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Original Research

Effect of Luting GIC Cement, 45S5 Bioglass Paste, Nano-Silver GIC, and CaP in GIC on Bond Strength of Orthodontic Brackets

[1]Nada Alshehri, [2]Nada Tashkandi

[1]Postgraduate Resident, [2]Assistant Professor, College of Dentistry, Riyadh Elm University, KSA

ABSTRACT:
Aim: To assess the effect of Luting GIC cement, CaP in GIC, Nano-Silver GIC, and 45S5 Bioglass paste on the bond strength of orthodontic brackets. **Materials and Methods:** Forty-eight healthy human premolars were selected and were randomly divided into four groups containing 12 teeth each. They were then bonded with Unitek metal brackets (Unitek™ Gemini Metal Brackets, 3M Unitek) according to the group assignment of the different luting cement as follows: Control group (GIC), the CaP in GIC group, Nano-silver GIC group, and 45S5 Bioglass paste group. A universal testing machine was used to debond the brackets to determine and compare the strength of the luting cement by statistical means. Samples were then loaded into the Micro-Computed Tomography and Scanning Electron Microscope to determine and compare the remaining cement thickness.Data were analyzed using SPSS. **Results:** The mean (SD) maximum load and shear bond strength was highest in CaP in the GIC group, followed by Luting GIC, Nano-silver GIC, and least in the 45S5 Bioglass group. The Mean (SD) volume of remaining cement was highest in Luting GIC, followed by Nano-silver GIC, CaP in the GIC group, and least in the 45S5 Bioglass group. **Conclusion:** Among the various luting agents compared in the study, CaP in GIC containing GIC shows better strength and also leaves less cement on the tooth surface compared to the other luting agents in this study.

Keywords: Orthodontic brackets, Shear Bond Strength, Glass Ionomer Cements, 45S5 Bioglass Paste.

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Corresponding author: Nada Alshehri, Postgraduate Resident, College of Dentistry, Riyadh Elm University, KSA

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INTRODUCTION

The fixed appliance system in orthodontics has changed the face of orthodontic treatment. Orthodontic brackets are an important component of fixed appliances. However, its success is dependent on many factors, one of which is the cement used to attach the brackets to the teeth. This needs to be selected carefully considering properties like bond and shear strength, anti-carious and enamel remineralization abilities, and others.

Any treatment comes with its unwanted side effects despite the greater good the treatment provides. With fixed orthodontic appliances, one of the main side effects is the propensity of biofilm accumulation which not only causes periodontal disease but also increases the possibility of white spot lesions (WSLs) and subsequent caries. These WSLs are the initial precursors of dental caries and are caused by organic acid produced by the microorganisms in the biofilm[1,2]. Incipient enamel caries results in subsurface demineralization beneath an intact surface layer of enamel. Light is reflected differently from demineralized enamel surfaces compared to the adjacent sound enamel, giving rise to its characteristic chalky white appearance[1]. Studies have suggested the prevalence of WSLs in patients undergoing orthodontic treatment can be as high as 45.9% which is an alarming sign[3]. WSLs can seriously damage the esthetic outcome of the treatment. The data indicates that white spot lesions can periodically be noticeable even 12 years after treatment and have reduced ability to improve even after removal of the appliance[4,5,6].

Since becoming a major issue during orthodontic treatment, several preventive strategies to prevent WSLs like oral hygiene control, use of fluoride toothpaste, and fluoride varnishes, use of casein phosphopeptides, amorphous calcium phosphate, use of probiotics, polyol, and use of antimicrobial mouthwashes like chlorohexidine have been studied and implemented. With these preventive treatments, the two major action plans after occurrence are masking the lesion and remineralizing the enamel[7,8].

A better way to aid enamel remineralization is the utilization of special luting cements to bond brackets. Several types of cements and adhesives have been used in orthodontic practice. Zinc phosphate, zinc silicophosphate, and zinc polycarboxylate cements were used as principal band cements until the early 1990s. However, after the innovation of GIC, modified GIC and other adhesive cements, the use of the previously mentioned cements has become minimal.

Several modifications of GIC have been introduced to the market with the promise of increased mechanical strength and enamel remineralization. Among them are 45S5 Bioglass paste, Nano-Silver GIC, and Calcium Phosphate (CaP) in GIC. Thus, the present study aims to assess these cements and compare their bond strengths and volume of remaining cement after debonding using GIC as a control.

