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Comparison of Different Dental Restorative Materials on Orthodontic Brackets Performance in Class V Lesions. (In Vitro Study)

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Abstract:

Background: Concern has been raised regarding the survival of restorations bonded to metal brackets for orthodontic treatment. Therefore, this in vitro study aimed to compare the shear bond strength of metal orthodontic brackets adhered to different dental restorative materials under erosive conditions. Also, the resistance of these restorations to secondary caries was evaluated.

Methods: A total of 60 previously extracted premolars were used. A single clinician prepared class V cavities. Two groups of 30 samples were randomly created according to restorative material: Group (1): bulk fill resin composite material (Tetric-N-ceram) and Group (2): resin-modified glass ionomer restorative material (Riva LC). Metal brackets were bonded to restorative surfaces by means of orthodontic adhesive (flowable resin composite). All specimens were stored in distilled water for 1 day at 37°C. Each Group was subdivided into three subgroups according to the test performed: 10 samples for the shear bond strength test using a Universal testing machine before thermo-erosive cycles (1000 cycles, 5-55°C), 10 samples for SBS testing after thermal cycles followed by immersion for 72 hours in demineralizing solution and 10 specimens were assessed for caries detection around restorations using DIAGNOdent pen at baseline and after both mentioned cycles. Data were statistically analyzed using Microsoft Excel ® 2016, Statistical Package for Social Science (SPSS)® Ver. 24. and Minitab ® statistical software Ver. 16.

Results: For shear bond results, significant decrease for both Gp I: bulk fill resin composite (7.72 ±1.08) and Gp II: resin modified glass ionomer (6.14 ± 0.23) after thermo-erosive cycles with insignificant difference between them; (P=0.06). For secondary caries, Gp I had significantly showed lower risk (28.25 ± 3.86) than GP II: (18.46 ± 3.94); (P= 0.0001) after all challenges.

Conclusion: Metal brackets' performance was in high risk when bonded to fluoride-releasing restorative materials in cervical carious lesions compared to resin composite restorative materials.

Clinical significance: Bulk fill restorations provided safer outcomes for restoring class V lesions in patients percussing orthodontic treatment. Patient must follow strict oral hygiene measures to avoid restoration's failure during orthodontic treatment.

Introduction

Sometimes, teeth in orthodontic treatment may be previously restored with various fillings. The main issue comes from patients with restored labial surfaces of anterior teeth or buccal surfaces of their posteriors. (1) In such cases, the type of restorative material may impact the performance of brackets bonding. (2) Bonding of brackets may be to resin composite or glass ionomer restorations. It was reported that bond strength was unaffected and clinically acceptable when brackets were bonded to resin composite surfaces with light-cured resin composite and resin-reinforced glass-ionomer cement GICs. (2)

On the other hand, regardless of the positive outcomes of orthodontic treatment, a broad range of percentages from 7% to 73% of orthodontic patients developed demineralization for enamel following fixed orthodontic treatment. (3) According to most research, bonded orthodontic appliances act as a mechanical trap for food accumulation and interfere with the natural self-cleaning processes of oral muscles and saliva. This process can lead to increased bacterial load and carbohydrate concentration in the plaque niche. In addition, streptococcus mutans bacteria which have a critical role in producing acids that initiate the enamel decalcification. Thereby clinical professionals and the orthodontic community have been concerned about demineralization in such cases. (4)

Numerous pieces of research have examined the bond strength of conventional resin composite orthodontic adhesives to the composite restoration surface. (2) However, none has examined the bonding success of metal orthodontic brackets to resin-modified glass ionomer and resin composite restorations after thermo-erosive cycles in correlation to the survival of both restorative materials under the same conditions.

The tested null hypothesis were as follows; (1) no notable difference exists in the bond strength of the metal brackets neither bulk fill resin composite nor RMGIC restorations after thermo-erosive cycles ; (2) Resin modified glass-ionomer restoration shows more resistance to erosive conditions due to fluoride release.

Materials & Methods:

Approval of this study received from the ethical research committee in Faculty of Dentistry, Ahram Canadian University, Egypt. (Research approval #: IRB00012891≠89).

