Original Article

Evaluating the effect of adding 10-MDP to resin-modified glass ionomer on its dentin bond strength and fluoride release

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Abstract

Purpose: The aim of this study was to evaluate the effect of adding 10-MDP to resin-modified glass ionomer on its dentin bond strength and fluoride release.

Keywords: Resin-modified glass ionomer, 10-MDP, bond strength, fluoride release.

Materials and Methods

The occlusal surfaces of thirty caries-free human third molars were ground flat to expose dentin and randomly divided into three groups (n=10) according to different concentrations of 10-MDP used with RMGI. Group 1: (RMGI+0% vol 10MDP), group2: (RMGI+ 5% 10MDP) and group3: (RMGI+10% 10MDP). In each group a cylinder of modified RMGI was bonded on each flat surface. Shear bond strength test was carried out using the universal testing machine (1 mm/min). The mode of failures was examined using a stereo microscope. Five disc-shaped samples were prepared from each group and the amount of fluoride released was measured on days 1, 7, 14 and 28 using a specific fluoride ion electrode. The data were analyzed by one-way and repeated measures ANOVA, Tukey and LSD tests (α = 0.05).

Results

Shear bond strength in the RMGI + 10% 10-MDP group was significantly higher than that in the control group ($P<0.05$). There was a significant difference in the amount of fluoride released in the three groups on days 7, 14 and 28, which was higher in the control group than other groups.

Conclusion

The addition of 10% vol of 10-MDP to the resin-modified glass ionomer significantly improves its dentin bond strength, although its long-term fluoride release is lower than conventional RMGI.

Introduction

Glass ionomers are one of the dental materials that were introduced in 1972 [1]. Advantages such as biocompatibility, chemical adhesion, fluoride release, thermal expansion coefficients similar to that of tooth, and the absence of shrinkage during polymerization have made glass ionomers one of the most important restorative materials [3]. However, disadvantages such as low bond strength to tooth, long setting time, dehydration during the initial setting, rough surface texture, and low initial strength limit their widespread clinical use [4].
Resin-modified glass ionomers (RMGI) are a hybrid of glass ionomer and composite resin [2] that were first introduced in 1989 by adding a small amount of light-activated resin to overcome the disadvantages of traditional glass ionomers. [5]. These materials, along with the desirable properties of conventional glass ionomers such as chemical bonding to tooth structure and fluoride release, have more benefits, including: decreased setting time, having higher initial strength, being more durable and improved appearance [7].
Adhesion of the RMGI to dental hard tissues occurs through 2 different mechanisms:
1) a chemical bonding between polyalkenoic acid chains and calcium ions in hydroxyapatite,
2) a micro-mechanical retention by the infiltration of the organic components into a partially demineralized dentin surface created by the self-etching characteristic of RMGIC [8].
Various studies have recommended different methods of improving RMGI bonding to dental tissues, most of

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which involve surface pretreatment prior to the application of glass ionomer. Previous studies concluded that the use of a polyacrylic-acid conditioner before the application of RMGIC provided stronger dentin bond strength. It cleans the surface, generates micro-porosities and improve the micromechanical bond, as well as react chemically with hydroxyapatite on the tooth surface [9,10]. Although, Surface conditioning especially with polyacrylic acid, is an accepted method, it has not found widespread clinical use because of adding more steps to the clinical procedure.

Some studies that evaluated chemical bond using X-ray have shown that the ionic bond between some functional resin monomers and calcium ions on the tooth surface may be stronger than the hydrogen and van der Waals bonds due to the mechanical integration of collagen fibrils by resin polymerization [11,12].

The most common functional monomers used in commercial adhesives are phosphate monomers such as 10-MDP and Phenyl-P [13], which react chemically with hydroxyapatite [14]. The 10-MDP monomer etches surface due to the presence of hydrogen phosphate groups that form two cationic waters [15]. The ionic bond formed with 10-MDP is stable in aqueous media. Compared to 4-META and Phenyl-P, 10-MDP is considered to be the best monomer for chemical bonding to dentin and enamel hydroxyapatite [16,17].

The use of functional monomers in bonding has become common today and has greatly reduced the limitations of dentin bonding. Their improved performance has been reported in various studies.

