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Shear Bond Strength of Bioactive Dental Restorative Materials to Dentin

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Abstract
Keywords: *Shear bond strength, Bioactive restorative material, Occlusal dentin, Thermocycling.*
Purpose: *to evaluate theshear bond strength of differentbioactive restorations (Fuji IX GPglass-ionomer, Beautifill II Giomer and ACTIVA ™BIOACTIVE) to occlusal sound dentin .*
Materials&Methods: *sixty freshly extracted sound human molars were selected from diabetic patients aged 45-55 years. The occlusal enamel is removed to expose the occlusaldentin,The prepared specimens were randomly divided into three groups according to the type of applied restorative bioactive material (n=20 each):Each group received a cylinder of the restorative material using Metallic and Teflon molds.Fuji IX(Conventional Glass-ionomer) Group I,beautifil IImaterial, (Giomer restorative material) Group II, and ACTIVA ™BIOACTIVE restorative material(Resin-modified glass-ionomerBioactive Ionic Resin-Based Composite) Group III were tested. All specimens were stored in distilled water for 24 hours. Half of specimens of each group were subjected to thermocycling. The shear bond strength of specimens was measured using an instron machine at a cross head spead of 0.5 mm/min. The debonded surfaces were examined under a stereomicroscope at magnification 40X to determine the mode of failure. All data was collected, tabulated and statistically analysed.*
Results: *Group III recorded a statistical significant most high shear bond strength values (6.587±0.979 Mpa), followed by group II recording (6.029±0.820 Mpa) while the lowest values were found at group I with mean values of(3.514 ±0.571). ANOVA test was used to compare the three tested groups in each subgroup at a level of significance 0.05. Using Pearson's correlation test, a positive correlation between cohesive mode of failure and shear bond strength was recorded for the three tested groups.*
Conclusion: *Under the present situation of this research, it was concluded that there is a* ***good bond between bioactive restorative materials and sound dentin****.*

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I. Introduction

A good aesthetic occupies a top priority in all fields of dentistryand may be one of the driving forces behind the current demand to improve smile. Therefore esthetic restorative materials are under constant development [1].

To achieve acceptable esthetics, an adequately strong bonding of the restorative material to tooth structure for optimum retention, minimal microleakage and color stabilitythus adhesivedentistry has gained a prime importance[2].

The material used is an important factor in adhesion. Direct bioactivetooth colored restorativematerials are the most frequently used due to the acceptable esthetic and durability [3]. These active materials are able to make agood seal with tooth structure through active mineral ions released which forms apatite crystals at interface between active tooth coloredmaterial and dentin surface[4].

The concept of bioactivity is not recent since conventional glass ionomer was considered a bioactive material releasing fluoride and forming chemical bonds to tooth structures [5].Many drawbacks of this materialhave been reported as moisture sensitivity and low wear resistance that treated by the invention of new materials involving both composite and glass ionomer[6].So a new hybrid material giomer distinguished by containingpre-reacted glass (PRG) filler in a resin matrix.Protection of the glass core from moisture gives it long-term esthetics , durability and good bond strength to tooth structure which is formed. Besides it has the advantage of fluoride release and recharge [7].

Moreover ACTIVA ™ BIOACTIVE which is a resin-modified glass ionomer bioactive ionic Resin-Based Composite has the strength, esthetics and physical properties of composites and delivers more fluoride release than conventional glass ionomers. It contains bioactive ionic resin matrix, a shock absorbing resin component and reactive ionomer glass fillers. It reacts to the continuous pH changes in the mouth to help fortify

and recharge the ionic properties of saliva, teeth and the material itself[8]. Activa BIOACTIVEcontains phosphate acid groups which in ionization release hydrogen ion which replace the calcium ions of tooth structure. This ionic interaction chemically bondingthe resin to the minerals in the tooth structures forming a strong resin-hydroxyapatite complex and a positive seal against microleakage. It continuously releases and recharges significant amounts of calcium, phosphate and fluoride ions [9].

Maintaining the strong bond of these materials to dentin is mandatory for their success and durability,so, the present study is designed to evaluate the shear bond strength of different bioactive dental restorativematerials to sound dentin .

