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Comparative Evaluation of Shear Bond Strength of A Self - Adhering Flowable Composite and Resin Modified Glass Ionomer Cement to Mineral Trioxide Aggregate, Light Cure Calcium Hydroxide and Biodentine - An in Vitro Analysis

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Abstract **Original Research Article**

The success of all vital pulp capping procedures depends on a proper bond between the pulp capping agent and the restorative material. If these two materials fail to bond, the bacterial toxins may penetrate into the pulp and the pulp capping procedure will fail. The present study is undertaken to evaluate the shear bond strength of three popular pulp capping agents namely, MTA, Biodentine and light cure calcium hydroxide to a new self-adhering flowable composite and resin modified GIC. Sixty acrylic blocks were prepared with a hole of 3mm diameter and 1.5mm height at the centre of the block. They were divided into 6 groups of 10 each. Group 1, MTA, Group 2, Biodentine and Group 3, light cure calcium hydroxide, over which self-adhering flowable composite(Dyad Flow) was placed in a plastic cylinder with a height and diameter of 2mm. In Group 4, MTA, Group 5 Biodentine and Group 6 light cure calcium hydroxide, over which resin modified GIC was placed in a similar manner as mentioned earlier. Shear bond strength was tested for failure using a universal testing machine with a crosshead speed of 1mm/min. The results demonstrated that the MTA - RMGIC and light cure calcium hydroxide - groups showed significantly higher shear bond strength values than the other groups. There is no statistically significant difference between MTA - RMGIC and light cure calcium hydroxide - RMGIC groups. The highest shear bond strength was shown by MTA - RMGIC group, followed by light cure calcium hydroxide - RMGIC group > Biodentine - RMGIC group > MTA – self adhering flowable composite group > Biodentine – self adhering flowable composite group. And the lowest shear bond strength was shown by light cure calcium hydroxide – self adhering flowable composite group. The groups with RMGIC showed significantly higher shear bond strength values than the groups with self-adhering flowable composite. MTA has emerged as the endodontic material. Its high bond strength and good compatibility with resin modified glass ionomer cement will further improve their clinical results.

Keywords: Shear bond strength, MTA, Biodentine, light cure calcium hydroxide, self-adhering flowable composite, and resin modified GIC.

INTRODUCTION

The primary objective of conservative dentistry is to preserve the vitality of the dental pulp and prevent pulpal pathology so as to preserve the natural dentition and restore the tooth to the best of health, function and esthetics [1].

If the pulp is exposed the long term success and preservation of vitality are endangered. The treatment protocol for deep carious lesions is a complicated task for the dental clinician, and the treatment modalities must aim to preserve the pulp vitality and achieve the formation of Dentin Bridge [2].

This aim is achieved by vital pulp therapy in open apex teeth to allow apexogenesis and normal development of the root and by pulp capping in mature teeth in order to avoid root canal therapy and the subsequent extensive restorations [2].

It is important to note that the success of all vital pulp capping procedures is directly related to the control of pathogenic agents. A pulp exposed in a sterile environment can repair itself and form a dentinal bridge. However in the presence of bacteria, pulpal infection and finally pulp necrosis is inevitable. Therefore, a proper bond between the pulp capping agent and the restorative material is of utmost importance because in the absence of a proper seal bacteria will penetrate into the pulp and the pulp capping procedure will fail[1].

To complete the final restoration, an adhesive restorative material can be applied over the pulp capping material used. Therefore, it is important to identify materials that are compatible in relation to the interface between the two different materials.

The old and traditional methods of cavity preparation were material driven and tooth destructive. With the advent of adhesive technology newer cavity preparation philosophies emerged. Cavity size and shape are strictly defecting oriented and minimally invasive.

An ideal endodontic repair material should seal the pathways of communication between the root canal system and its surrounding tissues. It is desirable for the selected materials to induce or dentin bridge formation, provide a good seal against bacteria and fluids, have antibacterial property, set in a wet environment, be unaffected by blood contamination and have reasonable compressive strength and hardness.

