Shear Bond Strength of Resin-Modified Glass Ionomer Cement as a Result of Enamel Surface Modifications

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Abstract

Objectives: To determine the mean shear bond strength (SBS) of metallic brackets bonded with Resin Modified Glass Ionomer Cement (RMGIC) after deproteinization by using sodium hypochlorite, 5.25% (NaOCl) prior to acid etching.

Methods: The Department of Orthodontics conducted an in vitro experimental study over a period of 2 months. Eighty healthy and fully developed human premolars were randomly allocated into group A and B. Group A teeth were treated with sodium hypochlorite, 5.25% for 1 minute before phosphoric acid, H_3PO_4 (37%) etching and moistened with water, then brackets were bonded using RMGIC as an adhesive material. In Group B, the teeth were treated with H_3PO_4 (37%) only and the brackets bonded directly with RMGIC. The SBS was measured in both groups.

Results: There was a significant difference between the mean shear bond strength (SBS) between the two groups. After deproteinization, it was higher (significant) in group A (11.33) than in group B (6.53) [Mean difference =4.80±0.95; p=0.0005].

Conclusion: Deproteinization with NaOCl (5.25%) for 1min before Phosphoric acid (37%) etching results in significantly higher shear bond strength with RMGIC. Therefore, deproteinization can save chairside time that might get wasted due to frequent debonding of brackets.

Key Words: Bracket Bonding, Deproteinization, RMGIC, Sodium hypochlorite (NaOCl), Shear bond strength.

Introduction

Orthodontic treatment requires a longer span of time and is considered successful if an orthodontist achieve acceptable occlusal relations in minimum time. [1] However, it is inevitable to avoid bond failure which is one of the prime contributory factors of prolonged treatment duration. Bond failure mostly results from moisture contamination, as the blood and saliva obstruct adhesive penetration. [2,3]

RMGIC is a moisture insensitive cement ideally used for bonding in patients with poor oral hygiene. Moreover, it releases fluoride and has a certain degree of anti-cariogenic effect.[4,5,6] This property of RMGIC gives an added advantage of decreasing white spot lesion which have shown to increase by almost 50 % in patients undergoing fixed orthodontic treatment.[7] Despite these properties, it is not preferred by orthodontists as a primary bonding material due to its low shear bond strength (SBS).[8]

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RMGIC has a SBS of approximately 5.71 MPa, which is lower than the ideal value.[8] Bishara et al. considered that the initial SBS of RMGIC is too low for an arch wire to be placed on the first appointment, thus its use might lead to repeated debonding and increase in chairside time.[9] Various enamel conditioning techniques are being developed by orthodontists to increase the retentive properties of RMGIC.[10] Deproteinization is one such non-invasive technique, which not only removes the outer organic layer and acquired pellicle from the tooth,[11] but also helps to improve the SBS of RMGIC.[12,13] Deproteinization is frequently used in endodontic procedures[14] and has been recently introduced in orthodontics by Justus et al. Their study concluded that deproteinization resulted in an increase in SBS of RMGIC to 9.64± 5.01 MPa [8,15]. This technique was also found to be effective before bonding a flourosed tooth by Rekha et al.[1]

Considering the limited data available in this context, this study was designed to assess the effect of deproteinization on the SBS of RMGIC while using metallic brackets. The null hypothesis of the study states that there is no difference in SBS of RMGIC after deproteinization by using sodium hypochlorite, 5.25% (NaOCl) prior to acid etching. The results of the study will add to the existing body of knowledge and will facilitate orthodontists to take informed decisions in conditions where RMGIC is the material of choice.

Materials and Methods

The Department of Orthodontics, Lahore Medical and Dental College (LMDC), conducted an in vitro experimental study from 8th January 2025 to 3rd March 2025 after obtaining permission from the Ethical Review Board (ERB) of the college FD/5507/25.The sample size (80 teeth ;40 per group) was calculated by assuming the power of the t-test to be 80% and a level of significance of 5%, with expected mean bond strength in group A of 13.86±4.41 and group B of 17±5.37.[8] A consecutive non-probability sampling technique was employed to collect the sample.