Table (1) lists the materials used in this investigation. Using G Power 3.1.9.7. and a previous study by Ozcan et al. [2] as a guide, the sample size was determined. This study found that the minimum acceptable sample size for each group was 7, with group I's mean ± standard deviation being 3.53 ± 1.9 and group II's mean ± standard deviation being 8.09 ± 3.16, with an effect size of 1.74, at 80% power and a type I error probability of 0.05. To make up for the 25% dropout rate, the total sample size was raised to 10. To conduct an independent t test, G.power3.1.9.7 was used.

Table (1): Materials used in coronal restorations and their compositions:

Type	**Materials**	**Main Composition**	**Manufacturer**	**Lot no.**
Nanohybrid sculptable Packable Resin Composite	Tetric N-ceram Bulk Fill	Dimethacrylates (19-20 wt.%). The fillers are barium glass, ytterbium trifluoride, mixed oxide, and copolymers (80-81 wt.%). Inorganic fillers (55–57) vol.%. / particle size (40 nm upto 3000 nm).	Ivoclar Vivadent, Schaan, Liechtenstein	Z041WM

NanohybridFlowable Resin Composite	Tetric N-Flow Bulk Fill	Monomethacrylates and dimethacrylates (28 wt%). The fillers (barium glass, ytterbium trifluoride) and copolymers (71 wt%). Inorganic fillers 68.2 wt% / 46.4 vol%. The particle size ranges between (0.1 µm - 30 µm) /particle size of 5 µm.	Ivoclar Vivadent, Schaan,Liechtenstein	Z0417F
Resin Modified Glass Ionomer	RIVA LC	Acrylic acid homopolymer (15–25%), 2-hydroxyethyl methacrylate (15–25%), dimethacrylate cross-linker (10–25%), Acid monomer (10–20%), tartaric acid (5–10%) Glass powder (93–100%) of Bioactive hybrid glass filler.	SDI Limited. Bayswater Victoria, Australia	1206798

Only sound maxillary premolars extracted for orthodontic purposes met the inclusion requirements while any history of defective cervical areas, bleaching and endodontic treatments was excluded from this study. Cleaning and polishing were performed using an ultrasonic scaler, a rubber cup, and a pumice. Later, immersion for one day was done within distilled water at thirty-seven-degree Celsius temperature.[(2)]

1. Samples grouping:

This study was performed on 60 maxillary premolars. Each tooth was fixed 2mm apical to the cementoenamel junction (CEJ) with heated wax (CAVEX, CAVEX Dental, Netherland). After solidification, teeth were placed in a custom-made plastic mold (10 mm radius x 15mm depth) and filled with self-curing acrylic resin (Acrostone; Acrostone Dental, Cairo, Egypt). After initial polymerization, teeth were removed from the acrylic resin, and wax remnants were cleaned out from both teeth and acrylic mold with hot water. Reinsertion of teeth was done parallel to its long-axis into the acrylic socket under constant finger pressure after injection of light-body polyvinyl siloxane impression material (Panasil® Initial contact; Kettenbach GmbH & Co) into the acrylic mold to simulate the periodontal ligament.

Samples were haphazardly divided into 2 groups of thirty samples. Grouping was done according to the type of restoration used. GP1: for Resin composite restoration (Tetric N-ceram Bulk fill; Ivoclar, Schaan, Liechtenstein) and the Gp2: for Resin Modified Glass Ionomer Restorative Material (Riva; Light cured resin reinforced glass ionomer restorative material; SDI, Australia). All samples were finished and polished, and then each group was subdivided into three subgroups according to the test performed; 10 samples for the shear bond strength test using a Universal testing machine before thermo-erosive cycles, 10 samples after thermo-erosive cycles and 10 specimens were assessed for caries detection around restorations using DIAGNOdent pen 2190 (KaVo, Germany) at baseline and after both cycles.

