ORIGINAL RESEARCH

Comparison of Shear Bond Strength of Adhesives to Enamel: An *In Vitro* Study

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Abstract

Aim: The aim of this study is to evaluate the shear bond strength (SBS) of a newly introduced self-adhesive resin cement, G-CEM ONE (GC Corporation, Itabashi-Ku, Tokyo, Japan), and compare it with Maxcem Elite (Kerr Corporation, Orange, California, United States of America), to enamel—an *in vitro* study.

Materials and methods: Cylindrical-shaped cement specimens (diameter, 2 mm; height, 3 mm) were bonded to etched buccal surface and nonetched lingual surface enamel of 40 caries-free premolars. Test specimens were stored in distilled water for 1 week. The test specimens were subjected to SBS using a universal testing machine with a crosshead speed of 0.5 mm/minute.

Statistical analysis: Data (n = 20 per group) were statistically analyzed using the Mann–Whitney and Shapiro–Wilk test at the 0.05 level of significance. The bond strength [megapascals (MPa)] of G-CEM ONE (GC) was statistically higher than Maxcem Elite (Kerr).

Results: The SBS of the G-CEM ONE (GC) group to enamel is better than the Maxcem Elite (Kerr) group.

Clinical significance: This study helps in following the proper protocol for the success of adhesive restorations.

Keywords: Bonding agents, Bond strength etchant, G-CEM resin cement.

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Introduction

Enamel bonding is one of the most significant advancements in dentistry in the 20th and 21st centuries, and it is the main reason for the clinical success of several restorative procedures. Such procedures include the bonding of ceramic veneers to etched enamel, the use of resin-based composite to close diastemas, the placement of sealants, the extension of class V restorations onto beveled enamel surfaces, and the placement of orthodontic brackets.[1]

Conventional adhesive systems are technique-sensitive as they use three different agents—an enamel conditioner, a primer solution, and an adhesive resin in the process of bonding to enamel and dentin. A unique characteristic of new bonding systems in operative dentistry is that they combine conditioning and priming to form a single acidic primer solution for simultaneous use on both enamel and dentin. This results in an improvement in bonding time and cost-effectiveness directly to the clinician and indirectly to the patient, thus reducing technique sensitivity.[2]

The self-adhesive properties are claimed to be based upon resulting in micromechanical retention as they use phosphoric acid methacrylates that demineralize and infiltrate the tooth substrate. Further reactions include chemical adhesion to hydroxyapatite (HAp). The basic inorganic fillers react with the phosphoric acid methacrylates. The dominant setting reaction is initiated either by light or by a redox system (dual-curing composite materials), which takes place in the form of free radical polymerization.[3,4]

Self-etch adhesive resins are claimed to have better bonding to both enamel and dentin. However, concerns emerged regarding the bonding potential of these cements to enamel. Kerr Maxcem Elite is a self-etch adhesive resin that is widely used in the restorative and prosthodontic fields. Various studies have claimed it to be the gold standard among luting cement due to its universal versatility, high bond strength, predictable handling, and ease of use.[2,5] GC Corporation has introduced a novel self-etch adhesive resin that can be used for luting various direct and indirect restorations to enamel and dentin. Although the basic adhesion mechanism appears similar for all self-adhesive cements, these materials are still relatively new, and detailed information on their composition and adhesive properties is limited.

Hence, the purpose of this study was to compare the SBS of novel G-CEM ONE (GC Corporation, Itabashi-Ku, Tokyo, Japan) and Maxcem Elite (Kerr Corporation, Orange, California, United States of America) to the enamel. The null hypothesis is that there are no statistically significant differences between the shear bond strengths (SBSs) of the two materials and also between the etched and the nonetched surfaces of the tooth used for bonding.

Materials and Methods

The study design chosen was an *in vitro* study with the IEC number 2019/P/CONS/71. The study duration was from November to December 2019. For this study, 40 caries-free human premolars,

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extracted for orthodontic reasons, were selected and stored in distilled water.

Inclusion Criteria

Extracted human premolars with intact buccal and lingual surfaces.

