The Open Dentistry Journal
ISSN: 1874-2106
DOI: 10.2174/0118742106282792240222071645, 2024, 18, e18742106282792

REVIEW ARTICLE
OPEN ACCESS

Choosing the Right Adhesive: A Review of Strategies for Composite Bonding to Glass Ionomers and Calcium Silicate-based Cements

Naji Ziad Arandi[1,*]

[1]Department of Conservative Dentistry, Faculty of Dentistry, Arab American University, Jenin, Palestine

Abstract:
Managing deep carious lesions has become increasingly complex due to the introduction of numerous materials and techniques. This review addresses contemporary concepts regarding selecting adhesive agents at the interface between glass ionomer cements (GICs) or calcium silicate-based cements (CSCs) and resin composite restoration in laminate and layered restorations. The published literature was retrieved from PubMed, Google Scholar, and Scopus by using specific keywords "adhesive agents," "TheraCal LC," "Biodentine," "Glass ionomer," "bond strength," "sandwich technique," "etch-and-rinse," "self-etch," "universal adhesive," and "bonding." The list of references from each identified article was examined to find other potentially relevant articles. Results: For GICs, self-etch adhesives (SE) appear more beneficial than etch and rinse adhesives (ER). The ER, or Universal adhesive (UA) used in the self-etch mode, might be recommended if the final composite is placed in a subsequent session after Biodentine has fully set. TheraCal LC, on the other hand, tends to yield higher bond strengths when used in conjunction with ER or UA systems in SE mode. Overall, selecting adhesive agents for laminate and layered restorations depends on various factors, including the specific materials used, the desired clinical outcome, and the setting time available. While some trends suggest the superiority of certain adhesive systems, the literature remains inconclusive for specific materials. Further research is needed to establish definitive guidelines for adhesive selection in these complex clinical scenarios.

Keywords: Adhesive agents, Biodentine, Calcium silicate cements, Dentine bonding agents, Etch and rinse adhesives, Glass ionomer, Resin-modified glass ionomer, Self-etch adhesives, TheraCal LC, Universal adhesives.

*Address correspondence to this author at the Department of Conservative Dentistry, Faculty of Dentistry, Arab American University, Jenin, Palestine; E-mail: Arandi@gmail.com

Cite as: Arandi N. Choosing the Right Adhesive: A Review of Strategies for Composite Bonding to Glass Ionomers and Calcium Silicate-based Cements. Open Dent J, 2024; 18: e18742106282792.
http://dx.doi.org/10.2174/0118742106282792240222071645

Received: October 26, 2023
Revised: January 06, 2024
Accepted: February 12, 2024
Published: March 01, 2024

1. INTRODUCTION

Direct posterior composite restorations are most often performed as part of everyday dentistry. However, when confronted with deep carious lesions, the procedure becomes challenging. These cases may necessitate certain restorative procedures and vital pulp therapies to preserve pulp vitality and overall tooth health. The management of deep carious lesions has witnessed the introduction of numerous materials and techniques over the years, making the selection process a daunting task for clinicians.

There is an evident shift towards simplifying materials and clinical procedures in dentistry. The integration of simplicity and quality is achievable when dentists use advanced techniques, modern materials, and evidence-based approaches [1].

When the cavity is deep, clinicians are advised to place laminate/ layered restorations [2]. The choice of materials used to manage such cases should ensure a hermetic seal of the cavity to stabilize the lesion and arrest caries progression. Glass ionomer cements (GICs) and calcium silicate-based cements (CSCs) have been advocated as intermediate layers positioned beneath composite restorations within deep cavities [3-5].

The sandwich technique was initially introduced during the late 1970s and early 1980s by Wilson and McLean [6]. This technique involved utilizing GICs to replace lost dentin and placing a composite restoration to replace lost enamel. The rationale for employing this method is to make the most of each material's physical and aesthetic properties. Doing so combines the chemical adhesion and fluoride release attributes of GICs with resin composites' durability and visual appeal. Two main types of GICs have been regularly employed as the initial layer: conventional glass ionomer cements (CGICs) and resin-modified glass ionomers (RMGI). Both of these materials exhibit distinct properties, and the success of this technique depends on the bonding strength of the GICs to both dentin and the overlying resin composite. Additionally, alternatives like CSCs such as Biodentine and TheraCal LC have been suggested for use beneath composite restorations in deep cavities [7, 8]. These bioactive materials offer clinical advantages over GICs, enabling a more conservative approach to preserving and regenerating the pulp.

Biodentine, developed by Septodont in Saint-Maur-des-Fossés Cedex, France, is a bioactive hydraulic material used to replace dentine and possesses similar mechanical characteristics to natural dentine [9]. This material is supplied as a two-part system: a powder contained in a capsule and a liquid in an ampule. The powder comprises tricalcium silicate, zirconium oxide, and calcium carbonate, while the liquid consists of water, calcium chloride, and a water-based polymer. Biodentine sets in about 12 minutes after mixing, potentially allowing for procedures to be completed in a single visit. Biodentine is an effective substitute for dentine when combined with a composite resin restoration [10, 11].

TheraCal LC, manufactured by Bisco Inc. in Schaumburg, IL, USA, is a single-paste, light-cure calcium silicate-based material. Originally marketed as a pulp capping agent and protective liner for resin composites, this material's light-curing property enables direct placement of the final restoration without delays [12], unlike other water-based pulp capping materials. TheraCal LC has demonstrated success in treating deep caries and for indirect pulp capping procedures [13-16]. However, limited evidence supports its application in direct pulp capping procedures [17-20].

The success of laminate or layered restorations depends on the bond quality between the GICs or the CSCs and the overlying composite restoration. This bonding interface is critical in maintaining the restoration's structural integrity [21]. Establishing a well-secured hermetic seal is imperative to prevent microleakage, ensure the restoration's long-term durability, and prevent clinical and radiographic failures [22, 23]. This bonding not only enhances the overall performance of the restoration but also promotes seamless integration between different materials, ultimately contributing to the clinical success of the restoration [24].

