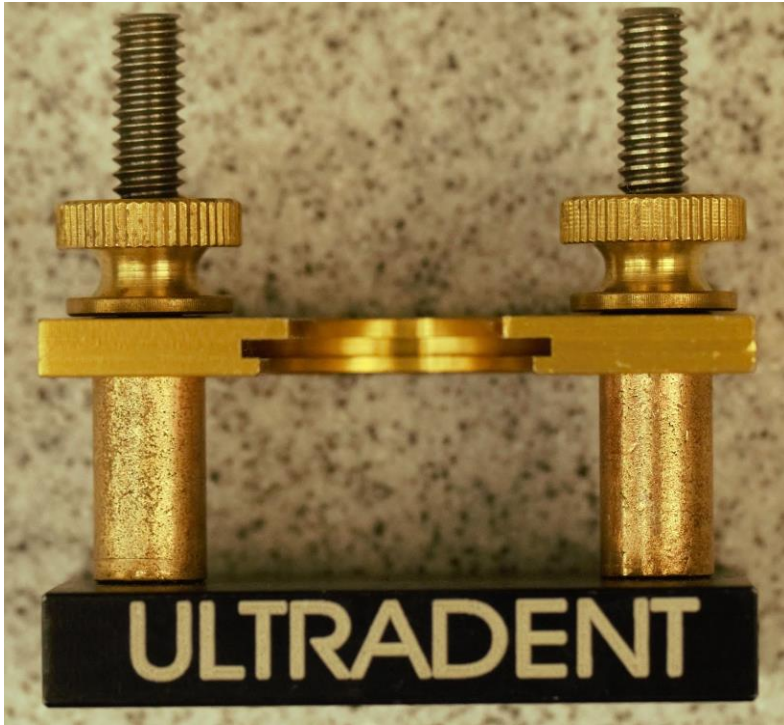
Last 15 bonding surfaces were treated as follow: 1) G-aenial Bond (GC America Inc., Alsip, IL) applied with microbrush for 10 seconds and leave for 10 seconds. 2) Gentle air dried for 5 seconds. 3) Light cured with an LED curing light, Valo Cordless (Ultradent, South Jordan, UT) for 10 seconds.

Each individual sample was prepared separately to ensure standardized application time for each step. Composite buttons, approximately 2.38 mm in diameter, were applied to specimen surfaces in accordance with ISO 29022¹⁷, the notched edge shear bond strength test. The jig used to form the buttons included a standardized button mould (Picture 3), bonding clamp mechanism (Picture 4), and metal washer (Ultradent Products Inc., South Jordan, UT). The metal washer was used to allow space for the composite button on composite bonding surfaces. Extra Care was

taken to not hit the previously formed composite buttons onto the metal washer. A finished samples with composite buttons from each group is shown (Picture 5).



Picture 3: Six samples in the ring polished using Buehler Automet 3 Powerhead and Ecomet 6 Variable Speed Polisher.



Picture 4: Ultradent jig used for creating composite samples on each block.