Yoshida et al. (2004) conducted a comparative study on the performance of functional adhesives and concluded that 10-MDP reacted with hydroxyapatite and the bond appeared to be very stable [18]. Another study (2005) on the hydrolytic stability of self-etched adhesives bonding to dentin found that the bond strength of adhesives containing 10-MDP did not decrease after thermocycling [19]. Li et al. (2010) also stated in their study that the interface formed with adhesive systems containing 10-MDP remained stable after acid and base changes [14]. Therefore, the aim of this study was to evaluate the effect of adding 10-MDP to resin-modified glass ionomer on its bond strength and fluoride release. The null hypothesis was that the addition of 10-MDP to the resin-modified glass ionomer has no effect on bond strength and fluoride release.

Materials and Methods

This study was approved by local Ethics committee of school of dentistry Mashhad university, Iran with code IR.MUMS.DENTISTRY.REC.1397.020. Thirty human third molars without crack, decay or previous restoration were obtained and stored in 0.5% chloramine T solution until use. Using periodontal scaler debris and inorganic remnants were cleaned. To obtain a smooth dentin surface, the teeth were horizontally cut from 1.5 mm of their occlusal surface's central groove, by a water-cooled diamond saw. They were embedded in a self-cure acrylic resin vertically till cementoenamel junction.

The teeth surface was abraded by paper discs up to 600 grits, to create a smear layer. An alcoholic solution of 10-MDP (Watson International, China) was mixed with RMGI liquid in a volume ratio of 5% and 10%, which were used for testing. The teeth were randomly divided into three groups(n=10):

Group 1: RMGI standard (Fuji II LC GC Inc., Tokyo, Japan). This group was classified control group.

Group 2: RMGI involving 5% volume of 10-MDP monomer.

Group 3: RMGI involving 10% volume of 10-MDP monomer.

For placing the material on teeth, a tygon tube with an inner diameter of 1.5 mm and a height of 2mm was placed on dentin surface next to DEJ. In each group, the material was placed inside the tube and cured from the occlusal surface for 20 seconds by Bluephase light cure device (Ivoclarvivadent. Schaan, Liechtenstein) at an intensity of 1200 mw/cm^2. After removing the tube with a razor blade, the samples were incubated at 37 °C and 100% humidity for 24 hours. Then the samples were examined with a 10x magnification microscope (XTL-ST2FF,Blue light USA) and those which had cracks, bubbles and defects were replaced with new ones.

The shear bond strength test was carried out using a universal testing machine (Santam, STM 20, Tehran, Iran) at a speed of 1 mm/min. For this purpose, each tooth was placed in device, and a force perpendicular to the junction of RMGI and tooth was applied using the device's chisel until the samples were separated from the tooth. The amount of force through fracture was recorded. After the test, the failure mode of each sample was determined under stereoscopic microscope.

To evaluate fluoride release, five disc-shaped samples (3*10mm) of each material were divided into 3 groups, each of them was placed in a sealed plastic container with 7 ml of double distilled water.

All samples were kept in an incubator at 37°C during the study and released fluoride amount was measured on days 1, 7, 14, and 28. Prior to each measurement, the samples were removed from the container and were washed twice with 1 ml of distilled water. Then this water was added to previous solution, and the samples were transferred to a new container of fresh solution. 7 ml of solution for each sample, along with 1 ml of water used for washing, was mixed with 4 ml of TISAB II buffer solution and examined for released fluoride amount. A potentiometer measured Fluoride releases. The electrode (WTW, Multi 9420, Germany) was immersed in solution for measurement, while the container was shaken to achieve a uniform dispersion of fluoride ions in solution. The number was recorded as soluble fluoride amount in ppm. At last, fluoride released in each period was determined in mg/cm^2.

Statistical analysis

Shapiro-Wilk test was used to determine normal distribution of data. One factor analysis of variance as well as Tukey test were used to analyze the data obtained from bond strength assessment. Variance analysis for repeated measures, as well as LSD, was used to assess the fluoride release. The significance level was set to 0.05.