The current research hypothesis is to prove that recent contemporary bioactive materials add a new bond strength relationship to dentin structure

II. Materials

Three systems of bioactive dental restorative materials and their composition were used in this invitrostudy as shown in table (1).

III. Methods

A total of sixty sound , freshly extracted, sound,non-carious humanmolars from patients aged (45-55) years old were collected from the Department of oral and maxillofacial surgery of faculty of DentistryTanta University .

The patients signed a written consent. The teeth were cleaned of debris and calculus using periodontal scalers and polished with pumice. They stored in an incubator of 37 °C using distilled water which is changed daily for a period of month maximum [10].

- Specimenspreparation and grouping:

Aluminum molds were prepared, the fitting surface was painted by vaselin to act as aseparating medium.Each specimen was embedded in acrylic resin filling these aluminum molds, until the cemento-enamel junction leaving the crown intact.Theocclusal enamel was trimmed and removed from each tooth by using a slow speed diamond disk* with water coolent to expose the occlusal dentin [11].A magnifying glass ** was used to ensure that no enamel was left on the occlusal surface.Occlusal dentin surface of all specimens were polished using 600-grit Wet Silicon Carbide abrasive papers in a circular motion under running tap water to create a homogenous smear layer. Each specimen wasinserted in the splitted metallic holder which was adapted in a specially prepared metallic ring . These two pieces form the metallic mold. The metallic ring is supplied by two metallic screws at each side to hold and secure the specimen . The metallic mold (holder and ring) is opened from the upper and lower end. Its upper surface was designed to receive the specially designed split teflonmold which has a hole 4mm diameter x 3mm height and well adapted to occlusal dentin surface of specimens. The teflonmold is surrounded with another metallic ring which is supplied by a metallic screw to be adapted on the outer surface of the upper end of metallic ring.

The prepared specimens were randomly divided into three groups of twenty teeth each **(n=20)** according to the type of restorative bioactive material to be investigated.

Each specimen was adapted in the metallic ring then the specially prepared Teflon mold was secured on the dentin surface to confine the area of dentin to be treated.

Group 1:

According to manufacturer's instructions, the occlusal dentin surface of each specimen was conditioned with 25% polyacrylic acidKetacConditioner*.which was agitated with a micro brush for 10 sec ,washed with water at room temperature, then was blotted using blot paper leaving dentin moist. Fuji IX GP EXTRA (chemical cure) (fig. 1) was prepared according to manufacturer's instructions with a powder/liquid ratio of3.6/1 , the first scoop of powder should be incorporated in the liquid using plastic cement spatula and as soon as it is fully wet add the second scoop and so on until a glossy mix was formed , this was applied to dentinsurface in this glossy state,reaching a total height of 3mm. A celluloid strip** was placed over the restoration , a glass slab with the weight of 250 gm was placed over it to obtain a smooth flat surface , then celluloid strip and the weight were removed after complete setting and hardening ,excess flashes were carefully removed using a sharp scalpel, andGC Fuji Coat , was placed to prevent dehydration during finalsetting of the material.Teflon mold was removed after two minutes and twenty seconds.

*Isomet, Buehler, Lake Bluff, IL, US
**Insten 10x magnifier. USA
*3MESPE
** polyester strip, TDV Dental Ltda., Pomerode, SC , Brazil

Group II:

According to manufacturer'sinstructions, FL primer of self-etch adhesive system was applied on the exposed dentin surface with a micro brush in a rubbing motionfor 10 s, air dried, then an even layer of FL bond IIwas applied, light-cured for 10 s using LED light curing unit (600mw/cm^2)***., followed by application ofbeautifill II material (Giomer) (fig. 2)in the form of two increments (1.5mm each) on the dentin surfacereaching a total height of 3mm. Each increment was light cured for 20 s.. A celluloid strip was placed over the second increment of restoration, a glass slab with the weight of 250 gm was placed over it to obtain a smooth flat surface,After curing celluloid strip and the weight wereremoved. Excess flashes were carefully removedusing a sharp scalpel and the Teflon mold was removed.

