Original Article

Effect of Nano-Hydroxyapatite Incorporation into Resin Modified Glass Ionomer Cement on Ceramic Bracket Debonding

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Abstract

Background and Aim: Preventing enamel demineralization around brackets is a concern for orthodontists. Fluoride releasing materials have been recommended to overcome this problem. The aim of this study was to evaluate the effect of incorporating nano-hydroxyapatite (NHA) into resin modified glass ionomer cements (RMGIC) on ceramic bracket debonding.

Materials and Methods: In this experimental study, 80 human premolars were divided into 4 bonding groups as follows: group 1: Transbond XT (TBXT) (control group), group 2: Fuji II LC (RMGIC), group 3: 5% NHA added to RMGIC and group 4 10% NHA added to RMGIC. After enamel etching, ceramic brackets were bonded. The shear bond strength (SBS) and the adhesive remnant index (ARI) were calculated for each group. The data were analyzed using one-way ANOVA, Tukey's post hoc HSD test and the Kruskal Wallis test.

Results: According to ANOVA, 10% NHA added to RMGIC had a significantly lower SBS compared to other groups (11.93±2.11) but no significant difference was found among the remaining groups. The mean SBS was 17.33±4.07 MPa in group 1, 17.22±3.55 MPa in group 2 and 16.56±2.59 MPa in group 3. According to ARI, the predominant failure mode in RMGIC groups was cohesive.

Conclusion: Resin modified glass ionomer cements containing 5% NHA can be as effective as composite resins for bonding ceramic brackets.

Key Words: Resin modified glass ionomer cement, Nano-hydroxyapatite, Ceramic brackets

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Received: 1 Dec 2013
Accepted: 15 May 2014

Introduction

Glass ionomer cements (GICs) were first introduced by Wilson and Kent in 1972 as the esthetic restorative material of choice for the anterior teeth [1]. In addition to their biocompatibility with enamel and dentin, these cements have cariostatic properties; the fluoride ions in their composition initiate the process of remineralization. However, the bond strength of these cements is clinically low [1-2].

Resin-modified glass ionomer cements were introduced to enhance fluoride release and improve the bond strength [3]. Different fillers including the silver cements, stainless steel powder, aluminosilicate and carbon fibers and also hydroxyapatite (HA) have been used to improve the properties of glass ionomers. The HA is the main mineral compound in the structure of teeth and bone. Its small particle size, similar to other minerals in the tooth structure, confers increased surface area and high solubility [4, 5]. The NHA, due to high solubility, can efficiently fill the micro-pores present in ena-

mel defects by releasing inorganic ions like calcium and phosphate, increase resistance to demineralization and improve the bond strength of restorative materials to tooth [6].

Ceramic brackets have been available for use in the clinical setting since 1987. These brackets have superior esthetic properties and durability similar to that of stainless steel brackets. However, increased risk of enamel fracture during debonding has limited their application [7].

The purpose of the current study was to evaluate the effect of incorporation of NHA on the SBS of RMGIC in comparison with light-cured orthodontic composite resin at the time of debonding of ceramic brackets.

Materials and Methods

This experimental study evaluated 80 sound premolar teeth extracted for orthodontic purposes. After cleaning, the teeth were stored in distilled water at room temperature. The teeth were randomly divided into four groups (n=20). To bond brackets, the buccal surface of teeth in all groups was etched with 37% phosphoric acid for 30 seconds and then Illusion® Plus^{TM} ceramic brackets (Ortho Organizer, USA) were bonded to the center of the buccal surface of the teeth using the following bonding systems according to the manufacturers' instructions. The understudy materials are summarized in Table 1. The bonding groups were as follows:

Group 1. Transbond XT (TBXT) (3M, St. Paul, MN, USA)

Group 2. Fuji II LC cement (RMGIC) (GC Corp., Tokyo, Japan)