2. Collection and preparation of samples

Following the mounting of sixty human maxillary tooth samples in acrylic, Class V cavities were created on the buccal surfaces of the teeth. The same operator produced standard Class V cavity preparations. Using a straight fissure bur (SF 41, MANI INC, Japan) under air-water cooling, a 3 mm × 2 mm × 1.5 mm (L × W × D) cavity was produced on the buccal surface of each tooth, with the gingival margin located in dentin and the occlusal margin placed in enamel. For every four preparations, the bur was replaced, and a graduated periodontal probe was used to measure the depth of the preparation. [5] After grouping, the application of Tetric N-Ceram Bulk fill Restorative Material was made as Group (I), and Resin Modified Glass Ionomer Restorative Material were applied as Group (II). For Group (I): etching gel was applied (37% ortho-phosphoric acid, Scotchbond Universal Etchant; 3M-ESPE, Seefeld, Germany) for up to 15 seconds, then rinsed with water spray for 30 seconds was performed, and cavities were dried with air spray for 30 seconds. The Scotchbond Universal adhesive was applied by a micro-brush to one layer on the surface, rubbed for 20 seconds, air sprayed for 5 seconds, and light cured for 10 seconds. Bonding the metal brackets (Mini Master; American Orthodontics, USA) using Tetric N- Flowable Bulk resin composite (Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's instructions.[6]

For Group (II), the application of 25–30% polyacrylic acid (Riva Conditioner, SDI Bayswater, Victoria, Australia) was done for 10 seconds, rinsed thoroughly with water, and then gently dried. Riva Light Cure was then applied, and light cured for 20 seconds. [7] Immersion for 1 day was done in distilled water at 37°C. [2] All specimens were dried, and bonding brackets were performed. Then they were re-kept in distilled water at thirty-seven degrees Celsius for twenty- four hours. [2]

For shear bond strength, twenty samples of each restorative group were assessed before and after demineralization and thermo- cycling. Thermo-cycling was performed in water baths 1000 times between five degrees Celsius and fifty-five degrees Celsius with a dwell time of 15 s in each bath and a transfer time of 10 s (Julabo, Germany). [8] A universal testing machine (Instron 2519-500N, United States) was used to stress samples in occluso-gingival direction at a cross head speed of 1mm/minute as in **figure 1**.[9] The shear bond strength in MPa was calculated by dividing the recorded maximum load- at-failure in Newton by surface area of the bracket base.

Figure (1): Shear bond strength test.

Ten samples of each restorative were recorded in baseline before immersion by DIAGNOdent pen for the demineralization process. The demineralization solution (1000 ml) was prepared by combining 2.2 mM KH_2PO_4, 0.05 M acetic acid, and 2.2 mM $CaCl_2$, bringing the resultant solution's pH down to 4.4 with 1 M KOH. Every sample was submerged separately into four milliliters of demineralizing solution in individual containers for seventy-two hours. [10] A pH meter was used daily to monitor the pH. Then, after a thorough cleaning with distilled water, the teeth were allowed to air dry. Data was recorded after immersion and reassessed after the same thermal cycling procedures as in **Figure 2**.

Figure (2): Demineralization detection using DIAGNOdent pen after immersion in demineralizing solution.

Statistical analysis:

Three tables and two graphs were used to present the statistical analysis, which was carried out using SPSS 16 ® (Statistical Package for Scientific Studies), Windows Excel, and Graph Pad Prism. Utilizing the Shapiro-Wilk and Kolmogorov-Smirnov tests to determine the normality of the provided data, it was determined that the data originated from normal data. Accordingly, a comparison was made between 3 different intervals performed by the One Way ANOVA test followed by Tukey`s Post Hoc test for multiple comparisons, a comparison between before and after was performed by using a Paired t-test, and a comparison between 2 groups was performed by using an Independent t-test.

Results:

I. Shear bond strength:

Intergroup comparison: comparison between Gp I & Gp II was presented in table (2) and figure (3):

Before thermo-erosive challenges, Gp I (20.36 ± 1.97) was significantly lower than Gp II (30.8 ± 2.39) with (-10.44 ± 1.18) as P=0.0001. After thermo-erosive challenges, Gp I (7.72 ±1.08) was insignificantly higher than GpII (6.14 ± 0.23) with a (1.58 ± 0.42) difference between them as P=0.06. In difference, the decrease in shear bond strength values for Gp I (-12.63 ± 1.71) was significantly lower than the decrease in GpII (-24.65 ± 2.62) with (12.02± 1.19) difference between them as P=0.0001.