The most popular and commonly used pulp capping agent calcium hydroxide is not being widely accepted now days because of its unpredictable results such as not adhering to dentin and dissolving over time and dentin bridges adjacent to the material containing tunnel defects. To overcome these disadvantages of short setting time and difficult handling properties of conventional calcium hydroxide, light cure calcium hydroxide was introduced.

Novel dental biomaterials such as mineral trioxide aggregate (MTA) and Biodentine are being used instead of calcium hydroxide. MTA has attracted considerable attention because of its desired properties such as low solubility, ability to set in a wet environment, setting in the presence of blood, prevention of bacterial leakage and biocompatibility. However, it has some disadvantages, such as difficult handling and long setting time. Biodentine has been developed to overcome the shortcomings of MTA. It has good sealing ability, high compressive strength, a short setting time, biocompatibility, and bioactivity and has remineralisation properties.

Resin composites and resin modified GIC's are very popular in restorative dentistry because of their adhesive qualities. Resin modified glass ionomer cement (RMGIC) has overcome the disadvantages of conventional GIC. Polyacrylic acid conditioner is used to improve the bond strength of RMGIC to dentin.

Flowable resin composites have desirable handling properties such as fluid injectability and non-stickiness. They are recommented for the restoration of small sized cavities and cavity lining.

Recently, a new self-adhering flowable composite have been developed. This new system eliminates the need for an additional adhesive application. Incorporation of bonding agent into a flowable composite holds great potential with respect to saving treatment time and minimizing handling errors.

For, the success of the restoration, the bond strength between two restorative materials is of utmost importance. Shear bond strength is the measure of strength between two restorative materials. It estimates the local stress that the bonding layer can withstand, and determines the integrity of the materials. High shear bond strength implies better bonding between two interfaces, provides favourable adhesion, and increases retention. Another important clinical significance of high shear bond strength is its relation to microleakage. Higher the shear bond strength, lesser the microleakage[2].

The bond strength between restorative and pulp capping materials is important for the quality of the filling and the success of the restoration. Moreover, proper bonding between the restorative materials to pulp capping biomaterials produces the adhesive joint which is capable of spreading stress relatively evenly over the entire region of the bond [1]. Hence, the present study is undertaken to evaluate the shear bond strength of a self-adhering flowable composite and resin modified GIC to three popular pulp capping materials, MTA, light cure calcium hydroxide and Biodentine.

METHODOLOGY

Sixty hollow metal tubes with a square cross section of dimension 2x2x2cm were fabricated. A metal plate with a cylindrical projection of 3mm in diameter and 1.5mm in height at the centre of the plate was placed on the bottom of the tube. They were then filled with cold cure acrylic resin. A glass plate was placed over the acrylic before it sets to get a flat smooth surface to obtain acrylic blocks of 2x2x2cm in dimension with a hole in the centre with dimensions of 3mm diameter and 1.5mm depth. The acrylic blocks were divided into three sets of 20 each, according to the pulp capping material and the restorative material used.

In 20 specimens, the holes were filled with light cure calcium hydroxide and light cured for 20 seconds. MTA was mixed according to the manufacturer's instructions and the holes of 20 specimens were filled with it. Biodentine was also were mixed according to the manufacturer's instructions and holes of 20 specimens were filled. Both MTA and Biodentine specimens were covered with a moistened cotton pellet.

The specimens were stored for 72 hours at 37^0C and 100% humidity to ensure complete setting of the material. All prepared surfaces were polished with 400 grain sandpaper for 60 seconds to create a smooth surface.

Then each set was divided into two groups of 10 specimens based on the type of restorative material applied over light cure calcium hydroxide, MTA and Biodentine.

GROUP 1: Self adhering flowable composite placed over light cure calcium hydroxide.
GROUP 2: Resin modified GIC placed over light cure calcium hydroxide.
GROUP 3: Self adhering flowable composite placed over MTA.
GROUP 4: Resin modified GIC placed over MTA.
GROUP 5: Self adhering flowable composite placed over Biodentine.
GROUP 6: Resin modified GIC placed over Biodentine.