MATERIALS AND METHODS

Forty-eight healthy human premolars were selected and divided into four groups (n=8). In preparation for tooth bonding, the surfaces of all teeth were cleaned using a rubber cup, non-fluoridated pumice paste, and water for 10 seconds to eliminate debris. The buccal surface of each tooth was the target of the current study. All teeth were preserved in distilled water for 24 hours and incubated at 37oc. It was then challenged by an erosive test by embedding in buffered demineralizing solution after bonding, which contained 1% citric acid for 30 min and continuously stirred by a magnetic stirrer to the similarity to the oral environment. Each group of teeth was covered with the assigned nail varnish colors except on the buccal/facial surface which was left unaltered. Each tooth was then embedded in acrylic cold cure clear orthodontic resin mixed according to the manufacturer.

Bonding of the bracket to the buccal surface was performed using GIC Luting cement, CaP-GIC, Nano-silver GIC, and 45S5 Bioglass. The samples then underwent aging by thermocycling for 7000 cycles in a thermocycler between 5-55^{o} C with a dwell time of 30 seconds and a transfer time of 15 seconds. Then shear bond strength testing was performed with a universal testing machine. Debonding force was recorded in Newton (N) and changed to megaPascal (MPa). Scanning of each sample was performed using micro-CT. After scanning, a reconstruction of the projected images was performed to produce a reconstructed cross-section image. Evaluation and scoring of the adhesive remnant were carried out. The buccal surface of each tooth was evaluated to determine the adhesive remnant index (ARI) score. Samples were loaded into the Jeol JSM-6610LV scanning electron microscope (SEM) for image processing and analysis.

Descriptive statistics of mean and standard deviations for maximum load, shear bond strength at maximum load and the volume of remaining cement in different groups were calculated. Analysis of variance tests (ANOVA) was applied to compare the maximum load, shear bond strength at maximum load, and the volume of the remaining cement. Tukey's post hoc tests were then performed to disclose the significant mean difference within the groups. All the data were analyzed using SPSS version 21 (Armonk, NY: IBM Corp., USA). A p-value of <0.05 was considered statistically significant.

RESULTS

The mean (SD) maximum load was highest in CaP in GIC group, followed by Luting GIC, Nano-silver GIC, and least in the 45S5 Bioglass group. One-way ANOVA showed that the mean difference of maximum load between the groups was statistically significant ($p<0.05$) (Table 1). Tukey's post hoc test showed a statistically significant mean difference within all the groups ($p<0.05$) (Table 2).

Table 1. Comparison of Mean (SD) maximum load between the groups

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.	p-value
					Lower Bound	*Upper Bound*			
Luting GIC	12	31.9688	2.23948	.64648	30.5459	33.3917	28.52	35.53	0.000*
CAP in GIC	12	34.7853	2.84649	.82171	32.9768	36.5939	31.01	41.00	
Nano-silver GIC	12	29.2713	1.93300	.55801	28.0431	30.4995	26.18	32.99	
45S5 Bioglass	12	22.0258	1.78324	.51478	20.8927	23.1588	18.96	24.54	

**Statistically significant at p<0.05*

Table 2. Pairwise comparison of maximum load within the groups

		Mean Difference	Std. Error	p-value	95% Confidence Interval	
					Lower Bound	*Lower Bound*
Luting GIC	CaP in GIC	-2.81659*	.91365	.018	-5.2560	-.3771
Luting GIC	Nano-silver GIC	2.69746*	.91365	.025	.2580	5.1369

Luting GIC	45S5 Bioglass	9.94300*	.91365	.000	7.5035	12.3825
CaP in GIC	Nano-silver GIC	5.51405*	.91365	.000	3.0746	7.9535
CaP in GIC	45S5 Bioglass	12.75959*	.91365	.000	10.3201	15.1990
Nano-silver GIC	45S5 Bioglass	7.24553*	.91365	.000	4.8061	9.6850

**Statistically significant at p<0.05*

The mean (SD) shear bond strength at maximum loadwas highest in CaP in GIC group, followed by Luting GIC, Nano-silver GIC, and least in the 45S5 Bioglass group. One-way ANOVA showed that the mean difference of maximum load between the groups was statistically significant (p<0.05) (Table 3). Tukey's post hoc test showed a statistically significant mean difference within all the groups (p<0.05) (Table 4).