Intragroup comparison: comparison between before thermo-erosive challenges and after thermo-erosive challenges was presented in table (2) and figure (3):

In Gp I: there was a significant decrease from (20.36 ± 1.97) to (7.72 ±1.08) as P 0.0001.

In Gp II: there was a significant decrease from (30.8 ± 2.39) to (6.14 ± 0.23) as P 0.0001.

Table (2): Standard deviation and mean of shear bond strength of GpI and GpII before and after both thermocycling and demineralization :

	Group I (Resin Modified Resin composite)		**Group II (Bulk fill resin composite)**		**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**		**P value**
	Mean	Standard Deviation	Mean	Standard Deviation			Lower	Upper	
Before thermo-erosive	20.36	1.97	30.80	2.39	-10.44	1.18	-12.98	-7.89	0.0001*

cycles									
After thermo-erosive cycles	7.72	1.8	6.14	1.23	1.58	0.42	0.67	2.49	0.06
Difference	-12.63	1.71	-24.65	2.62	12.02	1.19	9.45	14.59	0.0001*
P value	0.0001*		0.0001*						

**Significant difference as P<0.05.*

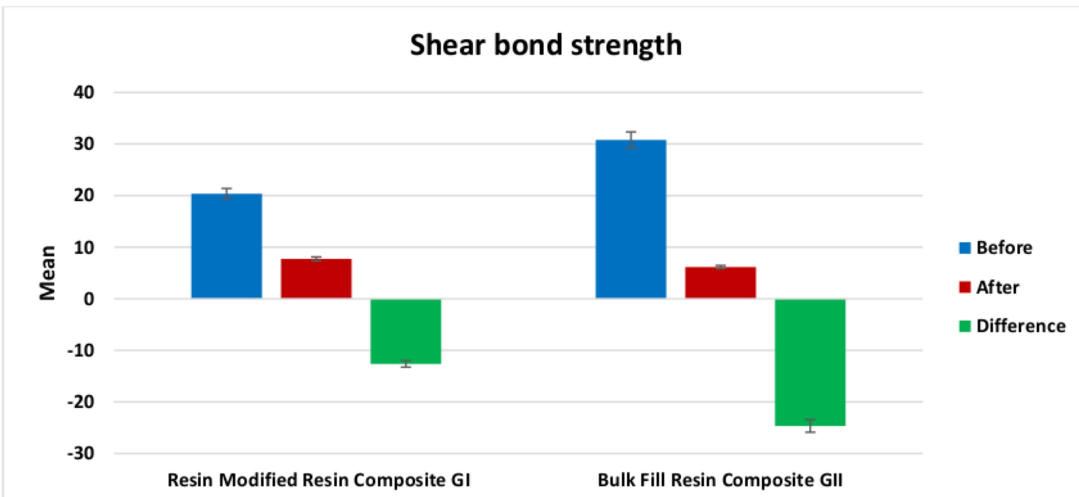

Figure (3): Bar chart showing mean of shear bond strength of GpI and GpII before and after thermocycling and demineralization.

II. Demineralization status:

<u>Intergroup comparison: comparison between Gp I & Gp II was presented in table (3) and figure (4):</u>

At baseline, there was insignificant difference between the groups as P=0.49. In deminarlization only, Gp I (12.37 ±1.79) was significantly lower than GpII (14.75 ± 1.04) with (-2.38 ± 0.73) difference between them as P=0.006. After both demineralization and thermocycling, Gp I (28.25 ± 3.86) showed significantly higher records than GpII (18.46 ± 3.94) with (9.79± 1.95) difference between them as P=0.0001.

Intragroup comparison: comparison between baseline - demineralization only, baseline - demineralization after thermocycling, and demineralization only - demineralization and thermocycling was presented in table (3) and figure (4):

In GpI: there was a significant difference between them (P<0.0001) as baseline (2.96 ± 0.77) was significantly the lowest, while demineralization and thermo-cycling (28.25 ± 3.86) was significantly the highest.