Exclusion Criteria

- Teeth having caries or restoration.
- Teeth have noncarious lesions—attrition, abrasion, and erosion.
- Teeth that have undergone previous bonding procedures.
- Teeth are treated with erosive agents like hydrogen peroxide or sodium hypochlorite.
- Teeth with surface cracks or infarction lines.

Buccal and lingual surfaces of the teeth were used in the study. Materials used were 37% phosphoric acid in gel (Prime Dental, Prime Dental Products Pvt Ltd, Thane, Maharashtra, India). The buccal and lingual surfaces of all 40 teeth were polished with pumice in order to obtain polished enamel surfaces (Fig. 1).

Groups Tested

The teeth were then randomly divided as follows:

- Group A: G-CEM ONE (GC Corporation, Itabashi-Ku, Tokyo, Japan).
- Subgroup 1 (20): The buccal surface was etched with 37% phosphoric acid gel.
- Subgroup 2 (20): The lingual surface was not etched.
- Group B: Maxcem Elite (Kerr, Orange, California, United States of America).
- Subgroup 1 (20): The buccal surface was etched with 37% phosphoric acid gel.
- Subgroup 2 (20): The lingual surface was not etched.

The buccal surface enamel was etched with 37% phosphoric acid gel for 20 seconds, the etchant gel was removed by a 20-second application of water, and the surfaces of the teeth were dried. The cements were managed strictly in accordance with the manufacturer's instructions. Table 1 mentions the composition of the materials used. A plastic cylinder (height 3 mm and diameter 2 mm) was placed perpendicular to the polished surface, and the materials were introduced into the molds. All excess material was removed. The materials were set for 2–3 minutes, which was followed by light polymerization (Bluedent LED Smart; output 1300 mW/cm^2) for 40 seconds (a 20-second exposure from each side of the cylinder). Once the material was light-cured, the completed specimens were removed from the mold and stored in distilled water at room temperature for 1 week in order to avoid dehydration.[6–10] The specimens were mounted in dental acrylic with the treated surfaces parallel to the shearing rod of the universal testing machine (UNITEST-10, ACME Engineers, Pune) with a smooth, 0.4 mm diameter stainless steel rod attached to its upper member as shown in Figure 2. They were subjected to shear stress with a crosshead speed

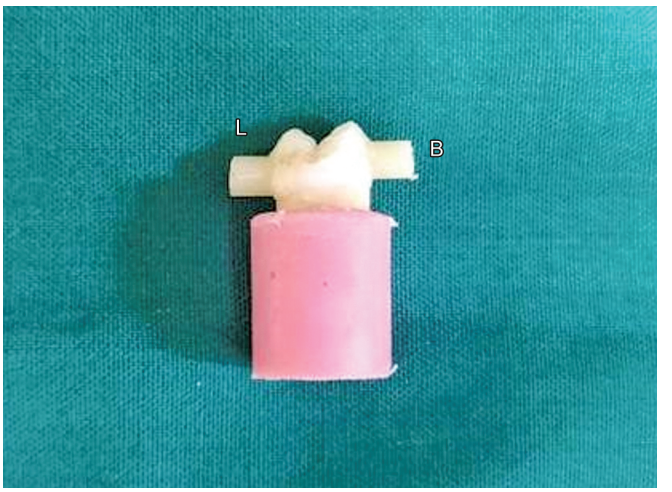

Fig. 1: Individual specimen–etched buccal surfaces (B) and nonetched lingual surface (L)

Fig. 2: Universal testing machine

Table 1: The composition of the cementing agents

Cementing agent	*Composition*	*Directions for use*
Maxcem Elite self-cure, Kerr Corporation, Orange, California, United States of America, Lot number—7029370	Resin matrix: GPDM, comonomers (mono, di, and trifunctional methacrylate monomers), proprietary self-curing redox activator, photoinitiator CQ, stabilizer Filler load: 67% wt: Fluoroaluminosilicate glass, fumed silica, barium glass, and ytterbium fluoride	4:1 dual barrel syringe with mixed tips, apply on the surface; light cure for 20 seconds from each side[5]
G-CEM ONE, GC Corporation, Itabashi-Ku, Tokyo, Japan, Lot number—1809055	Cement A: Fluoroaluminosilicate glass, methacrylate acid ester, and polymerization initiator Cement B: Silica filler, methacrylic acid ester, and phosphate ester monomer Adhesive reinforcement primer: Ethanol, water, 4-methacryloxyethyl trimellitic acid, phosphate ester system, mer-thiophosphate ester monomer, heavy amine initiator	Mix the two pastes and apply on the surface; light cure for 20 seconds from each side