Group III:

According to manufacturer'sinstructions,the dentin surfaceof eachspecimen of this groupwas etched with 38% phosphoric acid gel for 15s , rinsed for 10s using copious amount of water to remove the acid completely, excess water wasblotted leaving a wet dentin surface . ACTIVA ^{TM} BIOACTIVE restorative material tube (fig.3) was applied to a special gun and injected slowly with the mix tip maintaining contact tothe conditioned dentin surface according to instructions of manufacture. Thetip was slowly movedaround the dentin to allow ACTIVA to back fill. Then the tip was kept submerged in the material to avoid air bubbles, reaching a total height of 3mm. A celluloid strip was placed over the restoration , a glass slab with the weight of 250 gm was placed over it to obtain a smooth flat surface,then the weight was removed . After 20s light activation was performed for 20s , to allow the acid base reaction to occur. The celluloid strip was then removed and excess flashes wereremoved using a sharp scalpel. The Teflon mold was removed after setting of the material.
All specimens were stored in distilled water at 37 °C in an incupatorat 100% humidity for 24hjust before shear bond strength testing.

Sub grouping:

The final specimen (fig.4) of each group were subdivided randomly into two equal subgroups A and B (10 specimens each) according to the exposure to thermocycling stresses. Specimens of subgroup B were subjected to thermal stresses using athermocycling apparatus for500 cycles (5°C to 55°C) with 30 sec. dwell time and 20 seconds transfer time [12]. While those of subgroup A were not subjected to any stresses.

Shear bond strength testing:

All specimen were tested in shear mode using an Instron testing machine. The specimens were secured to the universal testing machine by means of its metallic mold and were oriented so that the straight stainless steel knife of the universal testing machine has to be perpendicular to the interface between the material and dentin surface to apply the load until fracture at a cross head speed of 0.5mm/min and load cell capacity of 25 kN[13]**.**
The fracture load was recorded in kilogram (Kg) and the shear bond strength values were calculated in Mega Pascal (MPa) following an equation [14]**.**

$$\textbf{Shear bond strength} = \frac{(\mathbf{F})\ \text{Fracture Load (Kg)}}{(\mathbf{A})\text{Surface area (Cm 2)}}$$

The surface area (A) was calculated from the following equation:$\mathbf{A= \pi\ r^2}$
Where $\pi = 3.14$
r = Radius of each specimen (0.2cm)
Thus A= 0.1256 Cm^2
The shear bond strength values were converted into MPa by multiplying the obtained results by0.098067
All data was collected, tabulated and statistically analyzed.

***Blue phase N Ivoclarvivadent

Mode of failure analysis:
The fractured surfaces of the debonded specimens were inspected under a stereomicroscope at 40x magnification to determine the mode of failure for each specimen[15]**.**
Adhesive failure; at dentin-restoration interface where no observable restorative material remained on the dentin surface.
Cohesive failure; either in dentin or restoration wherea visible thin coating or bulk of a restorativematerial remained on the dentin surface.
Or **Mixed failure**; if a part of restorative materialwas left on dentin surface and the rest of the surface had a partial adhesive failure**.**
Mode of failure data was also collected, calculated, tabulated and the percentage of each type of failure wasobtained to bestatistically analyzed.

IV. Result

Regarding the shear bond strength values of specimens not subjected to thermocycling stresses data ofsubgroup A of all tested materials showenin(table2) (fig.5)

The highest mean value was recorded for group III, recording 6.587 Mpa ± 0.979 followed by group II, recording 6.029 Mpa ± 0.820, while the lowest mean bond strength value 3.514 Mpa ± 0.570was found at group Iand there are statistical significant difference was reported with P-value 0.001 between different groups.

However after thermocycling (subgroup B), The shear bond strength mean values were recorded in an order as 2.838 Mpa,4.150 Mpa,4.651 Mpa for groups, II and III respectively as seen in (table3) (fig.6) .Using F test and P-values recorded that there was a statistical significant difference among tested groups where (p = 0.005) .

Concerning the effect of thermal cycling on shear bond strength values of the tested materials to dentin surface, T test was used to compare subgroup A vs subgroup B in each group (for each tested material) at 99% level of significance.indicating an obvious reduction positive effect of thermal loading treatment on each of the tested materials by different degrees as in (table4)(fig.7).

Mode of failure:

The tested specimens of all materials showed different modes of failure of fractured specimens. Before thermocycling (subgroup A), data was collected as shown in (table5),group I (GIC)showed that 40% of tested samples revealed adhesivemode of failure (fig. 8), and 30% a cohesive mode of failure. Concerning group II (Giomer),10% adhesive failureand 60% a cohesive mode of failure. However, group III (Activa Bioactive material) revealed (ZERO) no adhesive mode of failure has been recorded while 80% cohesive mode of failure .