Two different adhesion strategies are available: the etch and rinse strategy (ER), where the adhesive is applied after etching and rinsing, and the self-etch strategy (SE), which implies the application of self-etching primers without the need for etching and rinsing. The most recent generation of adhesives developed is the universal adhesive system (UA). These adhesives provide versatility and reduction in clinical steps. These adhesives can be applied to the tooth structures using any application approach (ER, SE, or selective etch) and can be used on a wide range of substrates; they can be used to bond to dentin and enamel for the placement of both direct and indirect restorations [25].

The wide variety of bonding agents currently poses a challenge for clinicians when selecting the optimal adhesive for laminate/ layered restorations. This challenge is particularly intricate when different intermediate materials are in consideration [26, 27]. This review addresses contemporary concepts regarding selecting adhesive agents at the interface between GICs or CSCs and the resin composite restoration. The review will facilitate decision-making and allow the selection of appropriate materials for predictable outcomes.

2. REVIEW

2.1. Layering over Conventional Glass Ionomers

An adequate bond at the interface between CGIC and composite resin is necessary for the success of the sandwich technique. The bond between these materials relies primarily on micromechanical adhesion, as they lack chemical bonding [28, 29]. Using phosphoric acid to etch CGIC before applying a composite resin restoration is still controversial. While certain studies have indicated that acid etching enhances the bonding strength between CGICs and resin composites by creating a porous surface that enables the bonding agent to infiltrate and form a hybrid-like layer [30, 31], other studies have found no consistent bond improvement [32-34] and others reported a decrease [35].

Etching and rinsing CGIC may cause moisture contamination during the setting of the material and may cause dissolution of the polyacrylate chains, altering their physical properties. Therefore, waiting for the initial setting to occur is mandatory before proceeding with the etching and rinsing procedure [33, 36]. Using SE adhesives may solve this problem since they do not require the rinsing step. Some studies reported that SE adhesives increase the shear bond strength (SBS) between composite resin and CGIC more significantly than ER adhesives [28, 37]. Zhang *et al*. [28] compared the micro shear bond strength (µSBS) of a resin composite to two CGICs (Fuji IX GP EXTRA, GC Corporation, Tokyo, Japan and Riva Self Cure, SDI Limited, Bayswater, Victoria, Australia) using four SE adhesives (Adper Scotchbond SE, Clearfil SE Bond, Clearfil S^3 Bond, and One Coat 7.0) and an ER adhesive (Adper Single Bond Plus) at three-time intervals (24 hours, 1 and 6 months). They reported that the ER adhesive showed significantly lower bond strength than the four SE adhesives at all time intervals. Furthermore, they observed no significant differences in bond strength among the SE adhesives. Using four different adhesives, Sharafeddin and Choobineh [37] evaluated the SBS between a composite resin and a CGIC (ChemFil Superior, Dentsply; German). The SE adhesives were reported to increase the SBS between both materials more significantly than the ER adhesive (Adper Single Bond 2). Moreover, they reported that mild SE adhesives (Clearfil SE Bond [pH=2]) performed better with CGIC (7.7 MPa) as compared to intermediate (OptiBond [pH=1.4]) (6.4 MPa) and strong SE adhesives (Adper Prompt L-Pop [pH=1]) (3.45 MPa). On the contrary, Jaberi Ansari *et al*. [38] assessed the µSBS of composite resin to a CGIC (Fuji II, GC International Corp., Tokyo, Japan) using an ER adhesive (Adper Single Bond) and various SE adhesives with different pH values (Adper Prompt L-Pop [pH=0.4], Clearfil SE Bond [pH=1.9], Clearfil Protect bond [pH=2], and AdheSE [pH=1.4]). They reported that the type and pH of SE adhesive had no significant effect on µSBS of resin composite to CGIC.

The literature reports that using a SE adhesive system on a half-set CGIC (before its initial setting) significantly increased the bond strength of the resin composite more than utilizing an ER adhesive system after the initial setting of the CGIC [29, 39, 40]. Furthermore, Kandaswamy *et al*. [40] reported that a mild SE adhesive agent (pH=2) applied over unset CGIC improved the bond strength of a resin composite as compared to the use of strong (pH=1) and intermediate (pH=1.4) SE bonding agents.

2.2. Layering over Resin-modified Glass Ionomers

The existing literature recommends the utilization of resin-modified glass ionomers (RMGI) over CGICs within the sandwich technique due to RMGI's superior mechanical properties, ability to seal, resistance to moisture, and stronger bonding with composites [30, 34, 38, 41]. RMGI achieves a chemical bond with composites through the co-polymerization of the residual and unreacted monomers (hydroxyethyl methacrylate [HEMA]) in the cured RMGI's superficial surface, interacting with adhesive systems or composite resins [42, 43].

Reports indicate that applying bonding agents enhances the bond strength between RMGI and composite [28, 44-48]. The bond strength of RMGI to composite resin may differ based on the specific adhesive system employed [28, 44, 45, 47]. In contrast to ER adhesives, SE adhesives have been shown to enhance the bond strength between RMGI and composite [29, 44, 45, 47]. Surface etching of RMGI with 37% phosphoric acid could compromise the surface layer by dissolving the fillers beneath the GIC's surface matrix. Consequently, the cohesive strength of RMGI reduces, potentially leading to a decrease in tensile and SBS between composite resin and GIC [29, 49].

Arora *et al*. [44] evaluated and compared the SBS of composite resin (Filtek Z-350 3M ESPE, St.Paul USA) to RMGI (Vitrebond 3M ESPE, St. Paul USA) using two different bonding agents: a 2-step ER(Adper Single Bond 2) and a 1-step SE adhesive (Adper Prompt L Pop). The maximum SBS values were recorded for Adper Prompt L Pop (5.86 *vs*. 4.64 MPa). After applying various adhesive systems, Bin-Shuwaish [47] investigated the SBS of different composites to RMGI (GC Fuji II LC, GC Corp., Tokyo, Japan). They reported that the SE adhesive (Clearfil SE Bond 2) has a higher SBS value for Filtek Z350 XT (3M ESPE) than the ER adhesive (OptiBond Solo Plus) (12.09 *vs*. 10.27 MPa). These observations were in line with other studies that showed that SE adhesives resulted in higher bond strengths between RMGI and composites than ER adhesives [43, 45, 50].

