Evaluation of Shear Bond Strength of Resin Reinforced Glass Ionomer Cement Modified by Nano-hydroxyapatite on Ceramic Bracket Debonding Using Full-dimension Wire

Elaheh Seyed Tabaii[1*] and Mohsen Nuri Sari[1]

[1]*Orthodontic Department of Shahed University, Italia St., Tehran, Iran.*

Authors' contributions

Authors EST and MNS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author EST managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

ABSTRACT

Aim: Using fluoride releasing materials such as Glass Ionomer Cement (GIC), can control the demineralization around brackets. In this study, the shear bond strength of resin reinforced GIC modified by Nano-hydroxyapatite (NHA) on ceramic bracket debonding is evaluated. In addition, using full-dimension wire for safe debonding is also examined.
Study Design: Original article.
Place and Duration of Study: Department of Dentistry, Shahed University, Tehran, IRAN, June 2013.
Methods and Material: 80 extracted human premolars received from a clinic were partitioned into 4 groups. Bonding materials used in each group was as follows: Group 1: Transbond XT as a control group, Group 2: Resin Modified GIC (RMGIC), Group 3: RMGIC added 5% NHA and Group 4: RMGIC added 10% NHA. In all groups the enamel was etched with 37% phosphoric acid and ceramic brackets were used. Each group halved into 2 subgroups which just in one of them full dimension wire was employed at the time of debonding. The shear bond strength, Adhesive Remnant Index (ARI) and bracket failure figures were collected for each group. The data was latter analyzed using one-way Analysis Of Variance (ANOVA), Tukey's HSD (Honestly Significant Difference) Post-hoc

---

*Corresponding author: Email: e.tabaii@gmail.com;

and Kruskal Wallis Test methods.

Results: According to ANOVA, RMGIC added 5% NHA has no negative effect while adding 10% NHA lowered the shear bond strength significantly. No bracket failure occurred at debonding, either using or not using full dimension wire. ARI for RMGIC groups were more cohesive than the control group.

Conclusion: RMGIC containing 5% NHA contributes bond strength similar to composite resins, in bonding ceramic brackets, while its known demineralization resistance is a favor.

1. INTRODUCTION

Glass Ionomer Cement (GIC) introduced by Wilson and Kent (1972) has many advantageous such as biocompatibility and cariostatic effect that promotes remineralization but, unfortunately, its bond strength is clinically low [1,2].

In an attempt to increase fluoride release and to improve bond strength, resin-modified glass ionomer cement (RMGIC) is proposed [3]. By incorporating various fillers such as silver cements, stainless-steel powder, carbon and alumino-silicate fibers and hydroxyapatite (HA) the physical properties of GIC is aimed to be improved. HA by itself is a major calcified component of tooth and bone, which its decreased particle size, similar to the size of minerals in teeth, leads to increased surface area and higher solubility [4,5]. However, Nano-hydroxyapatite (NHA) can fill the micropores of enamel defects more effectively than HA by releasing inorganic ions (like calcium and phosphate) due to its high solubility. Hence, bonding strength between restorative material and teeth is enhanced [6,7].

Ceramic brackets have been available for clinical use since 1987. They enjoy both excellent aesthetics and the well-known reliability of stainless steel brackets. However, a greater risk of enamel fracture during bracket debonding has hampered its wide use [8]. Unlike the stainless steel, the material cannot be flexed sufficiently during debonding, hence, higher initial force is needed for brackets removal [9]. This is a major concern. Knowing that using full dimension wire at the time of debonding in stainless steel brackets minimizes its deformation [10], it seems to be wise to engage wire in ceramic bracket for the aim of inhibiting its breakage.

The aim of this study is to evaluate the shear bond strength of RMGIC modified by NHA on ceramic bracket debonding using a full-dimension wire.

2. MATERIALS AND METHODS

Eighty sound premolar teeth were selected from a bunch of extracted teeth collected during ordinary dental treatments. The soft tissues were removed and stored in distilled water at room temperature. The teeth were divided randomly into four groups of each 20 teeth. All the samples were blindly prepared according to the following procedure in one day, by a single practitioner who was trained for the study. The buccal surfaces of the teeth in all groups were first etched with 37% phosphoric acid for 30 seconds and then Illusion® Plus™ Ceramic Brackets (Ortho organizer, USA) were bonded using the following bonding systems with details depicted in Table 1.