A hollow plastic cylinder with a height and diameter of 2mm was placed over the pulp capping material for the placement of the restorative material. The restorative material used was either self-adhering flowable composite or RMGIC. They were injected in the plastic tube which was placed over any of the three pulp capping material namely light cure calcium hydroxide, MTA or Biodentine. The restorative materials were light cured for 20 seconds. Then the plastic cylinder was cut off using a scalpel blade after the curing of the restorative material.

The samples were stored in a humid environment for 24hours at 37^0C. Shear bond strength was tested for failure using a knife edge blade in a universal testing machine with a crosshead speed of 1mm/min.

STATIATICAL ANALYSIS

The data obtained were statistically analyzed using two way ANOVA test and the Tukey test at a significance of $p<0.05$.

RESULTS

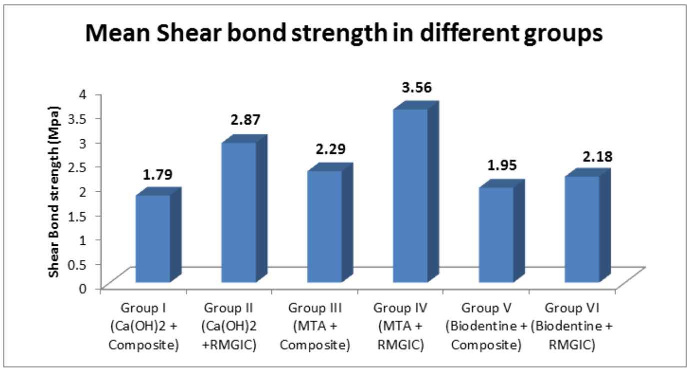
The objective of this study was to evaluate the shear bond strength of a self-adhering flowable composite and resin modified GIC to MTA, light cure calcium hydroxide and Biodentine. Shear bond strength was tested for failure using a knife edge blade in a universal testing machine with a crosshead speed of 1mm/min.

The data obtained will be statistically analyzed using ANOVA Test. According to the results of the present study, MTA - RMGIC and light cure calcium hydroxide - groups showed significantly higher shear bond strength values than the other groups. There is no statistically significant difference between MTA - RMGIC and light cure calcium hydroxide - RMGIC groups. Biodentine - RMGIC group showed a lower shear bond strength value than the MTA – RMGIC group and the light cure calcium hydroxide – RMGIC group which was statically significant. The groups with self-adhering flowable composite as the restorative material showed a statistically significant smaller shear bond strength values than that of the groups with the RMGIC. The MTA – self adhering flowable composite showed a higher shear bond strength value than the Biodentine – self adhering flowable composite. And the lowest shear bond strength was shown by light cure calcium hydroxide – self adhering flowable composite group.

Mean shear bond strength of different groups are summarized in Table 1 and Graph 1

Table-1: Mean Shear bond strength (Mpa) in different groups

	N	Mean	SD	95% CI for Mean		Min	Max
				Lower	**Upper**		
Group I Ca$(OH)_2$ + Composite)	10	1.79	0.27	1.59	1.98	1.42	2.21
Group II Ca$(OH)_2$ + RMGIC)	10	2.87	0.52	2.50	3.24	1.97	3.67
Group III (MTA + Composite)	10	2.29	0.29	2.08	2.50	1.89	2.79
GroupIV (MTA + RMGIC)	10	3.56	0.35	3.31	3.82	2.9	4.07
Group V (Biodentine + Composite)	10	1.95	0.32	1.72	2.18	1.33	2.37
Group VI (Biodentine + RMGIC)	10	2.18	0.66	1.71	2.65	1.38	3.65



Graph-1: Mean Shear bond strength (Mpa) in different groups

Comparison of the mean shear bond strength of each group is summarized in Table 2

Table-2: Post hoc pairwise comparison (Tukey HSD)