More studies need to be investigating the bond strength of resin composites to CGIC and RMGI using UAs. Hashem *et al*. [44] investigated the SBS of resin composite (N'Durance, Septodont, Louisville, USA) to RMGI (Fuji II LC, GC Corporation, Tokyo, Japan) and CGIC (Fuji IX GP, GC Corporation, Tokyo, Japan) in both SE and ER modes using Scotchbond Universal. They found no statistically significant variation in SBS bond strength between the two application modalities. In 2006, Knight *et al*. [51] proposed the simultaneous curing of unpolymerized composite resin and inactivated RMGI. Applying the co-curing technique using SE adhesives has been reported to improve the SBS between composite and RMGI [43].

2.3. Layering over Biodentine

When covered with a composite resin restoration, Biodentine has been reported as an appropriate dentine substitute [10, 11]. The quality of the adhesive bond between Biodentine and the composite material holds clinical significance as it influences the success and durability of the final restoration. Cengiz and Ulusoy [52] observed that after 12 minutes, 2-step ER adhesives (Prime & Bond NT) exhibited higher µSBS for composite restorations (Filtek Z250, 3M ESPE, St Paul, MN, USA) to Biodentine compared to 2-step SE adhesives (Clearfil SE Bond). Similarly, Meraji and Camilleri [53] reported that when Biodentine was allowed to set for 15 minutes, the SBS of composite resin (Evetric, Ivoclar vivadent, Liechtenstein) to Biodentine, in combination with a 2-step ER adhesive (Excite F), exceeded that observed with a 1-step SE adhesive (AdheSE One F). Mutluay and Mutulay [54] assessed the SBS of Biodentine to composite (Clearfil Majesty, Kuraray Dental, Tokyo, Japan) using three different adhesive systems (Adper Single Bond 2, Clearfil SE Bond, and Clearfil S3 Bond) after allowing Biodentine to set for 24 hours. Their study revealed that the SBS value for the 2-step ER adhesive (Adper Single Bond 2) (2.1 MPa) was significantly higher than that of the two-step SE adhesive (Clearfil SE Bond) (1.01 MPa). At the same time, no statistically significant differences were observed among the other adhesive options. Odabas *et al*. [55] investigated the SBS of resin composite (Clearfil Majesty, Kuraray Dental, Tokyo, Japan) to Biodentine using three different adhesive agents: Prime & Bond NT (2-step ER), Clearfil S3 (1-step SE), and Clearfil SE (2-step SE). They found no significant differences among all the adhesive systems at the same time intervals (12 minutes and 24 hours). Consequently, they concluded that the choice of adhesive system did not impact the bond strength of Biodentine.

The bond strength values of resin composites to Biodentine using UAs were investigated and compared to other adhesive systems. Keles and Simsek Derelioglu [56] assessed the SBS of a composite resin (Clearfil Majesty, Kuraray Noritake Dental Inc., Okayama, Japan) and a compomer (Dyract XP, Dentsply IH Ltd, United Kingdom) to Biodentine using three bonding systems (Clearfil SE Bond, Prime & Bond NT, and Clearfil Universal Bond). Composites had significantly higher SBS than Biodentine using the 2-step SE adhesive (Clearfil SE Bond) compared to the other adhesive agents tested (the 2-step ER and the UA system in the SE mode). The study found that the composite's mean SBS to Biodentine was significantly higher than the compomer's SBS regardless of the adhesive system used. This was in agreement with the results reported by Tulumbaci *et al*. [57], where they observed that resin composites (Filtek™ Z250; 3M ESPE, USA) had significantly higher SBS (9.34 MPa) to Biodentine than compomers (Dyract XP; LD Caulk/ Dentsply, USA) using Prime & Bond NT (7.58 MPa). Aksoy and Ünal [58] compared the SBS of a compomer (Dyract XP Bond) to Biodentine using various adhesive systems (Prime & Bond NT, Single Bond Universal, All Bond Universal, G-aenial Bond) at different time intervals (12 minutes, 24 hours, 48 hours, 72 hours, and 96 hours). They found no statistically significant difference between all the adhesive systems tested at each of the 5-time intervals. Carretero *et al*. [59] investigated the SBS between Biodentine and a nanohybrid composite resin (Grandio, VOCO GmbH, Cuxhaven, Germany), using different types of adhesives (Optibond FL, Solobond M, and Scotchbond Universal) at two-time intervals (12 minutes and 24 hours). The study reported a statistically significant difference among the adhesives at 12 minutes but not at 24 hours. The results showed that the three-step etch-and-rinse adhesive (Optibond FL) had higher SBS values than the 2-step ER adhesive (Solobond M) and the UA applied in both SE and etch-and-rinse modes (Scotchbond universal) after 12 minutes of Biodentine placement. Xavier *et al*. [60] studied the SBS between Biodentine and composite restorations (SDR, Dentsply DeTrey; Konstanz, Germany) flowable composite using two different adhesive agents (Clearfil Universal Bond Quick and Clearfil SE Bond 2) at two restoration times (12 minutes, 7 days). Clearfil Universal Bond Quick, used in the SE mode, showed statistically higher SBS values than Clearfil SE Bond 2 (2-step SE adhesive) at both time intervals. Similarly, Shin *et al*. [61] studied the SBS of Biodentine to composite resin (Filtek Z350, 3M ESPE, St. Paul, MN, USA) using different adhesive systems (Clearfil SE, AQ Bond Plus, and All-Bond Universal) and allowing Biodentine to set for 12 minutes. The study found that All-Bond Universal applied in the SE mode showed statistically higher SBS values than Clearfil SE Bond (2-step SE) and AQ Bond Plus (1-step SE). No significant differences were found in the SBS values reported for All Bond Universal applied in either the SE or ER mode or between All-Bond Universal applied in the ER mode and Clearfil SE. A study by Akbiyik *et al*. [62] evaluated the SBS of Biodentine to a resin composite (Filtek Ultimate, 3M ESPE St. Paul, USA) using different adhesive systems (Gluma 2 Bond, Clearfil SE Protect, Gluma Self-Etch, Clearfil S^3 Bond Plus, Gluma Bond Universal, and Clearfil S^3 Bond Universal) after leaving Biodentine to set for 12 minutes. They found no statistically significant difference regarding SBS between the adhesive agents (2-step ERvs. 2-step SE, 1-step SE *vs*. universal in the SE mode). Nekoofar *et al*. [63] conducted a study to assess the µSBS of a resin composite (Filtek Z350 XT, 3M/ESPE, St. Paul, USA) using various adhesive systems (Adper Single Bond 2, Clearfil SE Bond, All-Bond Universal) with Biodentine for setting periods examine the bond strength between ranging from 24 hours to one month and immediately after mixing. When All-Bond Universal was applied in the SE mode, it exhibited the highest µSBS for Biodentine allowed to set for 12 minutes, surpassing other adhesive systems. However, this particular adhesive agent displayed lower bond strengths to Biodentine after being allowed to set for one week and one month. Notably, extending the aging duration of Biodentine to one week led to a significant increase in bond strength values across all adhesive groups. Conversely, a one-month aging period for Biodentine resulted in significantly reduced bond strength values for the Clearfil SE Bond compared to those with a one-week incubation period. Tables **1** and **2** summarize adhesives' immediate and delayed mean bond strength values to Biodentine.