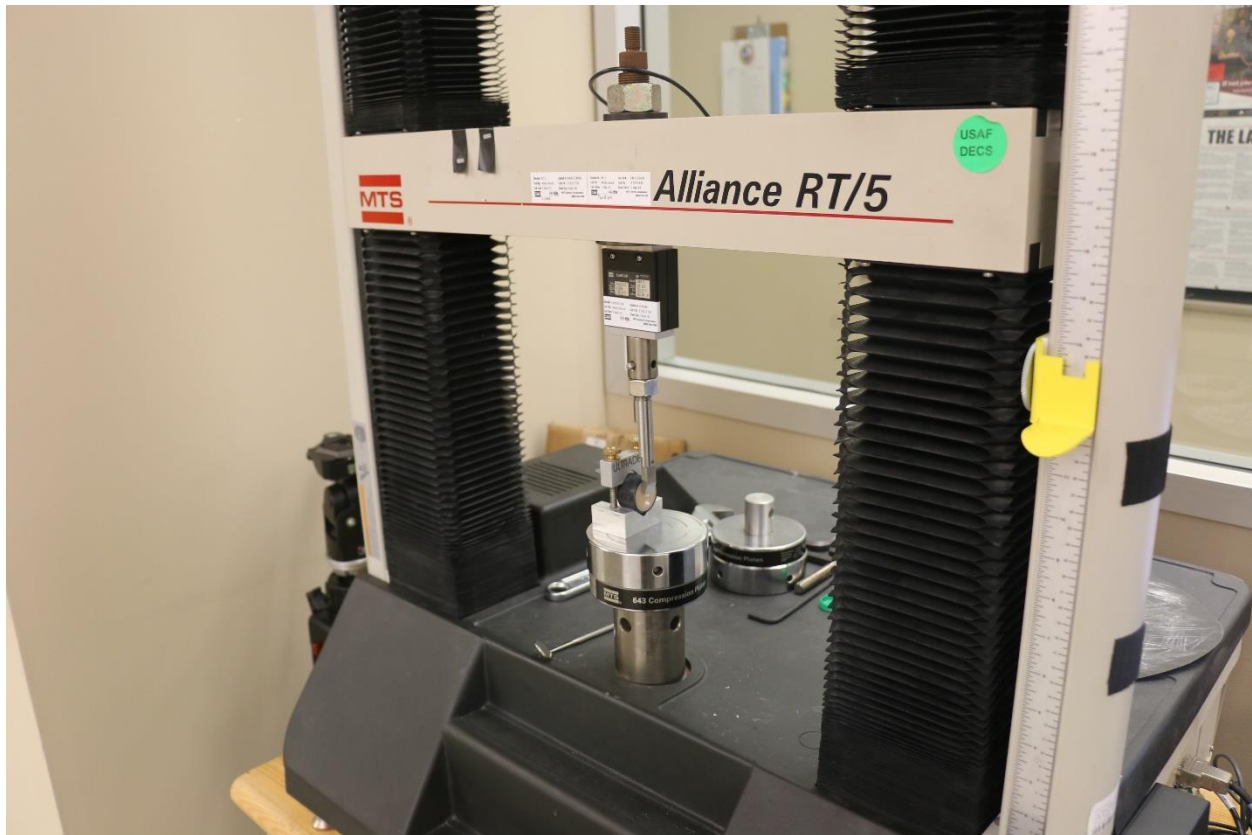
Picture 5: Standardized button mould for samples

Initial sample preparation of Maxitemp and sample placement to wells were completed at Fort Hood AEGD-2 dental lab. Finishing, polishing samples, bonding composite buttons to the samples, and the bond strength testing were completed at the USAF Dental Evaluations and Consultation Service (DECS). Two separate visits to DECS were made. First three days were preparing and finishing samples. After samples were all prepared, these samples were submerged under water with phosphate buffer and stored at 37°C in Thermo Forma Model 3110 Water Jacketed CO₂ Incubator for six days (Picture 6). Last day was dedicated to the bond strength testing and statistical analysis.

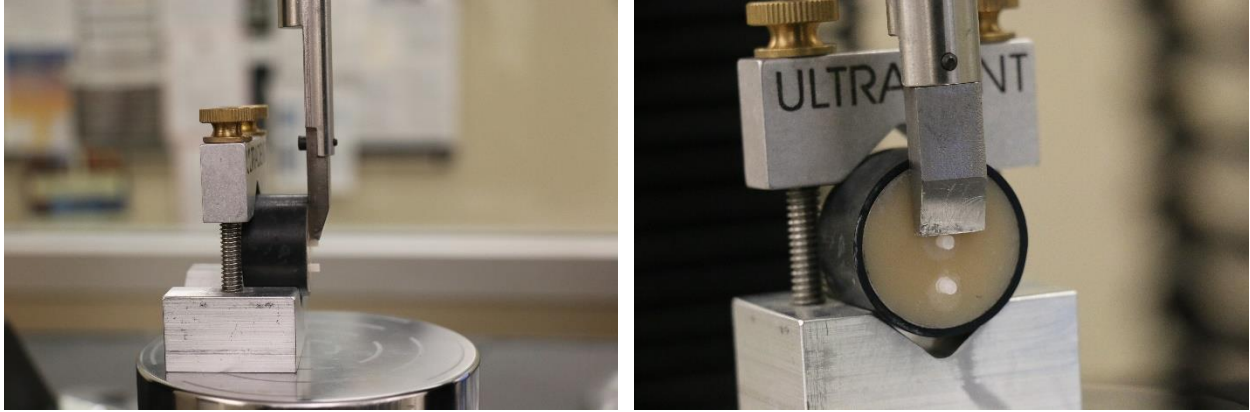


Picture 6: Samples were stored in 37°C in Thermo Forma Model 3110 Water Jacketed CO₂ Incubator for six days.