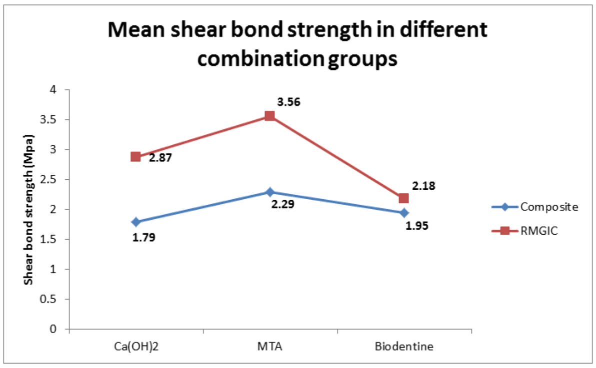
Comparison Pairs	Mean Difference	95% CI for MD		P value
		Lower	Upper	
GroupI **Vs** GroupII	-1.09	-1.65	-0.52	**<0.005(Significant)**
GroupI **Vs** GroupIII	-0.50	-1.06	0.07	0.112
GroupI **Vs** GroupIV	-1.78	-2.34	-1.21	**<0.005(Significant)**
GroupI **Vs** GroupV	-0.16	-0.73	0.40	0.955
GroupI **Vs** GroupVI	-0.39	-0.96	0.17	0.323
GroupII **Vs** GroupIII	0.59	0.02	1.15	**0.037(Significant)**
GroupII **Vs** GroupIV	-0.69	-1.25	-0.13	**0.008(Significant)**
GroupII **Vs** GroupV	0.92	0.36	1.49	**<0.005(Significant)**
GroupII **Vs** GroupVI	0.69	0.13	1.26	**0.008(Significant)**
GroupIII **Vs** GroupIV	-1.28	-1.84	-0.71	**<0.005(Significant)**
GroupIII **Vs** GroupV	0.34	-0.23	0.90	0.502
GroupIII **Vs** GroupVI	0.11	-0.46	0.67	0.994
GroupIV **Vs** GroupV	1.61	1.05	2.18	**<0.005(Significant)**
GroupIV **Vs** GroupVI	1.38	0.82	1.95	**<0.005(Significant)**
GroupV **Vs** GroupVI	-0.23	-0.79	0.33	0.832

The groups with RMGIC showed significantly higher shear bond strength values than the groups with self-adhering flowable composite. The mean shear bond strength and standard deviations of each group is summarized in Table 4 and Graph 2

Table-4: Mean Shear Bond Strength (MPa) and Standard Deviations of each Group

	CaOH2	MTA	Biodentine
Composite	1.79 (0.27)[a]	2.29 (0.29)[a]	1.95 (0.32)[a]
RMGIC	**2.87 (0.52)**[b]	**3.56 (0.35)**[c]	2.18 (0.66)[a]

Different superscript letters indicate statistically significant differences (P < .05).



Graph-2: Mean Shear Bond Strength (MPa) and Standard Deviations of each Group

DISCUSSION

The vital pulp has the capacity to heal through cell regeneration and dentine bridge formation when a proper biological seal is provided and maintained against leakage from oral contaminants.

Pulp capping, pulpotomy and apexogenesis are time tested procedures. The ultimate objective of these is to preserve the vitality of the pulp by completely removing the caries infected dentin followed by placement of a material that would enable the affected dentine to remineralize by stimulating the odontoblasts to form tertiary dentin and provide biological seal against the microleakage. Various materials are used for pulp capping. The most commonly used are calcium hydroxide, MTA, Biodentine, tricalcium silicates and bonding agents etc[2].

The ultimate success of all pulp capping procedures is directly related to the shear bond strength between the pulp capping material and the restorative material. Shear bond strength is the measure of strength between two restorative materials. A proper bonding of restorative material to pulp capping biomaterials produces the adhesive joint which is capable of spreading stresses relatively evenly over the entire region of the bond [1].

There are many studies in the literature evaluating the effect of various restoration techniques on the bond strength of MTA and Biodentine. However only a few reports with experimental data related to the bond strength of MTA and Biodentine to composites is published. Thus the present study was undertaken to estimate the shear bond strength of three pulp capping materials, light cure calcium hydroxide, MTA and Biodentine to the more popular RMGIC and a new self-adhering flowable composite.