Table 1. Mean bond strength values of adhesives (MPa) to Biodentine (Immediate).

Study	3-step ER	2-step ER	2-step SE	1-step SE	Universal-SE	Universal -ER
Keles and Simsek Derelioglu [56].	-	Prime & Bond NT 10.65 ± 1.74	Clearfil SE 14.10 ± 2.83	-	Clearfil Universal Bond 11.52 ± 2.77	-
Carretero *et al*. [59]	Optibond FL 20.34 (6.63)	SoloBond M 16.98 (3.56)	-	-	ScotchBond Universal 13.65 (4.62)	ScotchBond Universal 15.63 (5.79)
Akbiyik *et al*. [62]	-	Gluma Bond 2 5.94 (3.06)	Clearfil SE protect Bond 9.21 (4.28)	Gluma Self-Etch 3.53 (2.09) Clearfil S3 Bond Plus 6.07 (3.28)	Gluma Bond Universal 4.51 (4.55) Clearfil S3 Bond Universal 6.55 (3.31)	-

(Table 1) contd.....

Study	3-step ER	2-step ER	2-step SE	1-step SE	Universal-SE	Universal -ER
Odabas *et al*. [55]	-	Prime & Bond NT 9.127 ± 3.161	Clearfil SE Bond 16.903 ± 8.112	Clearfil S3 Bond 11.057 ± 3.850	-	-
Xavier *et al*. [60]	-	-	Clearfil SE 2 3.62 (2.78)	-	Clearfil Universal Bond Quick 6.01 (3.31)	-
Shin *et al*. [61]	-	-	Clearfil SE 3.68 ± 1.01=	AQ Bond Plus 2.06 ± 0.57=	All-Bond Universal 6.87 ± 2.55	-
Nekoofar *et al*. [63]	-	Adper Single Bond 9.26 ± 2.66	Clearfil SE Bond 5.72 ± 3.23	-	All-Bond Universal 62.49 ± 16.39	-
Cengiz and Ulusoy [52]	-	Prime & Bond NT 13.99 (3.48)	Clearfil SE 11.45 (1.07)	-	-	-

Table 2. Mean bond strength values of adhesives (MPa) to Biodentine (Delayed).

Study	3-step ER	2-step ER	2-step SE	1-step SE	Universal-SE	Universal-TE
Odabas *et al*. [55]	-	Prime & Bond NT 15.990 ± 3.409	Clearfil SE Bond 19.559 ± 7.582	Clearfil S3 Bond 15.193 ± 3.344	-	-
Mutluay and Mutluay [54]	-	Adper Single Bond 2 2.10 ± 0.59	Clearfil SE Bond 1.01 ± 0.49	Clearfil S3 Bond 1.93 ± 0.85	-	-
Nekoofar *et al*. [63]	-	Adper Single Bond 9.26 ± 2.66	Clearfil SE Bond 5.72 ± 3.23	-	All-Bond Universal 62.49 ± 16.39	-
Xavier *et al*. [60]	-	-	Clearfil SE 2 3.62 (2.78)	-	Clearfil Universal Bond Quick 6.01 (3.31)	-
Carretero *et al*. [59]	Optibond FL 20.34 (6.63)	SoloBond M 16.98 (3.56)	-	-	ScotchBond Universal 13.65 (4.62)	ScotchBond Universal 15.63 (5.79)

Research findings indicate that UA systems, whether applied in SE or ER modes, do not exert a statistically significant influence on the bond strength of composite materials, as demonstrated by several studies [21, 58, 59, 61, 64]. Consequently, adequate bonding performance may be achieved without acid etching, simplifying the adhesive procedure. The favorable outcomes observed with UAs could be attributed to incorporating 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) into its composition. This monomer, previously employed by Clearfil SE, Kuraray, for years, was used in UA formulations following the expiration of its patent [65]. Research has revealed that the 10-MDP monomer has an affinity for hydroxyapatite and establishes a more efficient and stable bond with tooth structure than previously utilized acidic monomers. Hence, it may be capable of forming ionic chemical bonds with calcium ions found in Biodentine, thereby facilitating chemical adhesion and enhancing micromechanical attachment.