In Gp II: significant difference was found between baseline (3.25 ± 0.9) which was significantly the lowest and demineralization/thermo-cycling (18.46 ± 3.94) the highest (P<0.0001). Insignificant difference was found between demineralization only for 72 hrs (before thermo-cycling) (14.75 ± 1.04) and after both demineralization/thermo-cycling (18.46 ± 3.94).

Table (3): Standard deviation and mean of DIAGNOdent pen of GpI and GpII at baseline, after demineralization only, and demineralization after thermo-cycling and diagnopen changes between baseline - demineralization only, baseline - demineralization after thermo-cycling, demineralization only and demineralization after thermo-cycling :

Resin Modified glass ionomer GpI		Bulk Fill Resin composite GpII		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P value
Mean	Standard Deviation	Mean	Standard Deviation			Lower	Upper	

Baseline	2.96 [a]	0.77	3.25 [a]	0.90	-0.29	0.42	-1.19	0.61	0.496
Demin. Only (before thermo-cycling)	12.37 [b]	1.79	14.75 [b]	1.04	-2.38	0.73	-3.95	-0.80	0.006*
Demin. & thermocycling	28.25 [c]	3.86	18.46 [b]	3.94	9.79	1.95	5.61	13.97	0.0001*
P value	<0.0001*		<0.0001*						

**Difference is significant when P<0.05. P<0.05 indicated a substantial difference between the means with various superscript letters. The means that shared the same superscript letters did not differ statistically because P>0.05.*

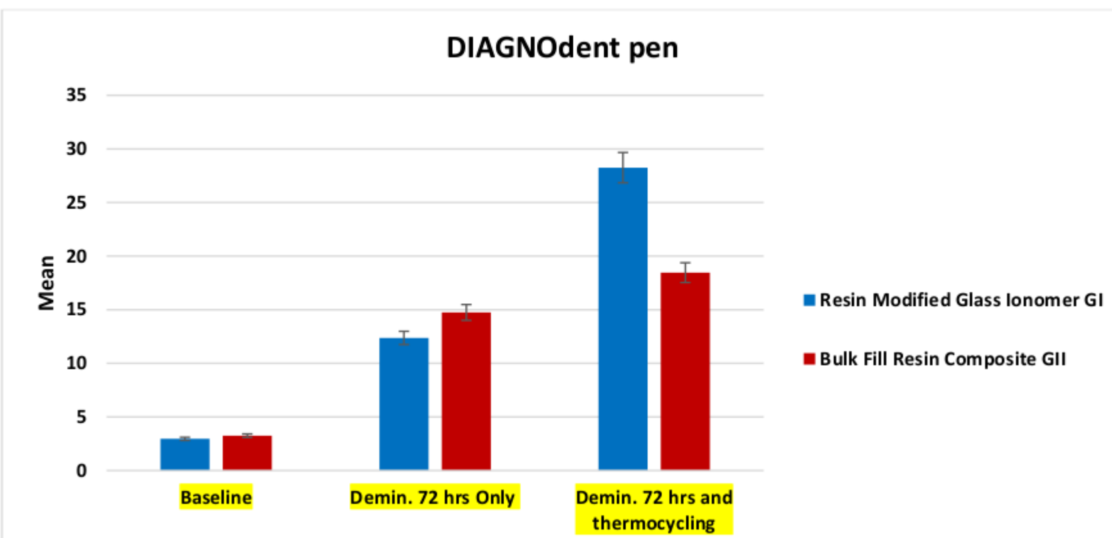

Figure (4): Bar chart showing Diagnodent pen of GpI and GpII at baseline, after demineralization only, demineralization and thermo-cycling.

Discussion:

Due to the increased average age of treated orthodontic patients, the number of restored teeth has increased. Dissimilar surface materials like glass ionomer, resin composite, and amalgam differ from enamel's surface structure. The behavior of the metal brackets against de-bonding forces may differ with those various restorations. [2]

Restorative materials for class V lesions must possess qualities like better wear resistance, a lower elastic modulus, a nice look, and the right bonding strength with orthodontic brackets. [2,11] It was noted that bond strengths on restorative materials should be nearly equal to those on enamel to prevent bond failure. However, extremely high strength values must be avoided to ensure a smooth de-bonding process free from restorative fracture or dislodgment. [12] Moreover, increased risk for demineralization around restorations in a poor oral environment may affect the longevity of the restoration. [13] These challenging scenarios highlight the necessity of selecting the appropriate type of restoration in class V lesions before treating orthodontic patients.