Results

Based on the results, the mean shear bond strength in the group 3 (10% 10-MDP monomer) was higher than other groups, and it was significantly different from the control group (P<0/05). There was no significant difference between the control group and the group 2 in terms

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of bond strength. The mean shear bond strength values of all groups and the standard deviations are presented in Table 1. The frequency of failure modes in each group are shown in Table 2. Most failures were recorded as adhesive failures.
According to the results, fluoride release was higher in the control group than the other two groups on all days. There was no significant difference between the three groups in terms of fluoride release on the first day ($p>0.05$). On days 7,14 and 28, the difference between the control group and the other groups was significant ($p<0.05$) , while there was no significant difference between group1 and group2($p<0.05$). The fluoride release chart for all groups is shown in Figure 1.

Table 1. Mean bond strengths (standard deviation) in MPa for different materials. (a Means followed by different lowercase letters are significantly different by Tukey test at 5% confidence level.)

GROUP	MEAN (SD)
RMGI	6.43 (2/12)a
RMGI + 5% 10-MDP	7.40 (1/78)ab
RMGI + 10% 10-MDP	9.57 (2/65)b

Discussion

The results of the present study showed that the addition of 10-MDP monomer by 5% and 10% volumes to RMGI increases its bond strength to human dentin. There was a significant difference between the 10% volume group and the control group, while the different between the 5% volume group and the control group was not significant. In terms of fluoride release, the amount was higher in the control group than that in the other two groups. This difference was not significant on the first day, while it was significant on days 7, 14 and 28. Therefore, the null hypothesis of the study was rejected and Addition of 10-MDP to RMGI increases bond strength and decreases fluoride release.
The ability to chemically bond with specific chemical monomers including 10-MDP with hydroxyapatite has been demonstrated [20].10-MDP forms an electrostatic bond with hydroxyapatite, which results in a long-term stable bond [21].Yoshihara et al. found that the bond between this monomer and hydroxyapatite was accompanied by a self-assembled Nano-layering feature. XRD and high-resolution TEMs of hydroxyapatite crystals attached to 10- MDP showed the formation of a 4nm layer, each layer of which contained two 10-MDP molecules with their methacrylate heads facing each other and their functional hydrogen phosphate groups were far apart and deposition of the Calcium salts between these layers hold them together [22]. This Nano-layering property

Table 2. Frequency of failure mode.

GROUP	ADHESIVE	COHESIVE	MIXED
RMGI	10	0	0
RMGI + 5% 10-MDP	9	1	0
RMGI + 10% 10-MDP	8	2	0

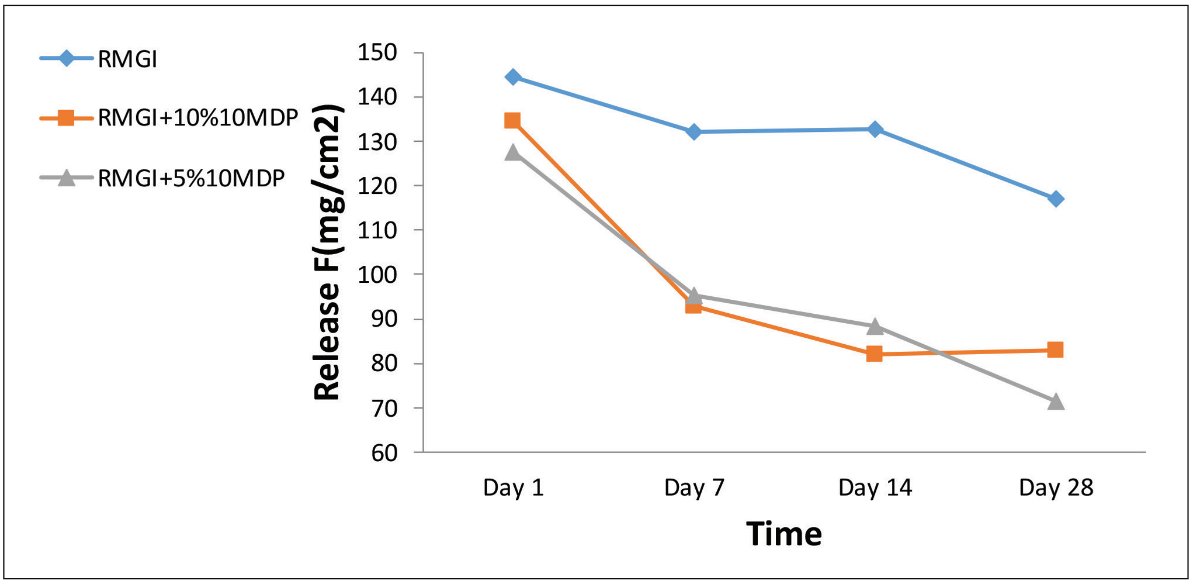

Figure 1. Fluoride release of different materials on different days

has not been observed in other functional monomers such as 4-MET and Phenyl-P and other experimental phosphate monomers [21].