Caries free, healthy and fully developed teeth of patients of any gender between the ages of 15 to 25 years were included in the study. Previously bonded, restored and hypo mineralized/hypocalcified teeth were excluded from the study.[14] Eighty human premolars extracted before orthodontic treatment (therapeutic extractions), were collected from the OMFS, Oral and Maxillofacial Surgery Department, LMDC, and were randomly assigned to the two groups.

After extraction, the teeth were cleaned and soft tissues were removed and stored in normal saline till the start of the study. The tooth roots were embedded in self-cure acrylic cylindrical blocks measuring 20x20x20 mm to standardize the tooth preparations.[8,13] Each tooth's buccal surface was also kept perpendicular to the base of the acrylic block for ease of handling of tooth at the time of testing. Teeth were randomly assigned to the two groups.

Bonding Protocol

Group A (experimental group)

The buccal surface of each tooth was properly dried after cleaning by fluoride free-pumice. Deproteinization was achieved by applying 5.25% NaOCl (Chloraxid, Cerkamed Medical Company, Poland) on the enamel surface for 1min followed by rinsing and drying with oil-free compressed air. Etching was done for 30 seconds with H_3PO_4 (37%) (Spident Co., Ltd., Korea) followed by washing and drying. The treated enamel surface was then moistened with water according to manufacturer's recommendations and bracket was bonded using RMGIC (Fuji Ortho LC, GC Corp, Tokyo, Japan) as the adhesive material and light cured for 40 sec (10 seconds on each side) utilizing an LED curing light (Rixi, China).

Group B (control group):

The buccal surfaces of the teeth were etched with only orthophosphoric acid (37%) (Spident Co., Ltd., Korea) for 30 seconds followed by washing and drying. The treated enamel surface was then moistened with water following the manufacturer's recommendations and the bracket was bonded using RMGIC (Fuji Ortho LC, GC Corp, Tokyo, Japan) as the adhesive material and cured for 40 secs (10 seconds on each side) utilizing an LED curing light (Rixi, China).

Bracket Specifications

The standard edgewise 0.22x0.28-inch metallic brackets with hooks were used in this study. The bracket base area was 10.5mm±0.5. The brackets were attached on the buccal surface and positioned centrally using a bracket holder. They were pressed against the surface and excess adhesive cement was removed.

Shear bond strength measurement

The bonded specimens were placed in distilled water at a temperature of 37°C for 24 hours. Assessment of SBS was done by an Instron (Dartech, England) testing machine with a crosshead speed of 1 mm/minute to the point of bracket failure (figure 1). The force to bond failure was recorded and calculated. The value in newtons was converted into MPa using the formula shown below.[16]

SBS (mpa) = debonding force (n)/bracket base area (mm^2) (1MPa=1N/mm^2).

Data analysis was done by SPSS version 20 and mean standard deviation (mean SD) was calculated for the quantitative variable of shear bond strength.

Comparison of mean SBS in Group A (experimental) and Group B (control) was done using independent sample t-test. Frequency and percentage were computed for gender. Data were stratified for age and gender. Post-stratification t-test was used taking a p-Value <0.05 as significant.

Results

The mean age of the patients was 19.81±2.77 years [95%CI: 19.20 to 20.43]. There were 38(47.5%) females and 42(52.5%) males. SBS after deproteinization was significantly high in group A (sodium hypochlorite 5.25%, 37% Phosphoric acid and RMGIC) than in group B (37% Phosphoric acid and RMGIC) as shown in Table I. The study showed that the mean SBS of group A was increased by 4.8 MPa. The t-test comparison also indicated that the two means were significantly different (p=0.0005). Stratification analysis revealed that mean SBS was significantly higher in group A as compared to group B as per stratified gender (male, female) as shown in Table II.

Table-I: Descriptive statistics of SBS for both groups (n=80).

GROUPS	n	MEAN(MPa)	Std.Deviation(MPa)
Group A	40	11.33	5.44
Group B	40	6.53	2.56

*n: number of teeth

Table II: Stratification of shear bond strength with respect to gender.