Resin composites have become the most popular restorative materials over last fifty years owing to their similarity to enamel shades. [2] Their durability, wear resistance and aesthetic properties have encouraged using them in anterior and posterior restorations. However, many drawbacks include technique sensitive, time and cost. Moreover, secondary caries especially with the use of fixed orthodontic appliances has been recognized. [2]

Resin Modified Glass Ionomers RMGIs have been announced to overcome the previously mentioned disadvantages of the conventional resin composite while preserving the clinical advantages of antibacterial activity with fluoride release. [14] A study mentioned that many systematic reviews proved a significant decrease in new carious lesions around RMGIC restorations compared to composite and amalgam restorations. [15] Zavare et al., claimed that such material is a suitable restorative treatment for class V lesions. [9] Moreover, it was claimed that they offer stable bonding to tooth structure by micromechanical adhesion. [14]

All specimens were prepared and stored in distilled water at thirty-seven degrees Celsius for one day to stimulate the aging process. [2] Laser fluorescence (DIAGNODent pen) was used in our study to detect caries beneath restorations under demineralizing conditions. [10,15] It was found that this is considered to be a helpful and quantitative method for recording the tooth mineralization status. [10] Moreover, 1000 thermo-cycles were performed to mimic thermal changes in the oral cavity environment. [6,8] Many studies mentioned that 500 thermal cycles in water bath ranging the temperatures between 5 and 55 °C proved to be suitable for aging and testing restorative dental materials, according to ISO TR 11405. [16, 17] Moreover, conducting 10,000 thermal cycles supposed to replicate approximately 1 year intra-oral functioning. [16, 17] Repetitive thermal cycles produce expansion-contraction stresses at the –tooth-restoration interface. This could be due to the greater expansion-contraction coefficient of the restorative material than the tooth. [16] For erosive cycle, it was explained that carious lesions could be induced by immersion teeth in demineralizing solution for 72 hours for in vitro-studies. [10,18,19] It is worth mentioning that no study assessed the cumulative consequences of unlike restorations of class V on metal brackets, which were bonded to under thermo-erosive cycling.

This study indicated that the mean shear bond strength of metal brackets bonded to bulk-fill resin composite (Gp II) was significantly higher than that bonded to resin-modified glass ionomer group (GPI) before thermo-erosive cycles. It could be due to the more potent chemical bonds of higher filler loads and organic matrix between resin composite restorations and the flowable resin composite adhesive in bracket bonding than the lower amount found in (GPI). [2] Our explanation was consistent with the only study with the nearest methodology [2]. Bayram et al. mentioned three available mechanisms for bracket bonding using adhesive material: chemical bond formation to the exposed fillers, chemical composition to the matrix, and micromechanical bonding through penetration of the monomer into micro-cracks of the matrix. [1]

In addition, an oxygen-inhibited layer of unpolymerized resin should be presented to obtain bonding between two composite layers. [2] Unfortunately, proprietary compounds with functional groups are not known to clarify the behavior of the adhesive material used. Whether using lower molecular weight monomers, acetone, or alcohol rather than water as solvents or using the proper proportion of the previous-mentioned components. [6]

Both materials' mean shear bond strength values showed a significant decrease after thermo-cycling due to the potentially weak link in bond strength between the bracket and the restoration. [24] An inherent property of water sorption of the organic matrix in both adhesives and restorations could lead to external movement of residual organic monomers and ions forming micro-cracks. [25] Arici et al., stated that the oscillating stresses of the system resulting from the massive mismatch of the thermal expansion coefficient adversely affect the adhesion of the resin to metal brackets. [27] Insignificant difference was found between the two materials after both challenges accepting the first null hypothesis.