The literature remains unclear regarding the adhesive strategy that would give the highest bond strength between Biodentine and composite restoration. Some authors suggest the superiority of the SE over the ER adhesives [56, 66]. In contrast, others report that the ER systems provide an improved bond strength [52-54] or that the choice of the adhesive system is irrelevant [21, 55, 58, 59]. An absolute conclusion cannot be drawn from the studies investigating the bond strength values of resin composites to Biodentine using various adhesive systems. Therefore, their results can only serve as a basis for further interpretation. Moreover, it presents a challenge to compare findings from these investigations due to the diverse range of relevant parameters, including the type of restorative materials, the technical application, waiting periods, and time for restoration. Additionally, discrepancies in experimental methodologies arise, encompassing factors like load speed and the magnitude of the maximum load during bond strength measurement. Furthermore, factors associated with adhesives, such as the type of solvent employed (acetone *vs*. water), chemical constituents (bis-GMA, HEMA), hydrophobic monomers (10-MDP), and the adhesive's pH, can significantly influence the bonding quality of adhesives [52, 56-58, 61, 67, 68].

Overall, Biodentine should be allowed to mature long enough to achieve the required hardness to withstand the contraction forces of the restorative material [69]. Studies suggest that the final composite restoration should be done after at least 14 days to allow adequate setting and sufficient intrinsic maturation of the Biodentine, which has been related to improved SBS to resin composite [7, 21, 58, 63, 70-73]. If the final composite is to be placed in a subsequent session when the Biodentine is fully set, ER or UAs (SE mode) might be recommended. Nevertheless, suppose the final composite restoration will be performed during the same session. In that case, SE or UAs used in the SE mode might be recommended to avoid etching and rinsing the freshly set material [74-76].

2.4. Layering over TheraCal LC

When assessing the bonding strengths of Biodentine and TheraCal LC to resin composites, Biodentine has been reported to display the lowest bond strengths in several studies [7, 21, 52, 72, 77]. The higher bond strength observed with TheraCal LC may be attributed to HEMA, which facilitates chemical bonding with resin-based restorative materials [12].

Table 3. Mean bond strength values of adhesives (MPa) to theracal LC.

Study	3-step ER	2-step ER	2-step SE	1-step SE	Universal-SE	Universal-TE
Akbiyik *et al*. [62]	-	Gluma Bond 2 16.24	Clearfil SE protect Bond 11.25	Gluma Self-Etch 14.17 Clearfil S3 Bond Plus 12.02	Gluma Bond Universal 9.35 Clearfil S3 Bond Universal 8.5	-
Karadas *et al*. [78]	Adper Scotchbond Multipurpose 16.40 ± 5.01	-	Clearfil SE Bond 10.88 ± 4.03 Clearfil Protect Bond 11.18 ± 2.82	Clearfil S3 Bond 12.88 ± 4.28 OptiBond All-In-One 7.99 ± 3.02 G-aenial Bond 5.52 ± 2.73	-	-
AlZraikat *et al*. [79]	-	Adper Single bond 2 12.84 (1.56)	-	Xeno V+ 14.78 (3.51)	-	-
Rendžova *et al*. [69]	-	-	Clearfil SE Bond 19.24	-	One Coat 7 Universal 19.28	-
Sismanoglu *et al*. [64]	-	-	-	-	Clearfil S3 Bond Universal	Clearfil S3 Bond Universal
Cengiz and Ulusoy [52]	-	Prime & Bond NT 13.99 (3.48)	Clearfil SE 11.45 (1.07)	-	-	-

Meraji and Camilleri [53] reported that the bond strength between TheraCal LC and the composite material (Evetric, Ivoclar Vivadent, Liechtenstein) using the Excite F adhesive (a 2-step ER system) was higher than that achieved with AdhesSe One F (a 1-step SE adhesive). Akbiyik *et al*. [62] examined the bond strengths of TheraCal LC to a composite material (Filtek Ultimate, 3M ESPE St. Paul, USA) using various adhesive systems (Gluma 2 Bond, Clearfil SE Protect, Gluma Self-Etch, Clearfil S3 Bond Plus, Gluma Bond Universal, Clearfil S3 Bond Universal). According to their findings, the 2-step ER adhesive (Gluma 2 Bond) demonstrated the highest bond strength. Similarly, Karadas *et al*. [78] assessed the SBS to TheraCal LC using Scotchbond Multipurpose Bond, OptiBond All-in-One, and G-aenial Bond. The 3-step ER adhesive (Adper Scotchbond Multipurpose) exhibited significantly higher bond strength to TheraCal LC than the other adhesives. The study also noted that Clearfil SE Bond, Clearfil Protect Bond, and Clearfil S3 displayed significantly higher bond strengths to TheraCal LC than those achieved with OptiBond All-in-One and G-aenial Bond. These findings were not in agreement with the results reported by Cengiz and Ulusoy [52], where they found that the µSBS between the resin composite (Filtek Z250) and TheraCal LC, when applied with Clearfil SE Bond (a 2-step SE system), yielded the highest bond strength values compared to Prime & Bond (a 2-step ER adhesive). Observations from other studies suggest that the choice of the adhesive agent may not have a significant effect. For instance, AlZraikat *et al*. [79] assessed the SBS of TheraCal LC to resin composite (Filtek Z250) using two different adhesive systems: a 2-step ER adhesive (Adper Single Bond 2) and a 1-step SE adhesive (Xeno V+). Their findings showed no significant difference in the SBS of TheraCal LC to the resin composite between these two adhesive systems [25].

Investigations into the bond strength between TheraCal LC and resin composite using UAs in various application modes are limited. Rendžova *et al*. [69] examined the SBS of composite restorations (Brilliant EverGlow, Coltene Whaledent, AG, Alstatten, Switzerland) to TheraCal LC, employing a 2-step SE adhesive (Clearfil SE Bond) and a UA (One Coat 7 Universal) when applied in the SE mode. Their study revealed no significant difference in bond strength between these two adhesive options. Similarly, Sismanoglu *et al*. [64] assessed the µSBS of TheraCal LC to composite resin (Filtek Ultimate Flowable Restorative, 3M ESPE, St. Paul, MN, USA) using a UA (Clearfil S3 Bond Universal) in both ER and SE application modes. Their findings indicated no significant difference in bond strength between these two application modes of the UA. Table **3** summarizes the mean bond strength values of adhesives to TheraCal LC.