In our study we have taken light cure calcium hydroxide which has overcome the disadvantages of conventional calcium hydroxide. Light cure calcium hydroxide also has the advantage in account of its compatibility as a pulp capping agent under restorative materials such as RMGIC and composites.

Light cure calcium hydroxide. Is taken up as a standard in this study against other materials tested to compare the shear bond strength of recently available pulp capping materials such as MTA and Biodentine and light cure calcium hydroxide to the restorative materials RMGIC and self-adhering flowable composite.

Recently, mineral trioxide aggregate (MTA) has emerged as an endodontic material. This was the first calcium silicate cement to be marketed. Since its approval by the Food and Drug Administration in 1998, it has been used with increasing frequency, with very good clinical and in vitro results. The composition of MTA is very similar to Portland cement. It is a mineral powder consists of fine hydrophilic particles that set in the presence of moisture. It contains tricalcium silicate, bismuth oxide, dicalcium silicate, tricalcium aluminate and calcium hydrate dehydrates. During the setting reaction, calcium hydroxide is released and a high alkalinity is present in the exposed area[32].

Histological studies in animals have shown high sealing ability and hard tissue inducing capacity. The material has been recommended for repair of root perforations, as a root end filling material, for root end closure of permanent teeth and for direct and indirect pulp capping and pulpotomy, furcation repair, internal root resorption and might be use in ART [32].

At present, MTA seems to be promising candidate as an alternative to calcium hydroxide. MTA has desired properties such as low solubility, ability to set in a wet environment, setting in the presence of blood, prevention of bacterial leakage and biocompatibility.

In a systematic review with a meta-analysis that compared the effectiveness of MTA and calcium hydroxide as pulp capping materials in permanent teeth by Li Z *et al*. in 2015, found that MTA has a higher success rate and results in less pulpal inflammation and more predictable formation of a hard dentine bridge than calcium hydroxide. This conclusion demonstrates that MTA is a suitable material for direct pulp capping procedures and argues against the continuing recommendation of calcium hydroxide as the gold standard for such treatments [17].

However, as the first calcium silicate material, MTA has some disadvantages such as difficult handling, long setting time and tooth discolouration develops over time [32]. New calcium silicate materials have appeared in recent years, and among them Biodentine is an improved calcium silicate material to overcome the shortcomings of MTA.

Biodentine, a popular and contemporary tricalcium silicate based dentine replacement and repair material, has been evaluated in quite a number of aspects ever since it’s launching in 2009. The studies are generally in favor of this product in terms of physical and clinical aspects despite a few contradictory reports. Though accumulation of further data is necessary, Biodentine holds promise for clinical dental procedures as a biocompatible and easily handled product with short setting time. This material has similar chemical composition like MTA and can be used in all cases in which MTA is used. Besides the biocompatibility, Biodentine has good sealing ability, bioactivity and remineralisation properties [35].

With the advent of MTA and Biodentine the current focus of pulp therapy is on achieving a good biological seal and thus preventing the bacterial microleakage.

There is a lack of studies that evaluate the mechanical properties of light cure calcium hydroxide, MTA and Biodentine as a pulp capping agents to the present adhesive restorative materials such as RMGIC and self-adhering flowable composite. So our present study compared the shear bond strength of light cure calcium hydroxide, Biodentine and MTA as pulp capping agents with the self-adhering flowable composite and resin modified GIC restorative materials.

It is important to identify the materials that can be applied over the pulp capping biomaterial like MTA and Biodentine, which can allow for immediate final restoration placement. In addition, the longevity of restorative material depend partly on the bond strength of restoration with the substrate. Choice of restorative material also has an important influence on bacterial microleakage. Resin modified glass ionomer cements and resin composites are very popular in restorative dentistry because of their esthetic and adhesive qualities.

RMGIC's have the advantage of a long working time combined with a rapid set and higher early strength. They are also easily bonded to resins. They have higher strength compared to conventional GIC's. RMGIC's are compatible with many other materials. And the main advantage of this material is that, it can have both mechanical and chemical bonding with other materials.