Table 1. Materials used in the study

Material	Company	Composition
Fuji II LC	GC Corporation Tokyo, Japan	Powder: Fluoro-alumino-silicate glass Liquid: Polyacrylic acid, 2-hydroxyethyl methacrylate (HEMA), dimethacrylate, camphorquinone, water
Transbond XT	3M Unitek Orthodontic Products, Monrovia, CA, USA	Adhesive paste: Silica, BIS-GMA, Silane, N-dimethyl benzocaine, hexa-fluoro-phosphate
Illusion® Plus™ Ceramic Bracket	Ortho organizer Carlsbad, CA,USA	Purest Polycrystalline, 99% Alumina
Hydroxy appatite Nano P	Nanoshel LLC Willmington DE, USA	$Ca_5(OH)(PO_4)_3$

Group 1: Transbond XT (TBXT) (3M, St Paul, Mn, USA), Group 2: Fuji II LC (RMGIC) (GC Corp. Tokyo, Japan), Group 3: Fuji II LC (GC Corp. Tokyo, Japan) added 5% NHA powder* (%5NHA), Group 4: Fuji II LC (GC Corp. Tokyo, Japan) added 10% NHA powder* (10%NHA),
*Nano sized, rod- like Hydroxyapatite particles (NHA) final product from NANOSHEL Corporation (Batch No #290090621)

In group 1, TBXT Primer (3M, St Paul, Mn, USA) was applied before bonding. The powder and liquid were mixed according to the manufacturer's instructions for the groups 2, 3 and 4. After bracket placement, excessive adhesive was removed and then the bonding material was cured for 40 seconds using LED light (L. E. Demetron, SDS Kerr, USA). The bonded teeth were stored in distilled water with 0.5 percent chloramines-T disinfectant (Chloramin-T trihydrate, Merck Corp. Germany) for 1 week at 37ºC in the incubator [10,11]. The teeth in each group was divided into 2 subgroups, each containing 10 teeth which in one of them a full dimension wire was inserted, Fig. 1. The teeth were mounted for testing and debonding was done with the Instron Universal Testing Machine (Zwick Roell, Germany), Fig. 2, as recommended previously by Fox et al. (1995) at a crosshead speed of 1mm/min [11]. A chisel-shaped rod applied the shear force as close to the bracket-tooth interface as possible. The load at failure point was recorded with the testXpert V11.0- software (Zwick Roell, Germany) and calculated in megapascals (Mpa). In 4 subgroups, a full dimension wire (0.021× 0.025 stainless steel) was inserted in the bracket slot before testing. Following debonding, each tooth was examined under the stereomicroscope at a magnification of ×10 and the percentage of adhesive that remained on the enamel was quantified according to the values of the adhesive remnant index (ARI), ranging from 0 to 3, previously reported by (Artun and Bergland, 1984) as follows:

0: no adhesive remained on the enamel surface.
1: less than 50 per cent of adhesive remained on the enamel.
2: more than 50 per cent of adhesive was left on the enamel.
3: the entire adhesive remained on the tooth structure [2,11].