Each specimen was then secured into an Ultradent test base clamp and loaded into an MTS universal testing machine (Picture 7). The long axis of the specimen was perpendicular to the applied force of the crosshead assembly as shown in Picture 8a. Bond strength was determined in shear mode at a crosshead speed of 1.0 mm/minute until the MTS detected a fracture (Picture 8b). Finally, samples were analyzed under microscope to determine failure mode (Picture 10). Failures were categorized as adhesive, cohesive or mixed failures. Mixed failures were assigned when samples showed both adhesive and cohesive failures.



Picture 7: MTS Universal testing machine



Picture 8a, 8b: Crosshead assembly shearing off a sample at side (a) and crosshead assembly shearing off a sample at front (b).

After shear bond strength testing, the diameter of each sample was measured with digital calipers at the base (Picture 9). This value was used for calculation of the surface area (mm^2) and the bond strength in megapascals (MPa), a unit that is measured in force per unit area. Although the diameter of the standardized button former is 2.38 mm, the ACTIVA and composite did not flow or pack into the button former uniformly for each sample. Therefore, each diameter measurement is taken for more accurate result.



Picture 9: The diameter of each sample was measured after the shear bond strength test was finished.



Picture 10: Olympus SZX16 Photo Microscope (Olympus Corporation, Tokyo, Japan).

In this study, the independent variable is composite material. The dependent variable is shear bond strength measured in megapascals (N/mm^2). The null hypothesis is that there is no difference in shear bond strength with respect to composite and/or bonding agents. The alternative hypothesis is that there is a difference in shear bond strength with respect to composite and/or bonding agents. The appropriate test is a one-way ANOVA followed by post

hoc independent sample t-tests corrected for multiple comparisons. If the research data are not normally distributed, the equivalent non-parametric test will be used for statistical analysis.

The investigator estimated a mean \pm standard deviation (SD) for the dependent variable. Estimated averages of μ_0 and μ_1 are 24.9 and 24.5 respectively with the standard deviation of .5. We used the on line power analysis program at Statistical Solution, LLC (https://www.statisticalsolutions.net/pssZtest_calc.php) to estimate the sample size needed for a power of 80% with a level of confidence of 95%. The investigator will need a sample size of 13 per group to detect a minimum .5 SD effect size. Effect size is the difference between group means measured in standard deviations (SD).

RESULTS

A total of 105 samples were included in this study, divided into three groups: Group 1 – 45 samples of Activa BioActive Composite, Group 2 – 45 samples of Filtek Supreme Ultra, and Group 3 – 15 samples of Activa BioActive Composite. Then, 45 samples of group 1 and group 2 will further divided based on adhesive agents. Group 1-1 15 samples of Activa BioActive Restoratives, OptiBond FL; 1-2 15 samples of Activa BioActive Restoratives, Clearfil SE 2; 1-3 15 samples of Activa BioActive Restoratives, G-aenial bond; Group 2-1 15 samples of Filtek Supreme Ultra, OptiBond FL; 1-2 15 samples of Filtek Supreme Ultra, Clearfil SE 2; 1-3 15 samples of Filtek Supreme Ultra, G-aenial bond; Group 3 Activa BioActive Restoratives, no adhesive system. The mean shear bond strength of Group 1 (ACTIVA+) was 3.954 MPa with a standard deviation of 2.174. The mean shear bond strength of Group 2 (Filtek) was 10.552 MPa with a standard deviation of 3.597. The mean shear bond strength of Group 3 (ACTIVA+Filtek) was 2.627 MPa with a standard deviation of 1.194 (Figures 1). According to the one-way ANOVA, there was a statistically significant difference ($p < .05$) found in shear bond strength between the three groups (Figure 2). Further analysis of the means was completed through the Tukey-Kramer honest significant difference (HSD) test. This post hoc test again resulted in significant difference ($p < .05$) in shear bond strength between the means of the three groups.