A recently introduced self-adhering flowable composite contain an all in one bonding system. It is a self-adhesive, light cured; resin based composite dental restorative material designed for direct placement. By incorporating OptiBond adhesion technology, this system eliminates the need for additional steps of etching, priming, and adhesive application for bonding. Incorparation of the bonding agent into the flowable composite hold great potential with respect to saving treatment time and minimizing handling errors. They offer high bond strength, high mechanical strength, and other physical attributes comparable to traditional flowable composites. These new self-adhering flowable composites are even more useful when a patient may be uncooperative during the treatment. The manufacturers have been proposed as an adhesive free restorative material indicated for the restoration of small class I cavities, class V cavities and noncarious cervical lesions as well as for lining in class I and class II restorations. Additional indications include, pit and fissure sealant, repair of enamel defects, repair of porcelain restoration, blocking of undercut, minor occlusal build-ups in non-stress bearing areas, and incisal abrasions.

Different methods are available to analyze the bond strength between two materials in vitro. The shear bond strength test has been widely used for evaluation of bond strength of dental materials. This method has the advantage of being easier to perform than other methods. Shear bond strength is the measure of strength between two restorative materials. It estimates the local stress that the bonding layer can withstand and determines the integrity of materials. The bond strength between restorative and pulp capping materials is important for the quality of filling and the success of restoration. High shear bond strength implies better bonding between two interfaces, provides favourable adhesion, increased retention and lesser microleakage[5].

Thus this study was designed to test the shear bond strength of three commonly used pulp capping materials, light cure calcium hydroxide, MTA and Biodentine with RMGIC and the newly introduced self-adhering flowable composite.

In the present study, pulp capping materials were filled in the holes prepared on the acrylic blocks over which the restorative materials were placed in a plastic cylinder. Shear bond strength was tested for failure using a universal testing machine with a crosshead speed of 1mm/min.

According to the results of the present study, MTA - RMGIC and light cure calcium hydroxide - RMGIC groups showed significantly higher shear bond strength values than the other groups. There is no statistically significant difference between MTA - RMGIC and light cure calcium hydroxide - RMGIC groups. Biodentine - RMGIC group showed a lower shear bond strength value than the MTA – RMGIC group and the light cure calcium hydroxide – RMGIC group which was statically significant. The groups with self-adhering flowable composite as the restorative material showed a statistically significant low shear bond strength values than that of the groups with the RMGIC. The MTA – self adhering flowable composite showed a higher shear bond strength value than the Biodentine – self adhering flowable composite. And the lowest shear bond strength was shown by light cure calcium hydroxide – self adhering flowable composite group.

The present study revealed that, MTA as a pulp capping material showed higher shear bond strength with the base materials such as RMGIC and self-adhering flowable composite than light cure calcium hydroxide and Biodentine. It has been estimated that a bond strength ranging from 17 to 20Mpa may be required to resist contraction forces to produce gap free restoration margins [7]. The higher shear bond strength of MTA-RMGIC bond can be explained by the following. MTA is a powder which consists of fine hydrophilic particles. It also contains small amounts of other mineral trioxides which modify its chemical and physical properties. When RMGIC is applied to MTA, one of the possible reactions that can occur at the interface is: the carboxyl (coo-) group of the polyacrylic acid could interact with the calcium of MTA to form calcium salts or the silicate hydrate gel of the MTA could condense with the silicate hydrate gel of the RMGIC to form byproducts. Due to high percentage of the mineral oxides in MTA, RMGIC would be expected to bond strongly to MTA. The addition of RMGIC to dental tissues relies primarily on the chemical interaction and the lesser extent on micro chemical interlocking. The porous surface of MTA might increase the strength of MTA-RMGIC bond [9].

The higher shear bond strength of the light cure calcium hydroxide and the RMGIC group could be because of the resin filler content of the light cure calcium hydroxide.