Chi square test was used to compare different modes of failure of fractured specimens in each group and recorded no significant difference in group I with a P = 0.634, while there was a significant difference in the modes of failure of group II and III with P-value 0.057* ,0.063* respectively.

After thermocycling (subgroup B). Data was collected in (table 6) (fig.9).Regarding group (I)60% revealed adhesive mode of failure while 20% were cohesive mode of failure. However for group (II) 30% adhesive mode of failure have been recorded and 40% cohesive mode of failure. Concerning specimens of group (III)recorded 20% adhesive mode of failure and 60% cohesive mode of failure.

Chi-square test was used to compare the three modes of failure of fractured specimens. There was a statistical significant difference in group I and III with P-value 0.032* and 0.014* respectively while no significant difference between different modes of failure in group II where P-value recorded 0.652 .

Finally, Pearson's correlation test was performed to find out the relationship between the shear bond strength and the mode of failure table (7) (fig.10).

A positivestatistically relationship was obtained and recordedbetween the cohesive mode of failure and the shear bond strength

V. Discussion

The current in-vitrostudy evaluate the shear bond strength of different bioactive restorative materials (Fuji IX conventional glass ionomer, Beautifil II giomer and Activa) to dentin.

Several studies reported that in- vitro shear bond strength testing is the most effective method to screen adhesives and the physical durability of new restorative materials [16].

Selection ofPolyacrylic acid conditioning agent (Ketac conditioner) before application of conventional glass ionomer(Fuji IX GP EXTRA)as it promotes cleaning of the dentin surface from the smear unite thus allow ionic chemical exchange to take place between glass ionomer and dentin [17].Currently Fuji IX GP Extra glass ionomer was chosen which is a condensable, high-strength conventional glass-ionomer, it contains reactive aluminofluorosilicate glass powder (smart glass) whichprovides higher strength , good chemical bond to tooth structure and a greater fluoride release. [18].

In addition, in the present study Giomer bioactive restorative was chosen which is a fluoride releasing materialand has a unique property which is the presence of pre reacted glass ionomer (PRG) filler which has the ability to release and recharge fluoride responding to the concentration of fluoride in the mouth [19].

FL Bond II was used with giomeras it contains the surface pre-reactedglass ionomer (S-PRG) fillers which helps to reinforce the bonding interface between the restorativebioactive material and the tooth structure [20].

Another resin material was chosen currently is ACTIVA BioACTIVE products which are considered the first dental resins with a bioactive ionic resin matrix that continuously releases and recharges a significant amount of calcium, phosphate and fluoride ions and reacts to the continuous pH changes in the mouth to help fortify and recharge the ionic properties of saliva, teeth and the material itself [21].Currently 38% phosphoric acid was used with Activa which is more potent in removing smear layer [22].

Thermo-cycling is a widely used artificial aging method. Thermo-cycling regimen comprising 500 cycles in water between 5°C and 55°Cwith 30 sec. dwell time and 20 sec transfer time is an appropriate artificial aging method that simulate 6 months of clinical service[23].

Regarding the results of the current study , group III (ACTIVA) recorded the highest value of shear bond strength to dentin followed by group II (Beautifill II) Giomer while the lowest shearbond strength value was recorded in group I (FUJI IX) conventional GIC.

This was explained asorthophosphoric acidincrease infiltration of the material into dentin surfacestimulating apatite formation that fills gap also the reactive glass fillers enhanced the chemical interaction with tooth structureforming a strong resin-hydroxyapatite complex. Thus a layer of apatite is formed and fuses the dentin to ACTIVA [24].

AlsoActiva contains a shock-absorbing rubber resin (Embrace resin) which providesintimate adaptation of the material to tooth structure due to formation of apatite layer at material/tooth interface [8].

This also was confirming the results of**Girn, William et al** [25]whostated that Activa has high bond strength to dentin as it release minerals which interact with tooth minerals that produce a good seal between tooth and material. In addition to **Tran A, et al** [26]and **Alkhudhairy et al**[27]who assured the same high bond strength results of Activa.