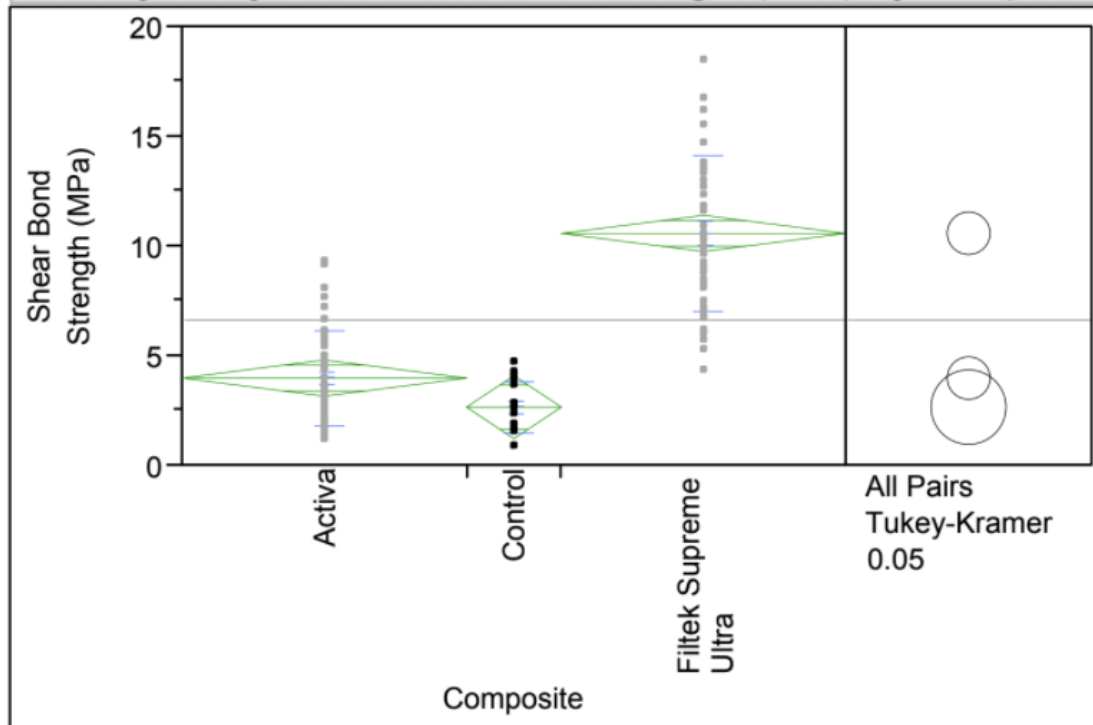
Interestingly, there was no significant difference found in shear bond strengths of sub-groups in each group (Figure 4). The mean shear bond strength of group 1-1 was 4.111 MPa with a standard deviation of 2.458; group 1-2 was 4.668 MPa with a standard deviation of 1.924; group 1-3 was 3.082 MPa with a standard deviation of 1.929. The mean shear bond strength of group 2-1 was 10.716 MPa with a standard deviation of 3.291; group 2-2 was 12.601 MPa with a standard deviation of 3.431; group 2-3 was 8.338 MPa with a standard deviation of 2.879.

Each group exhibited mostly adhesive failures of the samples (Figure 8). Filtek Supreme Ultra exhibited three mixed failures while ACTIVA exhibited one mixed failure. No cohesive failure found in this study. Group 3 only demonstrated adhesive failures.

Oneway Analysis of Shear Bond Strength (MPa) By Composite						
Oneway Anova						
Means for Oneway Anova						
Level	Number	Mean	Std Error	Lower 95%	Upper 95%	
Activa	45	3.9536	0.41676	3.1269	4.780	
Control	15	2.6266	0.72185	1.1948	4.058	
Filtek Supreme Ultra	45	10.5516	0.41676	9.7249	11.378	
Std Error uses a pooled estimate of error variance						
Means and Std Deviations						
Level	Number	Mean	Std Dev	Std Err	Lower 95%	Upper 95%
Activa	45	3.9536	2.17393	0.32407	3.3004	4.607
Control	15	2.6266	1.19426	0.30836	1.9653	3.288
Filtek Supreme Ultra	45	10.5516	3.59710	0.53622	9.4709	11.632
Means and Std Deviations						
Level	Number	Mean	Std Dev	Std Err	Lower 95%	Upper 95%
Activa + Activa Clearfil SE 2	15	4.6681	1.92438	0.49687	3.602	5.734
Activa + Activa G Aenial Bond	15	3.0818	1.92936	0.49816	2.013	4.150
Activa + Activa Optibond FL	15	4.1108	2.45758	0.63455	2.750	5.472
Activa + Filtek No Bond	15	2.6266	1.19426	0.30836	1.965	3.288
Filtek + Filtek Clearfil SE 2	15	12.6006	3.43120	0.88593	10.700	14.501
Filtek + Filtek G Aenial Bond	15	8.3382	2.87865	0.74327	6.744	9.932
Filtek + Filtek Optibond FL	15	10.7159	3.29085	0.84969	8.893	12.538