The mean and standard deviation of bond strength were assessed and analyzed by one-way analysis of variance (ANOVA) followed by Tukey's HSD (Honestly Significant Difference) Post-hoc for means contrast at α = 0.05. The modified ARI was calculated by Kruskal-Wallis test to determine statistically significant differences [12].
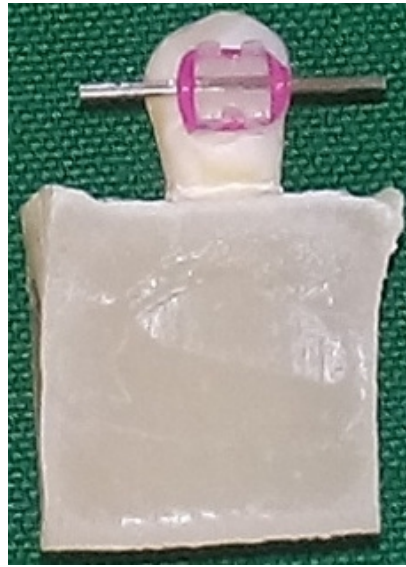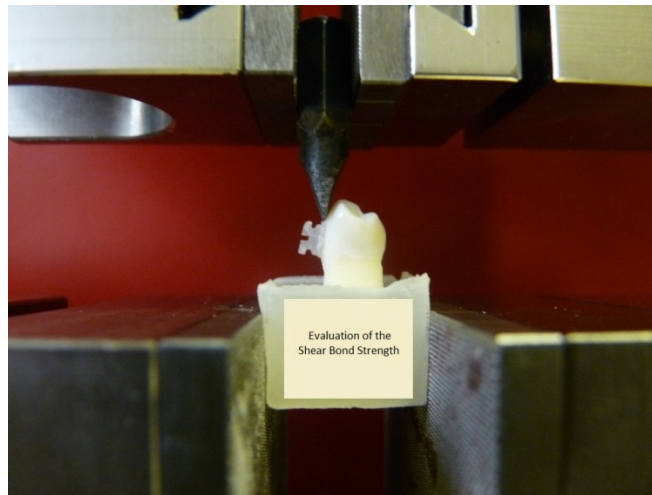
Fig. 1. A sample with full dimension wire

Fig. 2. Instron universal testing machine

3. RESULTS

The bond strength values of the brackets (in mega Pascal) and the description of the statistical analysis are shown in Table 2 and 3; exhibiting statistically significant differences. The bond strength of group 4 was statistically lower than the other groups (P<0.001) but there wasn't any significant difference between the others (P>0.05). The modified ARI scores of the debonded interfaces of the bracket base are shown in Table 4.

The kruskal wallis test showed that there were significant differences among the four groups (*P*<0.001). The Mann-Whitney U-test showed that ARI in group 1 was significantly different

than the other groups (P<0.001) but there wasn't any difference between the others (P>0.05). Also there wasn't any bracket failure in the groups. Meanwhile, using wire for debonding didn't show any significance.

Table 2. Shear bond strength and standard deviation

Material	Wire	N	Min.	Max.	Mean	Std. Dev.
Transbond XT	No	10	12.08	23.94	16.8520 (a)	4.27211
	yes	10	11.02	25.60	17.8110 (a)	4.04420
RMGI	No	10	13.67	22.20	18.8240 (a)	2.89473
	Yes	10	9.51	20.61	15.6210 (a)	3.54665
NHA 5%	No	10	12.91	20.77	17.5190 (a)	2.45906
	Yes	10	11.40	20.24	15.6070 (a)	2.47834
NHA 10%	No	10	6.87	14.04	11.9590 (b)	2.27467
	yes	10	9.51	16.31	11.9130 (b)	2.07168

Identical letters indicate no differences (P>0.05)

Table 3. P value (Mean and SD)

		Transbond XT	RMGI	NHA5%	NHA 10%
Transbond XT	Sig.		1.000	0.862	0.000
	Mean		0.1090	0.7685	5.3955*
	Std. Error		0.98247	0.98247	0.98247
RMGI	Sig.	1.000		0.908	0.000
	Mean	-0.1090		0.6595	5.2865*
	Std. Error	0.98247		0.98247	0.98247
NHA 5%	Sig.	0.862	0.908		0.000
	Mean	-0.7685	-0.6595		4.6270*
	Std. Error	0.98247	0.98247		0.98247
NHA10%	Sig.	0.000	0.000	0.000	
	Mean	-5.3955*	-5.2865*	-4.6270*	
	Std. Error	0.98247	0.98247	0.98247	

(*) Indicates that there is a significant difference

Table 4. Distribution of failure patterns (ARI scores)

Wire	Material	0	1	2	3
NO	Transbond XT	0	8	1	1
	RMGI	0	4	3	3
	NHA 5%	0	3	4	3
	NHA 10%	1	2	5	2
YES	Transbond XT	0	8	2	0
	RMGI	0	3	3	4
	NHA 5%	0	2	2	6
	NHA 10%	0	1	5	4