Since phosphate ester monomers contain methacryloxy functional groups, they can also support the adhesion of methacrylate-based resins to the tooth structure [21,23,24]. Therefore, there is a growing interest in developing of new phosphate ester monomers for use in restorative dentistry.

The beneficial effect of functional monomers on bonding, especially universal and self-etch bonds, has been proven. Cristina et al. reported that universal Scotch bond provides acceptable bonding performance due to the presence of 10-MDP monomer, which is an acidic monomer that stimulates demineralization and infiltration of monomers and chemically establishes bonds with the mineral tissue of the tooth. Scotchbond also contains a polyalkenoic acid polymer (Vitrebond™ Copolymer) and is in fact a glass ionomer-based bonding which, according to the manufacturer, provides a satisfactory bond to dentin in dry and humid environments [25,26].

Adper™ Easy Bond Self-Etch Adhesive is also a universal glass ionomer-based bonding that utilizes the methacryloxyhexyl phosphate (MHP) functional monomer. Functional monomers such as 4-MET, Phenyl-P, MHP, etc. are rapidly developing. However, the 10-MDP monomer is still better than others and offers more desirable properties because it has a longer carbon chain compared to others, particularly MHP. Therefore, in addition to its relatively strong etching effect, it produces more stable calcium-monomer salts or nanolayer[27].

Hajizadeh et al. showed that surface etching can improve the glass ionomer bond to dentin[10]. The capability of 10-MDP in surface etching in addition to the chemical bond could be another reason for its effectiveness in improving the glass ionomer bond to the teeth in this study. A recent study reported that the most effective 10-MDP concentration range for optimal reaction between 10-MDP and hydroxyapatite is 5-10% [24]. In the study by Yoshihara, concentrations of 1, 3 and 5% of 10-MDP monomer showed a low nano layering intensity, which in the case of 1% fell below the limit detectable by XRD [21]. In our study, the bond strength of RMGI containing 5% 10-MDP monomer was less than 10% concentration of this monomer. In addition, we initially had a group with a concentration of 20%. However, we excluded it from the study due to unsatisfactory results. This could be because the 10-MDP monomer is a viscose monomer and its presence in high amounts can reduce the penetration of adhesive into the tooth surface [28].

In this study, we also examined the rate of fluoride release from RMGI. In fact, fluoride release is an important feature of glass ionomers [29]. Since it can promote the formation of fluoroapatite on the tooth surface [30,31].

Resin-modified glass ionomer has less fluoride release than conventional glass ionomer due to the presence of HEMA, so it is expected that the addition of 10-MDP monomer will also affect fluoride release. In this study, the rate of fluoride release in groups containing 10-MDP was lower than that in the control group

Furthermore, the major fractures in this study were of the adhesive type. There are two possible reasons for this. First, although the bond strength was increased by adding 10-MDP, it was still far from the bond strength of composites. Second, the addition of 10-MDP also increased the bond strength of the material itself, just as the flexural strength of an RMGI is almost twice than that of conventional glass ionomer due to the addition of the HEMA resin monomer, therefore the cohesive fracture was rare.

Since this study was primarily performed in the laboratory, it is recommended that RMGI with 10-MDP be tested in clinical trials for more reliable results. It is also recommended in future studies to check the strength of the material itself to make sure that the internal strength of RMGI is improved by adding 10-MDP.Furthermore, because the 10-MDP monomer creates a stable bond to dentin, we also suggest investigating the durability of the RMGI bond to dentin in future studies.

Conclusion

The present study showed that the addition of 10% volume of 10-MDP to the resin-modified glass ionomer significantly improved its dentin bond strength, although its long-term fluoride release is less than that of conventional RMGI.

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