Figure 1: Means and standard deviations

Oneway Analysis of Shear Bond Strength (MPa) By Composite



Oneway Analysis of Shear Bond Strength (MPa) By Composite

Oneway Anova

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Activa	45	3.9536	0.41676	3.1269	4.780
Control	15	2.6266	0.72185	1.1948	4.058
Filtek Supreme Ultra	45	10.5516	0.41676	9.7249	11.378

Std Error uses a pooled estimate of error variance

Means and Std Deviations

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Activa	45	3.9536	2.17393	0.32407	3.3004	4.607
Control	15	2.6266	1.19426	0.30836	1.9653	3.288
Filtek Supreme Ultra	45	10.5516	3.59710	0.53622	9.4709	11.632

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
2.37843	0.05

LSD Threshold Matrix

Abs(Dif)-HSD

	Filtek Supreme Ultra	Activa	Control
Filtek Supreme Ultra	-1.4018	5.1962	5.9425
Activa	5.1962	-1.4018	-0.6556
Control	5.9425	-0.6556	-2.4280

Positive values show pairs of means that are significantly different.

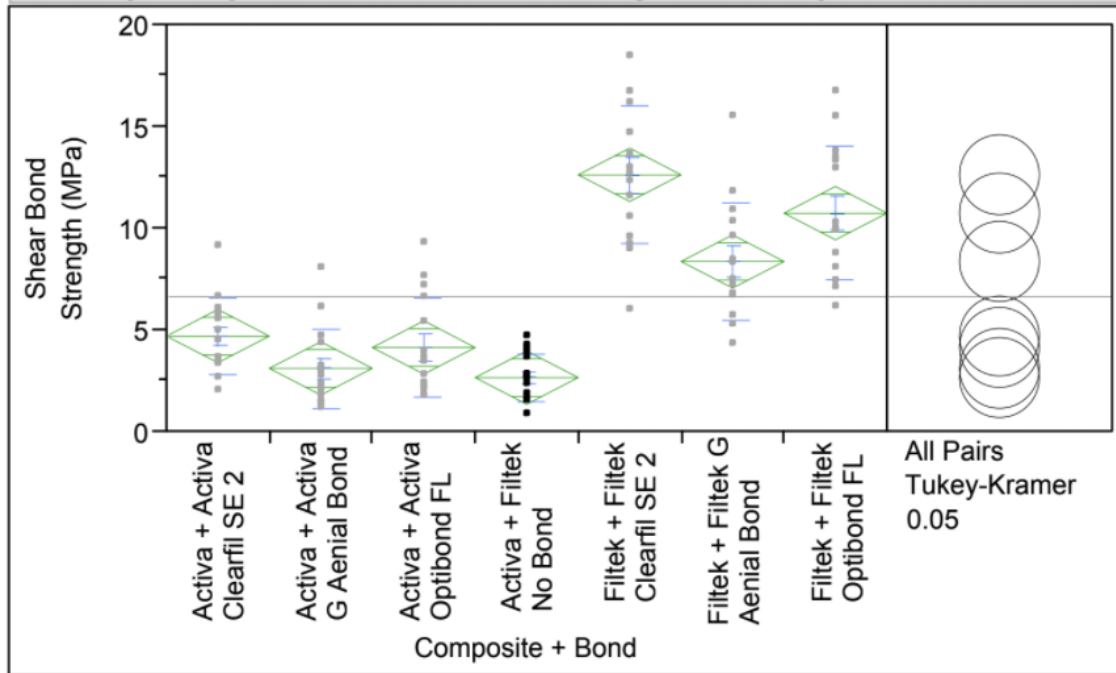
Connecting Letters Report

Level	Mean
Filtek Supreme Ultra A	10.551555
Activa B	3.953551
Control B	2.626632

Levels not connected by same letter are significantly different.

Figure 2: Results of Oneway Anova analysis and Tukey-Kramer HSD test of shear bond strength of three groups, showing statistical significant difference in means of the three groups.