4. DISCUSSION

Demineralization resistance and bonding strength are two major demands in orthodontic treatment. GIC can be used effectively in a moist environment, since basically its chemical compositions needs wetness. It is also a biocompatible material which releases fluoride resulting in demineralization resistance enhancement. Therefore, it is a candidate of choice in areas where dry isolation is difficult to be maintained [13]. Researchers have also shown that incorporating NHA into GIC increases more the favorite demineralization resistance [6,14,15]. This may be related to the smaller particle size of NHA; which enhances its deposition into micropores in demineralized enamel. In addition, high solubility of NHA leads to the effectiveness of the calcium and phosphate ions release, which fills the demineralized micropores [7]. As HA particles and inorganic ions infiltrate into the demineralized surface, they impede the movement of calcium released from enamel surface, therefore, resistance to demineralization is intensified [6].

From view point of bond strength, GIC chemically bonds to both enamel and dentin. The mechanism of chemical bonding of GIC has not been fully defined yet. One theory may be the formation of ionic bonding between polyalkenoic acid and HA of tooth. However, its bonding lacks sufficient mechanical properties, such as brittleness, inferior compressive and tensile strength [6]. In this respect, Suggestion has been raised for incorporating NHA into RMGIC for improving strength. This has also been due to the biocompatibility of HA. HA has a composition and crystal structure similar to apatite in human dental structure and skeletal systems. Moreover, it is the main mineral component of the enamel of the tooth. It is found that GIC interacts with HA via the carboxylate groups in the polyacid [16]. As a result, by incorporating HA into GICs expectation of better mechanical properties of material is elevated. Some studies have confirmed the assumption [6,14-16]. Lucas et al. [14] have shown that adding %8 HA into GIC exhibits bond strength to dentin similar to (no improvement) that of the control group (non-added HA glass ionomer cement). Our founding suggests that incorporating 5% NHA into RMGIC has no negative impact (similar results).

By using 10% NHA, weakness in the bonding strength was observed. Two reasons may be presented:

I. Santos et al. has investigated the water absorption characteristics of dental composites incorporated by HA filler. They have shown that the filled specimens had higher water absorption ability than it would be expected from the basis resin content. This increase in the water uptake was largely due to the presence of porosity and filler particle aggregates in the microstructure of composites [17]. It seems that by increasing the percentage of NHA, the porosity and filler particle aggregates would increase, which subsequently aid to more water absorption. The particles are loosely embedded in the matrix and provide room in between the agglomerate and the matrix to suck more water, which ultimately can reduce the bonding characteristics.
II. HA is opaque to visible light, hence, it seems reduction in the bond strength at high percentage of HA filler is to be a result of blockage of visible light [18].

Our results indicate no significant difference in shear bond strength (SBS) using either a conventional composite resin or RMGIC, similar to the previous findings [12,13]. Meanwhile, Sfondrini et al. observed that under non-etched conditions, the SBS achieved with the RMGIC was statistically lower than that of the conventional composite resin, similar to the results of Ref.'s [8,12,19,20].

In some research, the idea of pretreatment before bonding by RMGIC is recommended [11,13]. Valente et al. investigated the effect of different acid etch preparations and concentrations on the tensile bond strength of a RMGIC. No significant difference was achieved when 10 or 37% phosphoric acid or 10% polyacrylic acid is used [13]. But Maruo et al. shows that in comparison with polyacrylic acid, 37% phosphoric acid enhances the shear bond strength and is recommended for pretreatment before bonding by RMGIC [21].

According to ARI analysis, the score for the debonded interfaces of the RMGIC and RMGIC added 5% NHA groups were mainly 1 and 2. This, for 80 per cent of the samples in the Transbond composite resin group were 1 and approximately 50 per cent of the RMGIC added 10% NHA samples scored 2. The locus of bond failure is determined by a complex combination of contributory factors including the direction of the force applied, enamel pre-treatment, the adhesive itself and the bracket type [10].