A study suggested that SBS values ranging from 5.9 to 7.8 MPa are inadequate to bear masticatory forces. [23] On the contrary, according to Reynolds and Von Fraunhofer, resin-based glass ionomer and resin composite restorations showed acceptable clinical results with insignificant differences, which agreed with our findings. [2,6]

On the other hand, Ozcam et al., found that the mean value of shear bond strength for metal brackets bonded to resin-based restorations was statistically significantly higher than for glass-ionomer-based restorations. This may be due to differences in the chemical composition of restorations used in their study, precisely the absence of resin components in glass ionomer restorations. [2]

Cariogenic challenges in this study resulted in a statistical increase in readings indicating demineralization in the two groups of restorative materials. After only three days of immersion in an acidic medium, Riva LC showed statistically significantly lower demineralization results than Tetric N ceram bulk fill. The release of fluoride and calcium ions of the ionomeric materials in this study could indicate the consistent caries-protective features. This explanation aligns with other studies. [10,24] In addition, a study mentioned that calcium and phosphates' peak of ion release was identified during the initial hours and may initiate the formation of apatite-like, protecting the collagen from enzymatic degradation and then gradual diminishment. [24] Nica et al., in their study, agreed that water absorption and the internal diffusion of water beneath the fillers and micro-pores result in the dislodgment of the filling particles, forming a corroded layer removed during brushing or mastication. They discussed the mechanism of acidic challenge on resin-modified glass ionomer restoration, including decomposition of matrix components and removal of filler particles in a low pH environment. [26]

On the other hand, releasing high calcium ions may alter the material's mass and solubility. [24] It was reported that thermo-cycling should be obtained to obtain correct indicating results for oral condition. [6] This finding agrees with many investigations. [6, 12]

Significantly higher increase of caries recordings was identified with RMGI material after adding thermal cycles phase with significant difference compared to bulk fil resin composite resulting in rejected second null hypothesis. Zafare et al. explained in their study that the main resin component (HEMA) in resin-modified glass ionomer restoration absorbed water, resulting in a more hydrophilic functional group due to the setting. [9] Accordingly, more significant amounts of water are absorbed in an aqueous environment, and volume also increases after thermocycling. [9] Moreover, RMGIC materials have been previously proven to exhibit higher water solubility and sorption than resin composites. [25] Hence, reduction of mechanical properties and failure of the restoration with decreasing its durability. [25] Many studies agreed with our findings that resin-modified glass ionomer showed higher leakage scores among tested restorations and were concerned about using it as a permanent restoration. [7, 27]

The high water sorption of RMGIC may be due to the disruption of acid-base reactions during the initial desiccation procedure. Another study suggested its chemical structure as inorganic glass particles, poly-carboxylic acid, and HEMA maintain large amounts of water. [25]

According to adhesion performance, glass ionomer-based material showed weaker bonds in comparison to resin composite due to the ionic exchange mechanism in which polyacrylate ions (restoration part) replace phosphate ions on the surface of hydroxyapatite (tooth structure part), producing self-adhesion to dental tissue. [25]

Ion-releasing restorative materials have the potential to significantly aid in inhibiting demineralization, a crucial aspect of dental care. However, it's important to be aware that these materials may diminish in the long term, which is a factor that needs to be considered. [27] The presence of secondary caries in close proximity to the restorative material is a significant concern, particularly in the context of the orthodontic system. This knowledge can help us be more cautious and informed in our practice.

Contrary to our findings, a clinical investigation found no secondary caries in Riva LC after one year of follow-up in primary molars. [28] It could be due to differences regarding the mentioned in vivo study and class I restoration. A clinical study showed the successful and effective performance of Riva Light Cure as a liner overlying posterior composite restorations with no secondary caries after one-year follow-up period. They explained that the lack of secondary caries over time may be due to good oral hygiene and the selection of well-motivated and instructed participants after the placement of the restorations [14]

Limitations:

In this in vitro study, a lack of factors such as the mechanical, bacterial environment, and dietary influences should be added to acidification media and thermal changes via this study to assess the simulative effect of the oral environment on metal brackets bonded to restorative materials.

Conclusion:

In this study, for bond strength of metal brackets adhered to resin modified glass ionomer restoration or resin composite restoration, both were clinically acceptable after thermo-erosive cycles. While in testing with DIAGNOdent pen, resin modified showed higher risk for secondary caries. More in vitro and vivo studies are recommended for considering multi-factorial effects on behavior of different restorative materials on metal brackets.

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