The variations in research findings may be attributed to the diverse research methodologies and specimen preparation approaches employed across the studies. The bond strength values between resin composite materials and TheraCal LC, better results were typically observed when ER or UA agents were used in the SE mode [53, 62, 78].

CONCLUSION

In conclusion, the success of the laminate or layered restoration relies heavily on achieving a reliable bond at the interface between the chosen dental materials, whether it be CGIC, RMGI, Biodentine, TheraCal LC, or composite resin. The choice of adhesive system plays a crucial role in determining the quality of this bond. For CGIC, using SE adhesives appears to be more beneficial than ER adhesives, particularly when applied to unset CGIC. However, the type and pH of the SE adhesive may also influence the bond strength, and further research is needed to establish the most optimal adhesive for CGIC. RMGI generally offers better mechanical properties and bonding with composites than CGIC. Surface etching of RMGI with phosphoric acid should be cautiously approached, as it may compromise the material's surface. Hence, SE adhesives are indicated between RMGI and composite resin. The literature on the most suitable adhesive strategy for Biodentine and composite restoration remains to be seen. The ER or UA used in the self-etch mode might be recommended if the final composite is placed in a subsequent session after Biodentine has fully set. TheraCal LC, on the other hand, tends to yield higher bond strengths when used in conjunction with ER or UA systems in the SE mode. It's essential to note that the choice of adhesive system and its application mode can vary across studies, leading to diverse results. Material composition, setting time, and adhesive properties also impact the bond strength. Therefore, a definitive conclusion regarding the superior adhesive strategy still needs to be discovered. Further research and standardization of methodologies are needed to provide more concrete recommendations for clinical practice.

LIST OF ABBREVIATIONS

MPa	=	Megapascal
ER	=	Etch and Rinse
SE	=	Self-etch
UA	=	Universal adhesive

CONSENT FOR PUBLICATION

Not applicable.

FUNDING

None.

CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

[1] Peumans M, Politano G, Bazos P, Severino D, Van Meerbeek B. Effective protocol for daily high-quality direct posterior composite restorations: Layering and finishing. J Adhes Dent 2020; 22(6): 597-613. PMID: 33491404

[2] Woolford M. Composite resin attached to glass laminate technique. J Dent 1993; 21(1): 31-8. http://dx.doi.org/10.1016/0300-5712(93)90047-T PMID: 8425981

[3] Duncan HF, Galler KM, Tomson PL, *et al.* European Society of Endodontology position statement: Management of deep caries and the exposed pulp. Int Endod J 2019; 52(7): 923-34. http://dx.doi.org/10.1111/iej.13080 PMID: 30664240

[4] Hashem D, Mannocci F, Patel S, Andiappan M. Clinical and radiographic assessment of the efficacy of calcium silicate clinical and radiographic assessment of the efficacy of calcium silicate indirect pulp capping : A randomized controlled clinical trial. J Dent Res 2015; 94: 562-8.

[5] Hashem D, Mannocci F, Patel S, Manoharan A, Watson TF, Banerjee A. Evaluation of the efficacy of calcium silicate *vs.* glass ionomer cement indirect pulp capping and restoration assessment criteria: A randomised controlled clinical trial—2-year results. Clin Oral Investig 2019; 23(4): 1931-9. http://dx.doi.org/10.1007/s00784-018-2638-0 PMID: 30232625

[6] Wilson A, McLean J. Glass-Ionomer Cement. Quintessence Publishing Co 1988; pp. 159-78.

[7] Deepa V, Dhamaraju B, Bollu I, Balaji T. Shear bond strength evaluation of resin composite bonded to three different liners: TheraCal LC, Biodentine, and resin-modified glass ionomer cement using universal adhesive: An *in vitro* study. J Conserv Dent 2016; 19(2): 166-70. http://dx.doi.org/10.4103/0972-0707.178696 PMID: 27099425

[8] Sakr A, Soliman M, Shalaby H. Microshear bond strength of direct composite to dentine substitutes using two adhesive stratigies. Egypt Dent J 2015; 61: 857-36.

[9] Arandi NZ, Thabet M. Minimal intervention in dentistry: A literature review on biodentine as a bioactive pulp capping material. Biomed Res Int 2021; 2021: 5569313. http://dx.doi.org/10.1155/2021/5569313

[10] Koubi G, Colon P, Franquin JC, *et al.* Clinical evaluation of the performance and safety of a new dentine substitute, Biodentine, in the restoration of posterior teeth — A prospective study. Clin Oral Investig 2013; 17(1): 243-9. http://dx.doi.org/10.1007/s00784-012-0701-9 PMID: 22411260

[11] Camilleri J. Investigation of Biodentine as dentine replacement material. J Dent 2013; 41(7): 600-10. http://dx.doi.org/10.1016/j.jdent.2013.05.003 PMID: 23685034

[12] Arandi NZ, Rabi T. TheraCal LC: From biochemical and bioactive properties to clinical applications. Int J Dent 2018; 2018: 3484653.

[13] Gurcan AT, Seymen F. Clinical and radiographic evaluation of indirect pulp capping with three different materials: A 2-year follow-up study. Eur J P 2019; 20(2): 105-10. PMID: 31246084

[14] Mahapatra J, Nikhade P, Patel A, Taori P, Relan K. Comparative evaluation of the efficacy of light-cured calcium hydroxide and a fourth-generation calcium silicate cement (TheraCal LC) as indirect pulp capping materials in patients with deep carious lesions: A randomized parallel-group clinical trial. Cureus 2022; 2022(9): 1-15.