On the other hand,**Kanachanavasita *et al***[28]disagreed showing that Activa can absorb water up to 7% by mass. The amount of water uptake is dependent on its poly hydroxyl ethyl methaacrylate(HEMA) content. Hence, it is possible that water sorption might lower the strength **.**

Concerning group II (Beautifill II Giomer) the current results recorded higher significant shear bond strength than conventional GIC. This was explained by thepresence of surface pre-Reacted Glass ionomer particles (S-PRG) that contributes with theformation of hard particles enhancing adhesion. 4-META hydrophobic monomers make a good bond with the remaining hydroxyl apatite crystals and also releases silicon which promoteshydroxyapatite formation. Silicon particleswere adsorbed on the substrate surface, thereby providing sites for heterogeneous apatite nucleation which enhancing adhesion to tooth[19].

Okuyama et al [29]reported that giomer has high bond strength due to the presence of4-META, UDMA, HEMA, PRG filler, fluoroaluminosilicate glass.The current results confirmed those of**Fam M et al** [30]**&N Manuja,et al** [31]whomade a comparison between Fuji IX and Beautifill II Giomer . They found that Beautifill II has higher shear bond strength to dentin compared to Fuji IX.They explained these findings by the weak chemical bond of Fuji IX compared toBeautifill II which bonds to dentin with self etch adhesive that creates mechanical interlocking by means of resin tags which has greater bond to tooth.

Regarding Fuji IX (conventional glass ionomer) in this study, it recorded the lowest bond strength to dentin and these results agreed withmany authors **(Passi S, et al** [32]**) &Poggio C, et al** [33]**) .**Also**Thiago-SaadsCarvalho et al** [34]and **Vishnu Rekha C et al** [35]reported a weak chemical bond atglass ionomertooth interface andweak polyacrylic acid which only cleans the dentin surface without completely unplugging the dentinal tubules..

Again on the other hand, ,**Mohamed N *et al***[36] reported that highly viscous GIC (Fuji IXEXTRA) has high bond strength due to its higher powder: Liquid ratio (3.6:1) and good adhesion to tooth substrate due to it's chemical bond to tooth in comparable to nanoparticles glass carbomer.

Regarding **thermocyclingtreatment** , in the current research, there was decrease in shear bond strength of bioactive materials after thermocycling which was significant. This results disagreed with **Mark A et al** [37]who reported that there is no difference between shear bond strength before and after thermocycling in self etch adhesive (FL bond II) used with giomer Fuji XIII and concluded that this may be due to slight relaxation in polymers with heat.

In addition **Zeyad H et al.,** [38] stated thatthermocycling slightlynon significantly decrease the shear bond strengthof Activa because of minimalydecline in elastic moduli.

In other researches it was recorded that no significant differences in shear strength between the non thermocycled and thermocycledgroups**of** Glass ionomer cement (Fuji IX), Giomer (Beautifil), an Ormocer-

based composite (Admira) and Nano Ceramic restorative material (Ceram X)and also reported that theviscoelastic behavior of these materials was stable within the temperature range of 21–50[39].

Previous studies suggested that the mode of failure is an indicator to the strength of bond between restorative material and tooth structure. Adhesive failure usually indicated low bond strength while cohesive failure resembles high bond strength[40].

In agreement with our findings**, Leloup**[41]reported that there is a positive significant relation between high shear bond strength and the rate of cohesive failure.

Also, Furuse[42]**& Sabatini C** [43], concluded different results showing lower bond strength values which were significantly correlated with mainly adhesive fractures.

In the present study,group I recorded the highest adhesive mode of failure values and lowest shear bond strength values while group IIIrecorded the lowest adhesive mode of failure values and highest shear bond strength values before thermocycling. However, after thermocycling, adhesive mode of failure significantly increased in all tested groups.

Also**, Murali S et al,** [44] studied shear bond strength of Activa (resin modified glass ionomer) ,Filtek Supreme Ultra (nano filled composite) and Ketac Nano (nano glass ionomer) and found that bond strength of activa is comparable to Filtek and higher than KetacNano . Cohesive mode of failure was found to be predominant in activa accompanied by thehigh shear bond strength values of this material .