Altunsoy *et al*. in his study demonstrateded a mean shear bond strength value of 2.01Mpa between MTA and self-adhering flowable composite which is almost similar to the present study where the mean shear bond strength value of MTA to self-adhering flowable composite is 2.29Mpa[1].

Douglas *et al*. in 2004 and Yesilurt *et al*. in 2009 had demonstrated that restorative procedures should be postponed for at least 72 to 96 hours after mixing of MTA to allow the material to achieve its optimum physical properties. This was followed in the present study. Since resin composites cannot be placed directly over freshly mixed MTA because they can affect MTA setting and also unset MTA can dislodge the material. Therefore, placing RMGIC over partially set MTA should be considered as a part of permanent or provisional restoration.

The present study demonstrated a decreased shear bond strength value of Biodentine to the base materials than that of MTA and light cure calcium hydroxide. Altunsoy et al in his previous study conducted in 2016 also reported a similar result where the shear bond strength of Biodentine to self-adhering flowable composite was 1.2Mpa and where as that of MTA was 2.01Mpa[2].

It is reported by Odbas *et al*. that the initial setting reaction of Biodentine takes approximately 12 minutes after mixing the powder and liquid [18]. However, it takes up to two weeks to achieve complete maturation of Biodentine. This could be the possible reason for the decreased shear bond strength of Biodentine to the base materials than that of the other two pulp capping materials used where the incubation period was 72 hours in the present study.

In the present study, the shear bond strength of RMGIC to the pulp capping materials where higher than the self-adhering flowable composite. A contributing factor to this large variation could be due to the difference in specimen preparations.

Additionally, for self-adhering flowable composite the possible decreasing effect of light curing at the area away from the light source may results in reduced bond strength. Also, the bond strength values of this type of cements is related to the degree of conversion of the monomer which in turn decreased when the distance from the light increased leading to poor physical properties. Lack of pressure during the placement of the self-adhering flowable composite may also be a contributing factor in its low bond strength value. Pressure during cement application is necessary to avoid bubbles and open spaces on the interface, and may affect the longevity of the self-adhering flowable composite [6].

Even though the self-adhering flowable composite have desirable clinical handling properties, the results showed that its bond strength with the pulp capping biomaterial is less than that of RMGIC. The bonding mechanism of self-adhering flowable composite relies on the adhesive monomer glycerol phosphate dimethacrylate, which mainly binds calcium ions of which the phosphate group is responsible for acid etching. The dimethacrylate functional groups are involved in cross-linking reactions with other methacrylate monomers, thus providing mechanical strength to the adhesive material. This composite material can be expected to interact with dental substrate in a similar way as mild self-etch adhesives. The manufactures suggested a surface modification on enamel to increase the bonding capacity of this material, where as there is no suggestion to improve the bond strength to pulp capping materials [2].

The major limitation of the current research was the small sample size. And this being an in vitro study will not give an exact correlation with the oral environmental conditions. Also, the incubation period of our current study were 72 h, where in clinical conditions, we prefer to go for an immediate final restoration.

Future studies should include randomized clinical trials with larger samples; longer follow up periods, and study of pulpal inflammation status to evaluate the long term success of treatment by using different materials.

Our present study demonstrated that the MTA and light cure calcium hydroxide exhibited higher shear bond strength values than Biodentine to the restorative materials. Also, the RMGIC as a restorative material showed statistically significant higher shear bond strength values to the pulp capping materials than that of self-adhering flowable composite.

Thus MTA might be used as a pulp capping material (for direct and indirect pulp capping) because they show higher shear bond strength than Biodentine. Also, RMGIC is preferred as a restorative material over MTA than self-adhering flowable composite for better clinical results.

CONCLUSION

Within the limitations of this in vitro study it can be concluded that,

- Resin modified glass ionomer cement can be used as a restorative material over the pulp capping material MTA for improved results.
- Resin modified glass ionomer cement restorations gave better results than that of self-adhering

flowable composite restorations in pulp capping procedures.

- MTA pulp capping gave better bond strength than that of Biodentine and light cure calcium hydroxide.

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