Group 3. Fuji II LC cement (GC Corp., Tokyo, Japan) containing 5% NHA

Group 4. Fuji II LC cement (GC Corp., Tokyo, Japan) containing 10% NHA

In group 1, TBXT primer (3M, St. Paul, MN, USA) was applied. In groups 2, 3 and 4, the powder and the liquid were mixed according to the manufacturer's instructions. After placement of brackets, the excess adhesive was removed and light curing was performed using LED light curing unit (L.E. Demetron, SDS Kerr, USA) for 40s. The teeth were stored in distilled water containing 0.5% Chloramine T (Chloramine T Trihydrate, Merck Corp., Germany) in an incubator at 37°C for one week. To assess bond strength, the teeth were mounted and the shear bond strength was assessed using the Instron Universal Testing Machine (Zwick, Roell, Germany) at a cross head speed of 1mm/min by application of shear load [8]. The shear load was applied by a flat-end, chisel-shaped rod with 0.5mm cutting blade. The load was applied close to the bracket-tooth interface and the fracture load was recorded. Using the Test Xpert V. 11.0 software (Zwick, Roell, Germany), the fracture load was calculated in MPa by dividing the shear load by the surface area of the bracket base. After debonding, the fracture surfaces were evaluated under a light stereomicroscope at 10X magnification. The mode of fracture, and the ARI according to Artun and Bergland in 1984 [2, 8], were determined and scored as follows:

0.No adhesive remained on the tooth surface

1.Less than 50% of the adhesive remains on the tooth surface

2.More than 50% of the adhesive remains on the tooth surface

3.The entire adhesive remains on the tooth surface

Bond strength in the four groups was evaluated using one-way ANOVA and Tukey's post-hoc HSD test. The Kruskal Wallis test was applied to assess significant differences in ARI between groups. All statistical analyses were carried out using SPSS version 18.

Results

The bond strength values (MPa) and the results of statistical tests are shown in Table 2. The results of ANOVA revealed statistically significant differences among groups.

The bond strength in group 4 was significantly less than that of other groups ($p<0.001$). But, no significant difference existed among other groups in this regard ($p>0.05$). The ARI of the fracture surfaces is shown in Table 3. The Kruskal Wallis test revealed a significant difference among study groups ($p<0.001$). The mode of fracture in group 1 was predominantly adhesive; while in other groups, cohesive failures had the highest frequency (most bonding material remained on the enamel).

Table 1. Materials used in the current study

Material	Manufacturing company	Chemical composition
Fuji II LC	GC Corporation Hasunuma-cho, Itabashi-ku, Tokyo 174-8585, Japan	Powder: Fluoro-Alumino-Silicate glass Liquid: Polyacrylic acid, 2-Hydroxyethyl methacrylate (HEMA), Dimethacrylate, Camphorquinone, Water
Transbond XT	3M Unitek Orthodontic Products 2724 South Peck Road Monrovia, CA 91016 USA	Adhesive paste: Silica, BIS-GMA, Silane, N-dimethyl benzocaine, Hexa-fluoro-phosphate
Illusion® Plus™ Ceramic Bracket	Ortho organizer 1822 Aston Avenue, Carlsbad, CA 92008,USA	Purest Polycrystalline, 99% Alumina
Hydroxy appatite Nano P	Nanoshel Washington, USA	Ca5(OH) (PO4)3

Table 2. The mean and standard deviation of the shear bond strength values

Material	Number	Minimum	Maximum	Mean± SD
Transbond XT	20	11/02	25/60	17/33±4/07
RMGIC	20	9/51	22/20	17/22±3/55
5% NHA	20	11/40	20/77	16/56±2/59
10% NHA	20	6/87	16/31	11/93±2/11*

***Indicates statistically significant difference (P<0.05)**

Table 3. The frequency distribution of mode of failure according to the ARI

Material/ ARI	0	1	2	3
Transbond XT*	0	16	3	1
RMGI	0	7	6	7
5% NHA	0	5	6	9
10% NHA	1	3	10	6

***Indicates statistically significant difference (P<0.05)**

Discussion

Enamel demineralization and the adhesive bond strength are the two main controversial topics in orthodontic treatment. Glass ionomer cements can be efficiently used in humid environments due to their special chemical composition that requires moisture for setting. Also, these cements are biocompatible and release fluoride. Thus, they are often suggested for use in areas of the oral cavity where isolation is difficult to achieve (second molars, surgically exposed teeth or the lingual surface of the mandibular teeth) [6, 9]. Previous studies demonstrated that addition of NHA to GIC increased resistance to demineralization [6, 10, 11].

Due to small particle size, NHA can deposit on the demineralized enamel. Moreover, high solubility of NHA results in efficient release of calcium and phosphate ions that fill the micro-pores [12]. Penetration of inorganic ions and HA particles into th e demineralized tooth surface prevents the wash-off of calcium ions released from the enamel surface; thus, resistance to demineralization increases [6].