Oneway Analysis of Shear Bond Strength (MPa) By Composite + Bond



Oneway Anova

Summary of Fit

Rsquare	0.687634
Adj Rsquare	0.668509
Root Mean Square Error	2.557374
Mean of Response	6.591707
Observations (or Sum Wgts)	105

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Composite + Bond	6	1410.9369	235.156	35.9557	<.0001*
Error	98	640.9360	6.540		
C. Total	104	2051.8728			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Activa + Activa Clearfil SE 2	15	4.6681	0.66031	3.358	5.978
Activa + Activa G Aenial Bond	15	3.0818	0.66031	1.771	4.392
Activa + Activa Optibond FL	15	4.1108	0.66031	2.800	5.421
Activa + Filtek No Bond	15	2.6266	0.66031	1.316	3.937
Filtek + Filtek Clearfil SE 2	15	12.6006	0.66031	11.290	13.911
Filtek + Filtek G Aenial Bond	15	8.3382	0.66031	7.028	9.649
Filtek + Filtek Optibond FL	15	10.7159	0.66031	9.406	12.026

Std Error uses a pooled estimate of error variance

Figure 3: Results of Oneway Anova analysis and Tukey-Kramer HSD test of shear bond strengths of all groups, showing statistically significant difference in the means of the three groups.

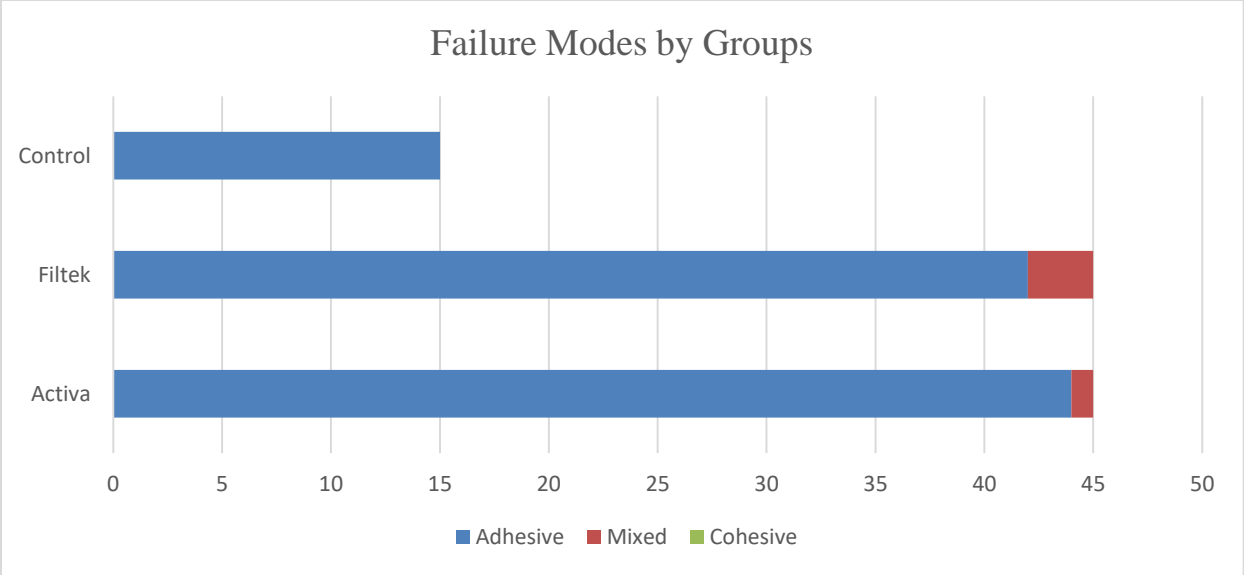


Figure 4. Failure modes by group.

DISCUSSION

Activa BioActive Restoratives is a new “bioactive” resin-reinforced glass ionomer that has recently come to market. It utilizes the ionic resin that is being advertised as the first bioactive resin. The manufacturer claims that the product’s bioactive resin component can generate ionic bond which can bridge between the dentin and resin component. Therefore, manufacturer’s recommendation for usage does not include utilizing bonding agents unless clinicians worry about retention of preparations. Indications for usage of this material is not only for class I preparation, but also class II preparation of posterior teeth. Although the manufacturer broadened the indication for use, there are currently no studies in the literature that conduct shear bond strength test for this material with different adhesive agents.