[15] Rahman B, Goswami M. Comparative evaluation of indirect pulp therapy in young permanent teeth using biodentine and theracal: A randomized clinical trial. J Clin Pediatr Dent 2021; 45(3): 158-64. http://dx.doi.org/10.17796/1053-4625-45.3.3 PMID: 34192759

[16] Betamar N. Evaluation of the success rate of indirect pulp capping treatment using different materials: A clinical study. Sci J Univ Benghazi 2020; 33(2) http://dx.doi.org/10.37376/sjuob.v33i2.7

[17] Kunert M, Kaminska RW, Galita G, *et al.* The cytotoxicity and genotoxicity of bioactive dental materials. Cells 2022; 11(20): 3238. http://dx.doi.org/10.3390/cells11203238 PMID: 36291107

[18] Jeanneau C, Laurent P, Rombouts C, Giraud T, About I. Light-cured tricalcium silicate toxicity to the dental pulp. J Endod 2017; 43(12): 2074-80. http://dx.doi.org/10.1016/j.joen.2017.07.010 PMID: 29032813

[19] Bakhtiar H, Nekoofar MH, Aminishakib P, *et al.* Human pulp responses to partial pulpotomy treatment with theracal as compared with biodentine and proRoot MTA: A clinical trial. J Endod 2017; 43(11): 1786-91. http://dx.doi.org/10.1016/j.joen.2017.06.025 PMID: 28822566

[20] Manaspon C, Jongwannasiri C, Chumprasert S, *et al.* Human dental pulp stem cell responses to different dental pulp capping materials. BMC Oral Health 2021; 21(1): 209. http://dx.doi.org/10.1186/s12903-021-01544-w PMID: 33902558

[21] Hashem DF, Foxton R, Manoharan A, Watson TF, Banerjee A. The physical characteristics of resin composite–calcium silicate interface as part of a layered/laminate adhesive restoration. Dent Mater 2014; 30(3): 343-9. http://dx.doi.org/10.1016/j.dental.2013.12.010 PMID: 24418628

[22] Hilton TJ. Keys to clinical success with pulp capping: A review of

the literature. Oper Dent 2009; 34(5): 615-25.
http://dx.doi.org/10.2341/09-132-0 PMID: 19830978

[23] Lee JS, Yahya NA, Gonzalez MAG. Revisiting the microleakage in tooth-coloured sandwich restorations. Ann Dent 2021; 28: 65-79.
http://dx.doi.org/10.22452/adum.vol28no11

[24] Ansari SH, Alkhalil G, Alhaj S. Longevity of posterior composite restorations and their reasons for failure: A systematic review. Arch Pharm Pract 2023; 14(3): 14-20.
http://dx.doi.org/10.51847/AzwMtDv6LU

[25] Arandi NZ. The classification and selection of adhesive agents; an overview for the general dentist. Clin Cosmet Investig Dent 2023; 15(9): 165-80.
http://dx.doi.org/10.2147/CCIDE.S425024 PMID: 37692095

[26] Arandi N, Thabet M. Knowledge and attitudes of dentists toward adhesive system selection: A cross-sectional study from Palestine. J Int Soc Prev Community Dent 2020; 10(1): 107-15.
http://dx.doi.org/10.4103/jispcd.JISPCD_385_19 PMID: 32181228

[27] Kusumasari C, Aprillia I, Wijayanti WM, Abdou A. Survey of adhesive systems knowledge among conservative dentistry specialist dentist in Indonesia. J Indones Dent Assoc 2023; 6(2): 75-85.

[28] Zhang Y, Burrow MF, Palamara JEA, Thomas CDL. Bonding to glass ionomer cements using resin-based adhesives. Oper Dent 2011; 36(6): 618-25.
http://dx.doi.org/10.2341/10-140-L PMID: 21864124

[29] Gopikrishna V, Abarajithan M, Krithikadatta J, Kandaswamy D. Shear bond strength evaluation of resin composite bonded to GIC using three different adhesives. Oper Dent 2009; 34(4): 467-71.
http://dx.doi.org/10.2341/08-009-L PMID: 19678453

[30] Pamir T, Şen BH, Evcin Ö. Effects of etching and adhesive applications on the bond strength between composite resin and glass-ionomer cements. J Appl Oral Sci 2012; 20(6): 636-42.
http://dx.doi.org/10.1590/S1678-77572012000600008 PMID: 23329245

[31] Hinoura K, Moore BK, Phillips RW. Tensile bond strength between glass ionomer cements and composite resins. J Am Dent Assoc 1987; 114(2): 167-72.
http://dx.doi.org/10.14219/jada.archive.1987.0021 PMID: 3546455

[32] Subrata G, Davidson CL. The effect of various surface treatments on the shear strength between composite resin and glass-ionomer cement. J Dent 1989; 17(1): 28-32.
http://dx.doi.org/10.1016/0300-5712(89)90004-3 PMID: 2645330

[33] Sheth JJ, Jensen ME, Sheth PJ, Versteeg J. Effect of etching glass-ionomer cements on bond strength to composite resin. J Dent Res 1989; 68(6): 1082-7.
http://dx.doi.org/10.1177/00220345890680060501 PMID: 2681306

[34] Bona ÁD, Pinzetta C, Rosa V. Effect of acid etching of glass ionomer cement surface on the microleakage of sandwich restorations. J Appl Oral Sci 2007; 15(3): 230-4.
http://dx.doi.org/10.1590/S1678-77572007000300014 PMID: 19089135

[35] Wexler G, Beech DR. Bonding of a composite restorative material to etched glass ionomer cement. Aust Dent J 1988; 33(4): 313-8.
http://dx.doi.org/10.1111/j.1834-7819.1988.tb04185.x PMID: 3075453

[36] Aggart SET, Pearson GJ. The effect of etching on glass polyalkenoate cements. J Oral Rehabil 1991; 18(1): 31-42.
http://dx.doi.org/10.1111/j.1365-2842.1991.tb00027.x PMID: 1904916