Our results also indicate that when Transbond composite resin is used, most of it remains on the bracket base; as reported in Ref.'s [10,12,20]. In contrast, Carvalho et al. has shown that the most debonding failure occurs at the composite/ bracket interface [8]. In the three other groups, cohesive failure commonly occurred. This is in accordance with the upshot of the study by Ngo et al., reporting stronger bonding between the hard tissue of tooth and cement matrix in comparison to the strength between cement matrix and glass particles [22] as confirmed by Ref.'s [6,16]. Moreover, pretreatment with phosphoric acid before the use of RMGI cements provide a clinical advantage since no enamel damage during debonding is faced. Furthermore, in case of accidental bracket debonding, cement remnant attached to the conditioned tooth surface still releases fluoride [21].

Factors may contribute to bracket failures are: bracket type, the method and the equipment/tools used for debonding and the location of force exertion. Applying force to the bracket wings increases the risk of bracket failure [23]. One of the difficulties with the ceramic brackets is the high possibility of breakage at debonding. Containment of this weakness is a long time concern. Most manufacturers offer a debonding plier, specific to their product to take most the advantage of their owned engineered technique embodied into the bracket. Alternatively, heating by thermal or laser instruments may be applied to weaken the adhesive before debonding; this method has not been widely adopted due to the possible pulp damage if the heat is not controlled precisely [24]. Arici et al. [9] has suggested the presence of archwire at the time of steel brackets debonding as a safety factor.

This idea of using wire may also be useful in ceramic brackets debonding, as it maintains the integrity of the bracket. In our study, debondings were conducted with and without using full dimension wire. No cases of bracket failure during debonding in either cases were observed, the same as Mirzakouchaki et al. [23] research. Because of the safe debonding in both cases, due to the quality of ceramic brackets, basically using wire was not fully justified.

Future studies should be conducted to evaluate the effect of time elapse on the materials characteristics and effectiveness in clinical conditions.

5. CONCLUSION

1. RMGIC is as effective as light cured composite resins in bonding ceramic brackets.
2. Incorporating 5% NHA in RMGIC is an effective way to enhance its characteristics.
3. By further increasing the concentration of NHA in RMGIC, the bond strength may decrease.

4. All debondings were conducted safely even without using wire.

ACKNOWLEDGEMENTS

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Pithon MM, Dos Santos RL, Oliveira MV, Ruellas AC, Romano FL. Metallic brackets bonded with resin-reinforced glass ionomer cements under different enamel conditions. Angle Orthodontist. 2006;76(4):700–4.
2. Pereira TB, Jansen WC, Pithon MM, Souki BQ, Tanaka OM, Oliveira DD. Effects of enamel deproteinization on bracket bonding with conventional and resin-modified glass ionomer cements. Eur J Orthod. 2013;35(4):442-6.
3. Rix D, Foley TF, Mamandras A. Comparison of bond strength of three adhesives: composite resin, hybrid GIC and glass-filled GIC. American Journal of Orthodontics and Dentofacial Orthopedics. 2001;119(1):36–42.
4. Arcís RW, López-Macipe A, Toledano M, Osorio E, Rodríguez-Clemente R, Murtra J, et al. Mechanical properties of visible light-cured resins reinforced with hydroxyapatite for dental restoration. Dent Mater. 2002;18(1):49-57.
5. Domingo C, Arcís RW, López-Macipe A, Osorio R, Rodríguez-Clemente R, Murtra J, et al. Dental composites reinforced with hydroxyapatite: mechanical behavior and absorption/elution characteristics. J Biomed Mater Res. 2001;56(2):297-305.
6. Lee JJ, Lee YK, Choi BJ, Lee JH, Choi HJ, Son HK, et al. Physical properties of resin-reinforced glass ionomer cement modified with micro and Nano-hydroxyapatite. J Nanosci Nanotechnol. 2010;10(8):5270-6.
7. Huang M, Feng J, Wang J, Zhang X, Li Y, Yan Y. Synthesis and characterization of nano-HA/PA66 composites. J Mater Sci Mater Med. 2003;14(7):655-60.
8. Carvalho RCC, Carvalho NMP, Herênio SS, Oliveira Bauer JR, Paiva AEM, Costa JF, et al. Evaluation of shear bond strength of orthodontic resin and RMGI cement on bonding of metal and ceramic brackets. RSBO. 2012;9(2):170-6.
9. Arici S, Minors C. The force levels required to mechanically debond ceramic brackets: an in vitro comparative study. European Journal of Orthodontics. 2000;22(3);327-34.
10. Pseiner BC, Freudenthaler J, Jonke E, Bantleon HP. Shear bond strength of fluoride-releasing orthodontic bonding and composite materials. Eur J Orthod. 2010;32(3):268-73.
11. Larmour CJ, Mccabe JF, Gordon PH. An ex vivo assessment of resin-modified glass ionomer bonding systems in relation to ceramic bracket debond. Journal of orthodontics. 2000;27(4):329-32.
12. Cheng HY, Chen CH, Li CL, Tsai HH, Chou TH, Wang WN. Bond strength of orthodontic light-cured resin-modified glass ionomer cement. Eur J Orthod. 2011;33(2):180-4.
13. Valente RM, De Rijk WG, Drummond JL, Evans CA. Etching conditions for resin-modified glass ionomer cement for orthodontic brackets. Am J Orthod Dentofacial Orthop. 2002;121(5):516-20.