Table 3. Comparison of Mean (SD) shear bond strength at maximum load between the groups

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.	p-value
					Lower Bound	*Upper Bound*			
Luting GIC	12	27.7507	1.94399	.56118	26.5155	28.9858	24.76	30.84	0.000*
CAP in GIC	12	30.1956	2.47091	.71329	28.6257	31.7656	26.92	35.59	
Nano-silver GIC	12	25.4091	1.67795	.48438	24.3430	26.4752	22.73	28.64	
45S5 Bioglass	12	19.1196	1.54795	.44685	18.1361	20.1031	16.46	21.30	

**Statistically significant at p<0.05*

Table 4. Pairwise comparison of shear bond strength at maximum load within the groups

		Mean Difference	Std. Error	p-value	95% Confidence Interval	
					Lower Bound	*Lower Bound*
Luting GIC	**CAP in GIC**	-2.44496*	.79310	.018	-4.5625	-.3274
Luting GIC	**Nano-silver GIC**	2.34155*	.79310	.025	.2240	4.4591
Luting GIC	**45S5 Bioglass**	8.63107*	.79310	.000	6.5135	10.7487
CAP in GIC	**Nano-silver GIC**	4.78651*	.79310	.000	2.6689	6.9041
CAP in GIC	**45S5 Bioglass**	11.07603*	.79310	.000	8.9584	13.1936
Nano-silver GIC	**45S5 Bioglass**	6.28952*	.79310	.000	4.1719	8.4071

**Statistically significant at p<0.05*

The mean (SD) volume of remaining cement was highest in Luting GIC, followed by Nano-silver GIC, CaP in GIC group, and least in the 45S5 Bioglass group. One-way ANOVA showed that the mean difference in the volume of remaining cement between the groups was statistically significant (p<0.05) (Table 5). Tukey post hoc test showed a statistically significant mean difference was found only between Luting GIC and CaP in GIC group; Luting GIC and 45S5 Bioglass; CaP in GIC and Nano-silver GIC; and Nano-silver GIC and 45S5 Bioglass (p<0.05) (Table 6).

Table 5. Comparison of Mean (SD) volume of remaining cement between the groups

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.	p-value
					Lower Bound	*Upper Bound*			
Luting GIC	12	1.637083	1.0352665	.2988557	.979306	2.294860	.2142	3.5224	0.000*
CAP in GIC	12	.072733	.0433184	.0125049	.045210	.100257	.0074	.1344	
Nano-silver GIC	12	.951058	.7344150	.2120074	.484433	1.417683	.0771	2.3387	
45S5 Bioglass	12	.006392	.0040487	.0011688	.003819	.008964	.0012	.0133	

**Statistically significant at p<0.05*

Table 6. Pairwise comparison of the volume of remaining cement within the groups

		Mean Difference	Std. Error	p-value	95% Confidence Interval	
					Lower Bound	*Lower Bound*
Luting GIC	**CAP in GIC**	1.5643500*	.2592485	.000	.872155	2.256545
Luting GIC	**Nano-silver GIC**	.6860250	.2592485	.053	-.006170	1.378220

Luting GIC	**45S5 Bioglass**	1.6306917*	.2592485	.000	.938497	2.322887
CAP in GIC	**Nano-silver GIC**	-.8783250*	.2592485	.008	-1.570520	-.186130
CAP in GIC	**45S5 Bioglass**	.0663417	.2592485	.994	-.625853	.758537
Nano-silver GIC	**45S5 Bioglass**	.9446667*	.2592485	.004	.252472	1.636862

**Statistically significant at* $p<0.05$

DISCUSSION

To date, several adhesives or cements have been used as luting agents for bonding orthodontic brackets to the enamel. Among these, resin compounds and glass ionomers are the most commonly used. Glass ionomers are preferred to resins because of their fluoride release potential[9]. This property can be further enhanced by the addition of certain bioactive agents[10]. (Spagnuolo 2022). Bioactive agents can be used to enhance the biological defense against caries or to prevent caries. However, the addition of these agents may alter the physical properties and that may be of greater concern and must be addressed along with their biological properties[11]. An efficient luting agent should be able to provide adequate retention and shear bond strength (SBS) during the entire course of treatment. At the same time, it should be easily removed during debonding after orthodontic treatment without affecting the integrity of enamel and without cracks or fractures. To prevent enamel fracture or crack, it is ideal that some luting agent remains on the enamel surface after debonding. Preferably, the luting agent that remains would be easily removed with slight force at the time of debonding without damaging the enamel surface[12,13].

In the present study, the maximum load and shear bond strength of variations in luting cement for bonding of orthodontic bracket were compared. It was found that both maximum load and shear bond strength has shown similar results with the levels highest in CaP in the GIC group, followed by Luting GIC, Nano-silver GIC, and least in the 45S5 Bioglass group. Moreover, the difference between the groups was statistically significant. The Luting GIC displayed adequate bond strength and was used as the control. Several studies found that GICs are cariostatic and have antimicrobial properties due to the release of fluoride, which helps in reducing demineralization, enhancingremineralization, and inhibiting microbial growth. The addition of any material into GICs could affect their unique characteristics[14].