On the other hand **,MohdSafwani et al.,** [45]disagreed with our results who studied two types of glass ionomer cement (GIC), Riva Self Cure and Fuji IX GP EXTR andassessed that cohesive failures in materials were predominant in Fuji IXand Riva specimens.This was explained by some authors [46] concluding that cohesive failures in Fuji IX are predominant at the material side and GICs fails cohesively in the cement rather than cohesive at interface with the tooth structure (ionic-exchange layer) .

VI. Conclusions

Under the limitations of this study, the results suggest that:

1- Both variables, the material type and the thermocycling affected the shear bond strength values significantly.

2- statistically significant correlation between cohesive mode of failure and shear bond strength was detected.

3- Giomer and ActivaBioactive restorative materials have a good bond strength to dentin surface with different levels of shear bond strength in comparable to conventional GIC .

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Tables:

Table I : Materials used in the study.

Material	Chemical composition	Manufacture	Web-site
Fuji IX GP EXTRA (Bioactive conventional glass-ionomer restorative material) ShadeA2 (Chemical cure)	**-powder** Alumino-fluoro-silicate glass(95%),polyacrylic acid(5%) **-liquid** Distilled water(50%), polyacrylic acid(40%), and poly carboxylic acid.(10%)	GC America Inc 3737 West 127th Street Alsip	www.GCAmerica.com
Conditioner 25%Polyacrylic Acid (Ketak-conditioner)	**Polyacrylic Acid (20-30%),Water (70-80%)**		
Beautifil II (Giomer restorative material) **Shade A2 (Light cure)**	BISGMA, TEGDMA, in organic glass filler, aluminum oxide, silica, prereacted glass ionomer filler, camphoroquinone.	SHOFU Dental GmbH,Japan Am Brüll 17 40878 Ratingen	www.shofu.com
FL Bond II (Self etch two stepadhesive system)	**-FL Primer:** Distilled water, initiator, aceton, Etchant:7%H3PO4 **-FL Bond:** Distilled water,2HEMA,4META , TEGDMA,UDMA,Prereacted glass ionomer		

Activa TM bioactive(A resin-modified glass-ionomer Bioactive Ionic Resin-Based Composite). **Shada A2 (Dual cure)**	• Bioactive ionic resin matrix. • ashock absorbing resin component. • bioactive glass filler.	Pulpdent Corporation USA	www.pulpdent.com
Etch-Rite etchant	38%phosphoric acid etching gel		

BISGMA*, bisphenoldiglycidyl ether dimethacrylate;* ***TEGDMA****, triethylene glycol dimethacrylate;* ***HEMA,*** *hydroxyl ethyl dimethacrylate;* ***4META,*** *methacryloxy ethyl trimellitate anhydride;*
UDMA, *urethane dimethacrylate****H3PO4****, phosphoric acid*

Figure 1: (FujiIX $_{GP}$EXTRA)Figure 2: Beautifill II Giomer

Figure 3: Activa^{TM} Bioactive Restorative materialFigure4: Final specimen

Table II: Showing shear bond strength values of the three tested bioactivematerials to dentin surface before thermocycling.

Groups	**Shear bond strength (Mpa)subgroup A**							**ANOVA**	
	Range /MPa			**Mean**		**±**	**SD**	**F**	**P-value**
				No	**MPa**				
Group I	2.777	-	4.294	14.056	3.514	±	0.570	41.094	0.001*
Group II	4.884	-	7.322	24.116	6.029	±	0.820		
Group III	5.499	-	8.023	26.328	6.587	±	0.979		

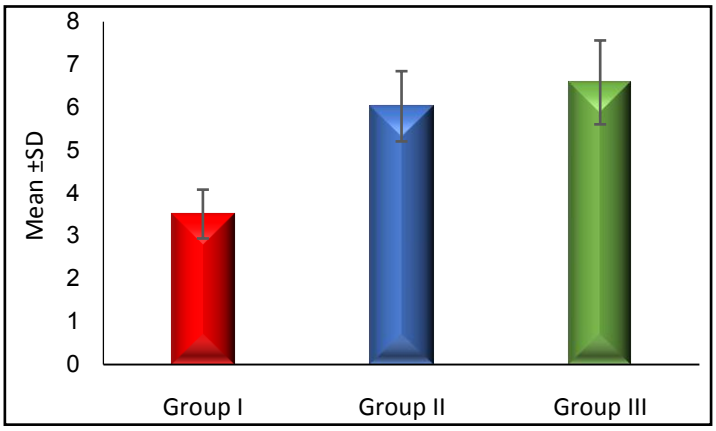

Figure. 5: Bar chart representing the mean shear bond strength values (Mpa) ±SD of the three tested material before thermocycling

Table III: Showing shear bond strength values of the three testedbioactive materials after thermocycling.