CQ, camphorquinone; GPDM, glycerol dimethacrylate dihydrogen phosphate

of 0.5 mm/minute and an accuracy of ±1%. The results were calculated in megapascals (MPa).

Flowchart 1 describes the methodology in a flowchart.

Statistical Analysis

Statistical Package for Social Sciences (SPSS) version 20. [IBM SPSS statistics (IBM Corp. Armonk, New York, United States of America released 2011)] was used to perform the statistical analysis. Data was entered in the Microsoft Excel spreadsheet and subjected to normalcy tests, such as the Shapiro–Wilk test. Since the data is not normally distributed, nonparametric tests, such as the Mann–Whitney test, were applied. Descriptive statistics of the explanatory and outcome variables were calculated by mean, standard deviation (SD), median, and interquartile range for quantitative variables frequency and proportions for qualitative variables. The level of significance was set at 5%.

Results

The intragroup mean values of subgroups A1 and A2 are 5.874 and 2.593, respectively, as shown in Table 2. The mean values of subgroups B1 and B2 are 1.916 and 1.326, respectively, as shown in Table 3. There was no statistical difference between the subgroups with a *p*-value of 0.3 (*p*-value > 0.05). The results showed that the surfaces etched with phosphoric acid showed greater bond strength when the specimens were subjected to shear stresses.

The intergroup result for etched surfaces showed significantly greater values for group A than group B, with the mean values being