The result of the present study is similar to the study by Sethusa et al. who showed that SBS for RelyXUnicem is 5.38 MPa and NRC is 4.70 MPa. This is considered to be weak compared to all the other materials where the means for the SBS are within the acceptable range of 5.9 to 7.8 MPa. They concluded that RelyXUnicem and NRC were found to be unsuitable for orthodontic bracket adhesion[15]. A study comparing the glass ionomer adhesive system with composite resin adhesive provided a significantly lower bond strength for glass ionomer (6.5 ± 1.9 MPa). It was reported that the use of either a fluoride-releasing glass ionomer or an acidic primer in combination with an available orthodontic composite adhesive resulted in a significantly reduced SBS when compared to that of the conventional composite resin adhesive system[16]. On the contrary, Heravi et al. showed no difference in the retentive strength between the Luting GIC, and CaP modified GIC. It was reported that there were no significant differences between the groups in retentive strength[17].

We found in this study that the mean (SD) shear bond strength at maximum load was highest in the CaP-GIC group when compared to the other groups. A similar positive effect of CaP was seen in previous studies where CaP enhanced the bond strength[18]. On the contrary, studies by Uysal et al. and Tabrizi and Cakirer did not show any change in the SBS[19,20]and another study has shown that adding CaP does not affect the shear bond strength while having a positive effect on remineralization[21]. Modification of GIC with 1.56% w/w CaP had no negative effects on the retentive strength of the bands. Thus, they have recommended CaP for fixed orthodontic treatment[17].

In the present study, the bond strength of the silver nanoparticles containing GIC was almost equal to that of the CaP.A previous study on increasing incorporations of NanoAg powder to GIC has shown a gradually decreasing trend of bond strength, however, all samples reached the ideal bond strength range[22]. While Sodagar et al. reported that the addition of Nano-silver to the orthodontic adhesive affects the shear bond strength by increasing the orthodontic SBS of the adhesive [23]. On the contrary, studies by Hamdy et al. concluded that the addition of Ag nanoparticles exhibited lower shear bond strength[24].

In the present study, 45S5 Bioactive glass showed the least bond strength compared to the others. However, there are only a few studies available comparing the 45S5 Bioglass paste bond strength when used for orthodontic bonding. Amirabadi et al. showed a significant drop in flexural strength of RMGIC doped with Bioglass which is similar to the present study results[25]. On the other hand, a study comparing the 30% w/v 45S5 BG to RMGIC has shown that there was no significant change in SBS of orthodontic brackets bonded to enamel indicating its use in the bonding is justified[11].

In the present study, remaining cement compared among the 4 groups was evaluated. It showed that the volume of remaining cement thickness was highest in Luting GIC, followed by NanoAg GIC, CaP in the GIC group, and least in the 45S5 Bioglass group. Contrary to the present study results, Heravi et al.

found no significant differences in the ARI score between the luting cement and modified by CaP[17]. Similarly, a study comparing CaP-containing composites to convention resin-based composites showed no difference in ARI scores[26].Naseh et al. in their study have shown that ARI scores were 0 after using CaP. Thus, they concluded that, treating the enamel using CaP before bracket bonding did not help to reduce the risk of enamel damage during bracket debonding[27].Shirazi and Sadeghi utilizing the 45S5 bioactive material reported that the RMGIC group showed the highest ARI score, while RMGIC doped with BG showed the lowest ARI score[11].

This present study aimed to compare the effect of Luting GIC cement, CaP in GIC, Nano-Silver GIC, and 45S5 Bioglass paste on the bond strength of orthodontic brackets. Each material was mixed according to the manufacturer's instructions, but the mixing of materials carries with it the risk of human error in mixing techniques and measurements. Different concentrations of the additives could affect the mechanical and physical properties of the resultant cement.

As this is an in-vitro study, whatever simulation of the oral environment created may not be similar to the actual or natural environment to which the luting cement is exposed. The presence of saliva, exposure to acidic beverages, behaviors related to the patient, or other factors can affect the bond strength and residual cement. Another factor could be the chewing pattern and parafunctional habits of patients that were simulated by the thermocycling of the samples but differ from patient to patient especially considering the length of time in orthodontic treatment. Thus, in vivo study results may be influenced by many other factors which become difficult to mimic.

CONCLUSIONS

Within the limitations of the study, the following conclusion can be drawn:

1. Maximum load and SBS were highest in CaP in the GIC group, followed by Luting GIC, Nanosilver GIC, and least in the 45S5 Bioglass group.
2. The remaining cement was highest in Luting GIC, followed by Nanosilver GIC, CaP in the GIC group, and least in the 45S5 Bioglass group.
3. CaP containing GIC shows better strength and also leaves less cement on the tooth surface compared to Nanosilver GIC.
4. 45S5 bioglass appeared to be least suitable for bonding as it shows weak bond strength.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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