In this study, samples were bonded on composite or RMGI surfaces. These sample surfaces were well-polished only one means of objective uniform smooth surfaces to bond. The mean shear bond strengths of Activa BioActive Restoratives, Filtek Supreme Ultra, and no bonding agent (control) were 3.954 MPa, 10.552 MPa, and 2.627 MPa, respectively. These values were slight lower than shear bond strength values found across similar shear bond studies in the literature. In 2017, a study by Irmak investigated different adhesive systems to repair resin composite and their bond strength.¹⁸ Researchers used two-step self-etch, two-step total-etch and one-stop self-etch systems on thermal-aged composites bonding to same composites. Mean shear bond strengths for two-step self-etch, two-step total-etch and one-stop self-etch systems are 13.66 MPa, 12.78 MPa, and 5.63 MPa respectively. In 1997, a study by Brosh analyzed the shear bond strength of composite repair of old composite material.¹⁹ The investigators recorded bond strength measurements under different surface treatments and bonding agents. Mean shear bond strengths range from 5.44 MPa to 10.77 MPa which are not different from this study.

Wide variation in bond strengths is not uncommon in shear bond studies due to the nature of resin adhesive. Adhesive dentistry is very technique sensitive, with the possibility of introducing error at any step of the process. In our study, we recorded bond strength values ranging from 0.819 MPa to 18.420 MPa. This bench-top study attempted to reduce error by standardizing methods and materials for the preparation of each sample. However, error was still introduced in this study despite adherence to strict controls.

The introduction of human error could have first been seen in the sample preparation process. Although polishing processes may have been equilibrated for each sample, some samples have gone through more cycles because of minor scratches visible under light microscope prior to ultrasonic. This would have resulted in varying degrees of surface smoothness of the sample prior to application of adhesive systems.

Another section where error could have been introduced was in the bonding process itself. First of all, all bonding surfaces were smooth and non-scratched, meaning that possibly oxygen-inhibition layer which includes non-polymerized resin may have been all removed. Therefore, the shear bond strength may have been compromised due to well-polished, no oxygen inhibition layer of composites. In addition, all adhesive systems were first loaded to wells and applied with a microbrush and air dried per manufacturer's instructions. Application of the bonding agent could not be standardized due to the fact that each application produced different thickness measurements of the bonding agent. This thickness is all dependent on how much bonding agent the investigator procured each time with the microbrush, and this could have varied from one sample to the next.

Another possible source of variability could have been happened during the creation of composite buttons. Although customized button formers standardized the diameter of each composite button same, it was especially difficult to fill the button formers to the exact same level with ACTIVA because of its low viscosity. The depth of the button former is about 3 mm, and varying heights of the samples are noticed after fabrication of samples. This could have affected the bond strength because samples with greater depth may have achieved less polymerization of the composite at the bonding interface, which is the deepest part of the composite sample. Additionally, after composite or RMGI were loaded into the button and light-cured, a possible error could have been introduced while removing button former from the bonding surfaces. Although the investigator carefully removed the button former after loading, some of materials were over-loaded and harder to remove. Therefore, some disturbances between bonding surfaces may result lower shear bond strengths.

Once all samples were de-bonded, the composite or RMGI substrate was evaluated under a microscope to determine method of failure. Cohesive failures were not expected from this study, and results were concurred. All adhesive failures were expected for control group and results have been concurred. Only three mixed failure on Filtek Supreme Ultra and one failure of ACTIVA were observed in this study.

ACTIVA BioACTIVE Restorative is being advertised as a possibly better alternative to resin-based composites and core build-up materials used in dentistry due to its bioactive resin and fluoride release. In this study, Filtek Supreme Ultra exhibited the highest bond strengths, and the results were statistically significant. These results can lead clinicians to conclude that RMGIs are still not as fully competitive as nanohybrid resin-based composites in multi-surface large composite restoration or composite restoration repair. Even though the results of this study did

not show impressive results of ACTIVA, this study did not include bonding to tooth structure which ACTIVA claims to have ionic bond and possibly produce better shear bond strength. Further in-vitro study with tooth structure is required to fully confirm the manufacturer's claim. Ultimately, the clinician must decide on a case-by-case basis whether to use ACTIVA for large build up or class II restorations over resin-based composites.