Flowchart 1: Methodology

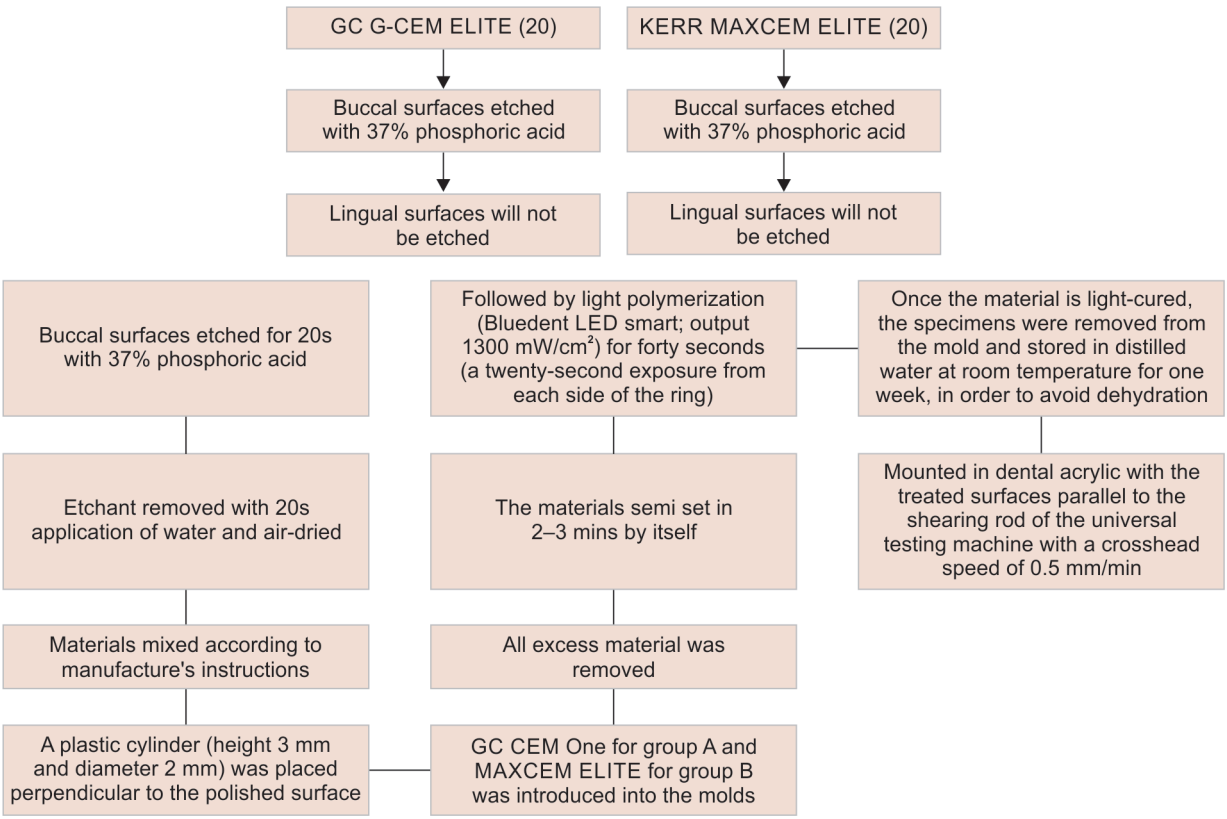

Table 2: Comparison of the SBS in the G-CEM ONE (GC) (A) group

		N	*Minimum*	*Maximum*	*Mean*	*SD*	*Median*	*U-value*	*p-value*
SBS	With etching (A1)	20	1.07	11.42	5.874	3.014	6.54	67.50	0.00*
	Without etching (A2)	20	0.58	6.60	2.593	1.725	1.99		

*, significant

Table 3: Comparison of the SBS in Maxcem Elite (Kerr) (B) group

		N	*Minimum*	*Maximum*	*Mean*	*SD*	*Median*	*U-value*	*p-value*
SBS	With etching (B1)	20	0.21	5.20	1.916	1.445	1.36	165	0.344
	Without etching (B2)	20	0.17	2.90	1.326	0.639	1.27		

Table 4: Comparison of the load and SBS between the groups (with etching)

		N	*Minimum*	*Maximum*	*Mean*	*SD*	*Median*	*U-value*	*p-value*
SBS	GC G- CEM (A)	20	1.07	11.42	5.874	3.014	6.54	46.00	0.00*
	Maxcem Elite (Kerr) (B)	20	0.21	5.20	1.916	1.445	1.36		

*, significant

Table 5: Comparison of the load and SBS between the groups (without etching)

		N	*Minimum*	*Maximum*	*Mean*	*SD*	*Median*	*U- value*	*p-value*
SBS	GC G- CEM (A)	20	0.58	6.60	2.593	1.725	1.99	120.0	0.03*
	Maxcem Elite (Kerr) (B)	20	0.17	2.90	1.326	0.639	1.27		

*, significant

5.874 and 1.916, respectively, as shown in Table 4. The values for nonetched surfaces for both groups were low when compared to their significant etched surfaces, as shown in Table 5.

The results state that etched surfaces, when bonded with group A (G-CEM ONE), showed significantly greater SBS.

Discussion

Recent advancements made in the field of direct restorative bonding have revolutionized the concepts in the field of restorative dentistry. The traditional bonding procedure consists of a three-step procedure that includes etching, bonding, and priming, which is necessary for good wetting and ensures sufficient penetration of sealant present in the composite. This allowed excellent bonding but also consumed a greater chairside time. Recently, self-etch adhesives were introduced to reduce chairside time during restorations. Self-etch adhesives form a single acidic product by combining the conditioner and primer, thus improving clinical handling efficiency. Although the pKa of the acid present in self-etch adhesives is enough to cause demineralization of the enamel.[11] The bond strength is still found to be less than that of conventional etchant in multiple studies.[12–15] Thus, only enamel was used as a substrate in this study to evaluate and compare the bond strengths of the two luting cements.