In terms of SBS, GICs chemically bond to enamel and dentin and have a coefficient of thermal expansion similar to that of tooth structure. Their mechanism of chemical bonding has yet to be fully understood; but, one suggested mechanism is the formation of ionic bonds between polyalkenoic acid and HA crystals of the tooth. However, they have poor mechanical properties including low fracture and compressive and tensile strengths [6]. Attempts have been made to enhance the mechanical properties and improve the cariostatic activity of these cements. Recent studies have focused on the effect of incorporation of HA particles on the properties of GICs. Lucas et al. demonstrated that addition of 8% HA to GIC did not have a destruc-

tive effect on its bond strength to dentin and this compound released fluoride continuously for 13 weeks [10]. Golcar et al. investigated the effect of incorporation of NHA particles on the mechanical properties of RMGIC. They demonstrated that addition of 5% NHA to RMGIC significantly improved its flexural strength and modulus of elasticity [13]. A few other studies have also confiremd such improvement in bond strength [6, 10, 11, 14, 15]. Our study showed that addition of 5% NHA to RMGIC had no negative impact on bond strength yielding the same SBS as in the control group. But, addition of 10% NHA decreased the bond strength. Santos et al. evaluated the water sorption properties of dental composites containing HA fillers. They showed that the water sorption of filler-containing specimens was higher than that obtained for the base resin. This increase may be related to the presence of porosities and filler particles in the internal structure of composite [16]. It appears that by increasing the percentage of NHA, aggregation of filler particles and the porosities increase. These components play a role in water sorption because they are loosely placed in the matrix and thus, excess water can penetrate between them and the matrix and eventually decrease the bonding properties.

In our study, no significant difference was noted in the SBS of conventional composite resin and RMGIC. Similar results have also been reported previously [9, 17]. However, Sfondrini et al. demonstrated that if etching is not performed prior to the use of RMGIC, the resultant SBS would be lower than that of conventional composite resins. This finding has also been confirmed by some other studies [7, 17-19].

Several researchers have recommended enamel treatment before the application of RMGICs [8, 9]. Valente et al. investigated the effects of different concentrations of acid etchant on the tensile bond strength of RMGICs at the time of bonding of orthodontic attachments. They reported that RMGIC can efficiently bond to etched enamel; but, no significant difference was noted in tensile bond strength after using 10-37% phosphoric acid and 10% polyacrylic acid prior to the application of RMGIC (9). Based on these results, it may be concluded that etching prior to the use of RMGIC can effectively improve the characteristics of the bond.

Based on the obtained ARI scores, the fracture surfaces in RMGIC and RMGIC+ 5% NHA mostly showed ARIs 1 and 2; whereas, 80% of the TBXT specimens showed ARI 1 and 50% of RMGIC + 10% NHA showed ARI 2. The mode of bond failure is influenced by several confounders including the direction of the load applied, enamel treatment, type of adhesive and type of bracket [20].

The results of the current study revealed that when TBXT was used as the adhesive for bonding, the adhesive mainly remained on the bracket. Previous studies have also confirmed this finding [17, 19, 20]. This result is in contrast to that of de Carvalho et al, who reported that the highest number of fractures occurred at the bracket-adhesive interface when TBXT was used [7]. In the remaining groups containing RMGIC, the mode of fracture was dominantly cohesive. This result is in line with that of Ngo et al; they discussed that the bond strength between tooth and cement was higher than the bond strength between cement matrix and glass particles [21]. Other studies have also confiremd this result [6, 14]. Moreover, enamel treatment with phosphoric acid prior to the application of RMGIC is a clinical advantage; because no enamel damage occurs during debonding and in cases of accidental debonding, cement remains attached to the conditioned tooth surface and continues to release fluoride [22].

In the current study, no case of bracket fracture was seen. Mirzakouchaki et al. reported similar results [23]. Type of bracket, method and instruments used for debonding and the site of load application are among the factors playing a role in bracket fracture. Load application to bracket wings increases the risk of bracket fracture [23].

Future studies are required to focus on the effect of time on the properties of materials. The efficacy of these materials in the clinical setting must also be evaluated.

Conclusion

1.RMGICs can be as effective as the light-cured composite resins for bonding of ceramic brackets

2.Incorporation of 5% NHA into RMGIC is an effective method to improve the cement properties.

3.Further increase in the concentration of NHA added to the cement decreases the bond strength.

4.The fracture mode in the RMGIC and groups containing NHA was dominantly cohesive.

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