Groups	Shear bond strength (Mpa)subgroup B							ANOVA	
	Range /MPa			Mean		±	SD	F	P-value
				No	MPa				
Group I	1.896	-	3.661	11.352	2.838	±	0.594	20.123	0.005*
Group II	2.969	-	5.113	16.60	4.150	±	0.668		
Group III	3.670	-	5.713	18.604	4.651	±	0.713		

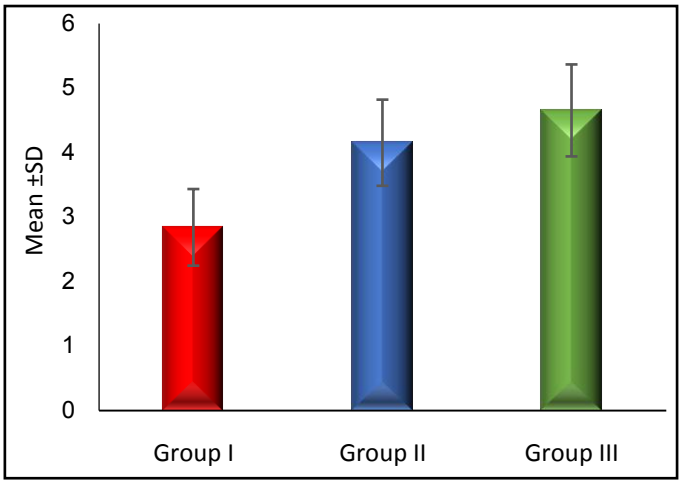

Figure 6: Bar chart representing the mean shear bond strength values (Mpa) ± SD of the three tested materials after thermocycling.

Table IV: Statistical analysis of the mean shear bond strength values (Mpa) ± SD of each group for subgroup A&B.

Groups	Shear bond strength (Mpa)	Subgroups						T-Test	
		Subgroup A			Subgroup B			T	P-value
Group I	**Range**	2.777	-	4.294	1.896	-	3.661	2.597	0.018*
	Mean ±SD	3.514	±	0.570	2.838	±	0.594		
Group II	**Range**	4.884	-	7.322	2.969	-	5.113	5.619	0.001*
	Mean ±SD	6.029	±	0.820	4.150	±	0.668		
Group III	**Range**	5.499	-	8.023	3.670	-	5.713	5.055	0.001*
	Mean ±SD	6.587	±	0.979	4.651	±	0.713		

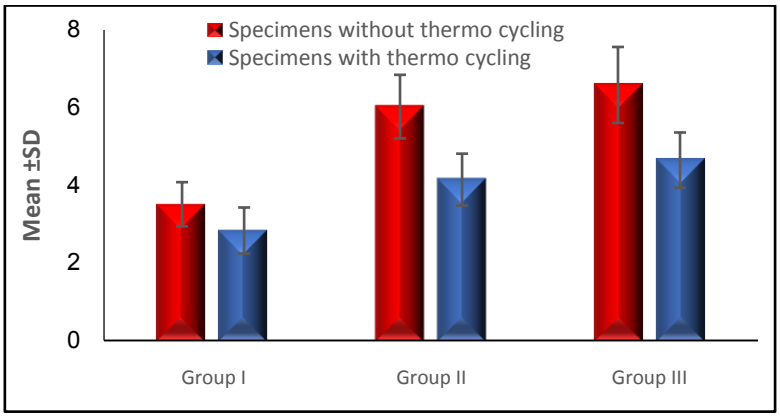

Figure 7: Bar chart of the mean shear bond strength values(Mpa) ± SD between bioactive restorative materials and dentin surface of each group for subgroup A&B.

TableV: Percentage of mode of failure of the tested groups without thermocycling (subgroup A).