The type of teeth chosen for this study were premolars since they are the most common vital teeth extracted for orthodontic purposes and are easily available. Moreover, the study could be standardized by selecting a particular type of teeth so that the results are consistent. The stresses at the restoration—tooth interface can be identified as mainly a tensile or shear type of stress. Thus, successful bonding of the restoration or prosthesis is imperative for retention and good marginal adaptation. The restoration should also be able to withstand the contraction forces during polymerization. Thus, this study was done to evaluate their SBS to enamel as it is crucial for successful retention of the resins for a variety of clinical purposes like indirect restorations (metal, composite, and porcelain inlays, onlays, crowns, bridges, and endodontic posts).[4] In order to get pure bond strength data to the tooth structure without any interacting bonding effects of the restorative materials, the luting systems were applied directly on the enamel surface.[3]

This study investigated the bonding effectiveness of novel self-etch/self-adhesive cement [G-CEM ONE (GC)] and a universal self-adhesive resin luting agent [Maxcem Elite (KERR)] to the enamel. Statistically significant differences among the cements were found between the etched and nonetched surfaces; thus, both the null hypothesis of the study was rejected. The special features of the novel material, as claimed by the manufacturers, are its excellent self-curing ability, easy handling, good initial durability, and better bonding to tooth structure compared to other self-adhesive resin cement.[3]

Self-etch adhesives like Maxcem Elite (Kerr) and G-CEM ONE (GC) have some advantages over the phosphoric acid etchant. They prevent aggressive demineralization and reduce the risk of enamel damage due to their reduced ability to sufficiently etch and penetrate the enamel surface, which are characteristics of phosphoric acid etching.[5]

The concept of bonding to enamel is based on an exchange process in which the resin monomers replace the minerals of the dental hard tissues that, upon polymerization, become micromechanically interlocked in the created porosities. This process is called "hybridization," which is described in the "AD-concept" or "adhesion-decalcification concept." Initially, all acids react ionically to HAp with the release of phosphate (PO_4^{3-}) and hydroxide (OH^-) ions into their own solution, thus making the surface electroneutral. The stability of the bond formed with calcium will determine whether the molecule will remain bonded or will debond. More specifically, self-etch adhesives contain molecules like 10-methacryloyloxydecyl dihydrogen phosphate or 10-MDP, which forms stable calcium phosphate salts and will cause a limited surface decalcification by keeping the HAp crystals within the submicron hybrid layer. On the contrary, a typical etch pattern at enamel and a relatively deep (3–5 µm) hybrid layer at dentin that no longer contains any HAp crystals is seen due to the replacement of positively loaded calcium from the surface with negatively loaded phosphate/carboxyl ions of the monomers/acids.[16–18] This could be the reason why the bond strength of the self-etch adhesives to etched enamel was significantly higher than that of the nonetched enamel in this study.

This study concluded that the SBS of the G-CEM ONE (GC) to etched enamel is higher than that of Maxcem Elite (Kerr). Comparable bond strength values to those found in this study have been reported in previous studies like Lee et al. when Maxcem Elite (Kerr) was used to bond zirconia crowns to the tooth.[19] In another study by Sabatini et al., Maxcem Elite (Kerr) showed comparable SBS when bonded to various pretreated prosthodontic substrates like metal, noble metal, zirconia, and

ceramics.[20] Another study by Malik and Laxmikanth compared the SBS of orthodontic brackets to enamel using Maxcem Elite (Kerr) with Transbond Plus (3M, Unitek). The SBS of Maxcem Elite (Kerr) was found to be higher than that of Transbond Plus (3M, Unitek).[5]

Thus, this study showed that self-etch resin cement bonds better to enamel structures when etched with phosphoric acid gel prior to the bonding process. Also, shear tests of bond strength can provide insight into the adhesion of a specific material to the tooth structure, but they cannot be used to predict clinical performance.

Limitations

Overall, as promising as self-adhesive cements might seem due to their simplicity, adequate data on their true clinical performance are not available. Large comparative studies are needed to understand their overall behavior to various substrates under multiple testing conditions.

Conclusion

The SBS of the G-CEM ONE (GC) group to enamel is better than the Maxcem Elite (Kerr) group. SBS was found to increase when enamel was etched first and then bonded with the resins. Even though their simplicity renders the use favorable; their performance is far from being comparable to that of multistep conventional resin cement. Since these cements have limited bond performance, they must be used with caution.

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