Gender	Group A (n=40)		Group B (n=40)		P-value
	SBS		SBS		
	Mean	SD	Mean	SD	
Male	10.82	3.99	6.40	2.93	0.0005
Female	11.84	6.65	6.68	2.12	0.0005

Discussion

SBS is one of main factors that needs to be considered in the development of adhesive materials used in orthodontics. It must be sufficiently high to withstand the masticatory stresses and prevent fracture of enamel on debonding.[17] RMGIC was introduced in the twentieth century to improve the SBS of the adhesive.[18] It is a hybrid of GIC and composite resin and has the ability to release fluoride. Moreover, the resin component allows for better bond strength[19] although despite better SBS than GIC, RMGIC failed to match the SBS of composite resin. Several studies have been designed across the world to find a

suitable method to improve the SBS of this adhesive.[20]

The present study focused on finding a method by which better retention of metallic brackets could be achieved through enhancing the SBS of RMGIC as an adhesive material. To achieve this objective, enamel deproteinization was done with Sodium hypochlorite (NaOCL) before etching and then bonding the bracket with RMGIC. NaOCL does not harm the healthy tooth structure and is mostly used in endodontics as an irrigant.[21] It was introduced in orthodontics by Justus et al. in 2010.[22] According to them, NaOCL dissolves the organic layer (acquired pellicle) of the enamel and facilitates deeper penetration of etchant in the enamel core, subsequently producing more type 1 and 2 etching patterns. Type 1etching pattern involves dissolution of prism heads, whereas peripheral zones of the prisms are dissolved in type 2 etching patterns. These patterns are proven to be of better quality and most retentive etching patterns in the studies done by Espinosa et al. (2008) and Sharma et al. (2017).[13,14] On the other hand, there is strong evidence that by using phosphoric acid (37%) for etching the enamel surface before bonding orthodontic brackets, [23] only 2% of enamel surface is etched and more than 69% of the surface is not etched at all.

In the present study, Group A (experimental) was exposed to enamel deproteinization before etching with H_3PO_4 (37%) later bonding with RMGIC whereas in the Group B (control), bonding was preceded by etching with phosphoric acid (37%) only. The technique used for the experimental group led to an increase in SBS (11.33 ±5.44 MPA) while it stood at a low (6.53 ±2.56 MPA) for the control group. These results are in line with earlier studies conducted in this context.[7,9,13] The technique was also found to be effective for bonding flourosed teeth and enhance roughness of enamel surface as it results in higher amount of enamel microporosities.[14,24] Despite favourable outcomes demonstrated by numerous researchers, the study conducted by Pereira et al. (2012) revealed contrasting results. They considered the use of polyacrylic acid might be the reason of reduced SBS in their study as it has larger molecules that fail to move deeper in the enamel.[25]

There are various reasons that limit the credibility of any research. Likewise, this study is limited by factors including small sample size, variation in etching time, possible human error during bonding procedure and in vitro rather than in vivo conduct of experiment. In vivo experiments may reveal lower SBS. To overcome these limitations and to study shear bond strength more precisely, it would be ideal to increase the sample size and create suitable standards in the oral environment to conduct a study in vivo.

Conclusion

SBS of RMGIC significantly increases with the use of 5.25% NaOCl as deproteinization agent for 1 minute before acid etching with 37 % $H_3 PO_4$ for bonding metallic brackets as it results in better etching patterns. Deproteinization with NaOCL helps to reduce the surface stress, increases the materials penetration and adherence, resulting in higher SBS. Our results are favourable, suggesting more often use of RMGIC in routine clinical practice, particularly in hypo mineralised teeth and situations where moisture contamination is a major challenge.[15] Furthermore, deproteinization as a routine procedure in enamel pre-treatment saves clinical time that is wasted otherwise due to frequent debonding.

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5. Aamina Sagheer – Literature Review, Data Analysis, Proofreading
6. Mehvish Sajjad – Editing, Final Approval of Manuscript