14. Lucas ME, Arita K, Nishino M. Toughness, bonding and fluoride-release properties of hydroxyapatite-added glass ionomer cement. Biomaterials. 2003;24(21):3787-94.
15. Moshaverinia A, Ansari S, Movasaghi Z, Billington RW, Darr JA, Rehman IU. Modification of conventional glass-ionomer cements with N-vinylpyrrolidone containing polyacids, nano-hydroxy and fluoroapatite to improve mechanical properties. Dent Mater. 2008;24(10):1381-90.
16. Moshaverinia A, Ansari S, Moshaverinia M, Roohpour N, Darr JA, Rehman I. Effects of incorporation of hydroxyapatite and fluoroapatite Nano-bioceramics into conventional glass ionomer cements (GIC). Acta Biomater. 2008;4(2):432-40.
17. Santos C, Clarke RL, Braden M, Guition F, Davy KWM. Water absorption characteristics of dental composite incorporating hydroxyaptite filler. Biomat. 2002;23(8):1897-1904.
18. Sadat-Shojai M, Atai M, Nodehi A, Nasiri Khanlar L. Hydroxyapatite nanorods as novel fillers for improving the properties of dental adhesives: Synthesis and application. Dent Mater. 2010;26(5):471-82.
19. Sfondrini MF, Cacciafesta V, Pistorio A, Sfondrini G. Effects of conventional and high-intensity light-curing on enamel shear bond strength of composite resin and resin-modified glass-ionomer. American Journal of Orthodontics and Dentofacial Orthopedics. 2001;119(1):30–5.
20. Shammaa I, Ngan P, Kim H, Kao E, Gladwin M, Gunel E, et al. Comparison of bracket debonding force between two conventional resin adhesives and a Resin-reinforced glass ionomer cement: an *In vitro* and *In vivo* study. Angle Orthod. 1999;69(5):463-9.
21. Maruo IT, Godoy-Bezerra J, Saga AY, Tanaka OM, Maruo H, Camargo ES. Effect of etching and light-curing time on the shear bond strength of a Resin-modified glass ionomer cement. Braz Dent J. 2010;21(6):533-7.
22. Ngo H, Mount GJ, Peters MC. A study of glass-ionomer cement and its interface with enamel and dentin using a low-temperature, high-resolution scanning electron microscopic technique. Quintessence Int. 1997;28(1):63-9.
23. Mirzakouchaki B, Kimyai S, XHydari M, Shahrbaf S, Mirzakouchaki-Boroujeni P. Effect of self-etching primer/adhesive and conventional bonding on the shear bond strength in metallic and ceramic brackets. Med Oral Patol Oral Cir Bucal. 2012;17(1):164-70.
24. Proffit WR, Fields HW, Sarver DM, Ackerman JL. Contemporary Orthodontics. 5th ed. Mosby. Elsevier, Canada; 2013.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=419&id=32&aid=3502