Specimens without thermo cycling	Mode of failure of subgroup A						Chi-square	
	Mixed		Adhesive		Cohesive		X^2	P-value
Group I	3	30.00	4	40.00	3	30.00	0.873	0.634
Group II	3	30.00	1	10.00	6	60.00	1.217	0.057*
Group III	2	20.00	0	0.00	8	80.00	0.911	0.063*

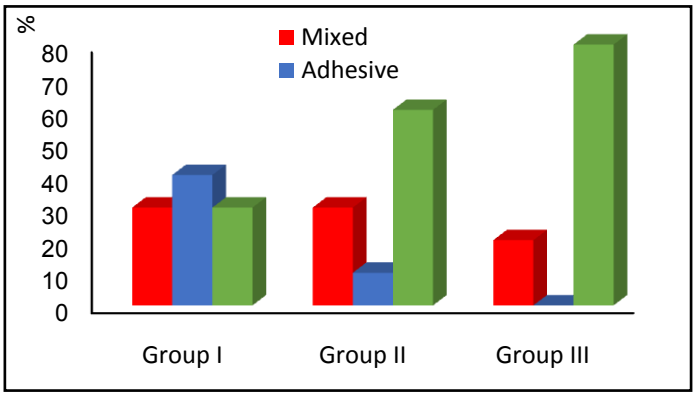

Figure 8: Bar chart representing percentage of mode of failure of the tested materials without thermocycling (subgroup A).

TableVI: Percentage of mode of failure of the tested groups after thermocycling (subgroup B).

Specimens with thermo cycling	Mode of failure of subgroup B						Chi-square	
	Mixed		Adhesive		Cohesive			
	No	%	No	%	No	%	X^2	P-value
Group I	2	20.00	6	60.00	2	20.00	2.131	0.032*
Group II	3	30.00	3	30.00	4	40.00	0.521	0.652
Group III	2	20.00	2	20.00	6	60.00	1.241	0.014*

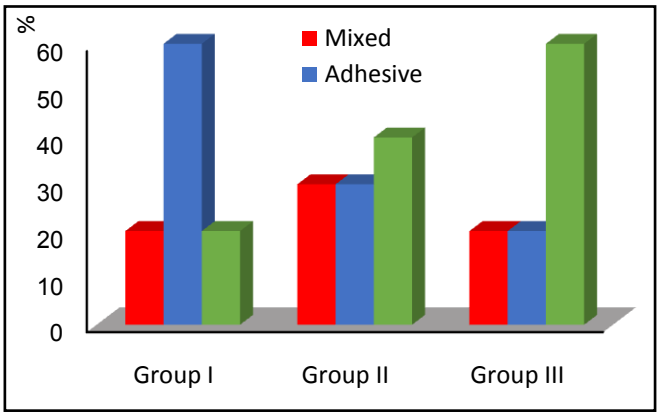

Figure 9: Bar chart representing percentage of mode of failure of the tested materials after thermocycling.

TableVII:correlation between mode of failure and shear bond strength of the tested materials regardless thermocycling.

Mode of Failure	Shear bond strength			pearson`s correlation	
	Group I	Group II	Group III	r	P- value
Mixed	25%	30%	20%	0.2538	0.003*
Adhesive	50%	20%	10%		
Cohesive	25%	25%	70%		

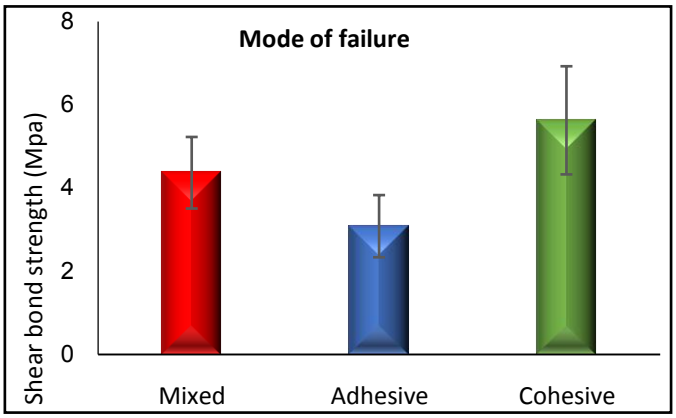

Figure10 : Correlation between mode of failure and shear bond strength of the tested materials regardless thermocycling.

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