Further research is definitely recommended with ACTIVA BioActive Restorative, given that it is a relatively new bioactive resin-modified glass ionomer and is being advertised for a wide versatile range of uses. Our protocol tested the bond strength of the material with resin-based composites in response to shear stress. However, as comprehensive nature of occlusion and lateral guidances, in-vitro research of shear bond strength with tooth structures such as enamel and dentin as well as different composite materials including flowable composites and packable composites. Finally, ACTIVA will require to have longitudinal in-vivo studies for retainability, marginal leakage and wear in long-term.

CONCLUSION

The results of this in-vitro study lead one to conclude:

1. There is a statistically significant difference in the bond strengths between ACTIVA and Filtek Supreme Ultra using different bonding agents.
2. There is no statistically significant relationship between bond strength and different adhesive systems used for this study.

The findings in this study lead to the reject of null hypothesis #1 and the acceptance of null hypothesis #2.

BIBLIOGRAPHY

1. Uno S., Finger WJ., Fritz U. "Long-term Mechanical Characteristics of Resin-modified Glass Ionomer Restorative Materials." *Dental Materials*, 1996, 12(1): 64-69
2. Walls AW. "Glass Polyalkenoate (Glass-ionomer) Cements: A review." *Journal of Dentistry*, 1986, 14(6): 231-46
3. Reinhardt JW., Swift EJ Jr., Bolden AJ. "A national survey on the use of glass-ionomer cements." *Operative Dentistry*, 1993, 18(2): 56-60
4. Mathis RS., Ferracane JL. "Properties of a glass-ionomer/resin-composite hybrid material." *Dental Materials*, 1989, 5(5): 355-358
5. Wilson AD. "Resin modified glass ionomer cements." *Int J Prosthodont*, 1990, 3(5): 425-9
6. Mount, GJ. "Color atlas of glass ionomer cement. 3rd ed." London: Dunitz; 2002.
7. Coutinho E., Cardoso, MV et al. "Bonding Effectiveness and Interfacial Characterization of a Nano-filled Resin-modified Glass-ionomer." *Dental Materials*, 2009, 25:1347-1357
8. Cho, GC., Kaneko, LM., et al. "Diametral and compressive strength of dental core materials." *Journal of Prosthetic Dentistry*, 1999, 82(3): 272-276
9. Activa BioActive Restorative Powerpoint. Available at https://www.pulpdent.com/shop/category/activa-bioactive-restorative/?slides=activa-bioactive-restorative&shopp_category=activa-bioactive-restorative
10. Garcia-Godoy, F., et al. "Flexural Strength and Fatigue of New Activa RMGICs." University of Tennessee College of Dentistry and UConn School of Dental Medicine. *J Clin Dent*, Vol 26, 2015, 23-27
11. De Gee, A., et al. "Early and Long-term Wear of Conventional and Resin-modified Glass Ionomers." *Journal of Dental Research*. Vol 75, Issue 8, 1996, 1613-1619
12. Bansal, R., et al. "Wear of an Enhanced Resin-modified Glass-ionomer Restorative Material." *American Journal of Dentistry*. Vol 29. Issue 3, 2016, 171-174
13. Tam, L., et al. "In vitro Caries Inhibition Effects by Conventional and Resin-modified Glass-Ionomer Restorations." *Operative Dentistry*. Vol 22, 1997, 4-14
14. Slowikowski, L., et al. "Fluoride Ion Release and Recharge over Time in Three Restoratives." *J Dent Res* 93 (2014)
15. Mitra SB. "Adhesion to dentin and physical properties of a light-cured glass-ionomer liner/base." *Journal of Dental Research*. Vol 70, 1991, 72-74

16. Swift, E., et al. "Shear Bond Strengths of Resin-modified Glass-ionomer Restorative Materials." *Operative Dentistry*, Vol 20, Issue 4, 1995, 138-143
17. International Standard: ISO 29022. Dentistry—Adhesive—Notched edge shear bond strength test; 2013-06-01
18. Irmak, O., Celiksoz, O., et al. "Adhesive system affects repair bond strength of resin composite." *J Istanbul Univ Fac Dent*, Vol 51, Issue 3, 2017, 25-31
19. Brosh, T., Pilo, R., et al. "Effect of combinations of surface treatments and bonding agents on the bond strength of repaired composites." *J Prosthet Dent*, Vol 77, 1997, 122-26.