[37] Sharafeddin F, Choobineh MM. Assessment of the shear bond strength between nanofilled composite bonded to glass-ionomer cement using self-etch adhesive with different pHs and total-etch adhesive. J Dent 2016; 17(1): 1-6.
PMID: 26966701

[38] Ansari JZ, Panahandeh N, Shafiei TZS, Baghban AA. Effect of self-etching adhesives on the bond strength of glass-ionomer cements. J Dent 2014; 11(6): 680-6.
PMID: 25628698

[39] Gupta R, Mahajan S. Shear bond strength evaluation of resin composite bonded to GIC using different adhesives. J Clin Diagn Res 2015; 9(1): ZC27-9.
http://dx.doi.org/10.7860/JCDR/2015/10224.5462 PMID: 25738081

[40] Venkateshbabu N, Porkodi I, Kandaswamy D, Rajan KJ. Shear bond strength evaluation of resin composite bonded to glass-ionomer cement using self-etching bonding agents with different pH: *In vitro* study. J Conserv Dent 2012; 15(1): 27-31.
http://dx.doi.org/10.4103/0972-0707.92602 PMID: 22368331

[41] Li J, Liu Y, Liu Y, Söremark R, Sundström F. Flexure strength of resin-modified glass ionomer cements and their bond strength to dental composites. Acta Odontol Scand 1996; 54(1): 55-8.
http://dx.doi.org/10.3109/00016359609003510 PMID: 8669242

[42] Manihani ADS, Mulay S, Beri L, Shetty R, Gulati S, Dalsania R. Effect of total-etch and self-etch adhesives on the bond strength of composite to glass-ionomer cement/resin-modified glass-ionomer cement in the sandwich technique – A systematic review. Dent Res J 2021; 18(1): 72.
http://dx.doi.org/10.4103/1735-3327.326645 PMID: 34760063

[43] Boruziniat A, Gharaei S. Bond strength between composite resin and resin modified glass ionomer using different adhesive systems and curing techniques. J Conserv Dent 2014; 17(2): 150-4.
http://dx.doi.org/10.4103/0972-0707.128055 PMID: 24778512

[44] Kundabala M, Parolia A, Thomas MS, Pai V, Arora V. Comparison of the shear bond strength of RMGIC to a resin composite using different adhesive systems: An *in vitro* study. J Conserv Dent 2010; 13(2): 80-3.
http://dx.doi.org/10.4103/0972-0707.66716 PMID: 20859480

[45] Shokripour M, Safari M, Kasraie S. Evaluation of micro-shear bond strength of resin modified glass-ionomer to composite resins using various bonding systems. J Conserv Dent 2013; 16(6): 550-4.
http://dx.doi.org/10.4103/0972-0707.120956 PMID: 24347892

[46] Becci ACO, Benetti MS, Domingues NB, Giro EMA. Bond strength of a composite resin to glass ionomer cements using different adhesive systems. Rev Odontol UNESP 2017; 46(4): 214-9.
http://dx.doi.org/10.1590/1807-2577.01717

[47] Shuwaish BMS. Shear bond strength of bulk-fill composites to resin-modified glass ionomer evaluated by different adhesion protocols. Clin Cosmet Investig Dent 2020; 12: 367-75.
http://dx.doi.org/10.2147/CCIDE.S273842 PMID: 32982465

[48] Barcellos DC, Petrucelli N, Gonçalves SEP, Palazon MT, Sobue BMG, Pucci CR. What is the best protocol for bonding resin-modified glass ionomer cement to composite resin? Braz Dent Sci 2015; 18(2): 103-8.
http://dx.doi.org/10.14295/bds.2015.v18i2.1077

[49] Kermanshah H, Omrani LR, Hemati O, Pedram P, Ahmadi E. Modified microtensile bond strength of glass ionomer to composite resin using universal adhesive in self-etch and total-etch modes. Open Dent J 2020; 14(1): 390-5.
http://dx.doi.org/10.2174/1874210602014010390

[50] Pattanaik N, Chandak MG, Das A. Comparative study to evaluate shear bond strength of RMGIC to composite resin using different adhesive systems. Contemp Clin Dent 2012; 3(3): 252-5.
http://dx.doi.org/10.4103/0976-237X.103613 PMID: 23293476

[51] Knight GM, McIntyre JM, Mulyani . Bond strengths between composite resin and auto cure glass ionomer cement using the co-cure technique. Aust Dent J 2006; 51(2): 175-9.
http://dx.doi.org/10.1111/j.1834-7819.2006.tb00423.x PMID: 16848267

[52] Cengiz E, Ulusoy N. Microshear bond strength of tri-calcium silicate-based cements to different restorative materials. J Adhes Dent 2016; 18(3): 231-7.
PMID: 27045140

[53] Meraji N, Camilleri J. Bonding over dentin replacement materials. J Endod 2017; 43(8): 1343-9.
http://dx.doi.org/10.1016/j.joen.2017.03.025 PMID: 28662878

[54] Mutulay A, Mutulay M. Characterisation of the calcium silicate-based cement–composite interface and the bonding strength with total-etch or single/twostage self-etch adhesive systems. Aust

Endod J 2021; 48(3): 501-9.

[55] Odabaş ME, Bani M, Tirali RE. Shear bond strengths of different adhesive systems to biodentine. ScientificWorldJournal 2013; 2013: 1-5.
http://dx.doi.org/10.1155/2013/626103 PMID: 24222742

[56] Keles S, Derelioglu SS. Shear bond strength of composite and compomer to biodentine® applied with various bonding agents: An ,*in-vitro* study. J Dent Fac Atatürk Univ 2019; 29(1): 49-54.

[57] Tulumbaci F, Almaz M, Arikan V, Mutluay M. Shear bond strength of different restorative materials to mineral trioxide aggregate and Biodentine. J Conserv Dent 2017; 20(5): 292-6.
http://dx.doi.org/10.4103/JCD.JCD_97_17 PMID: 29386773

[58] Aksoy S, Ünal M. Shear bond strength of universal adhesive systems to a bioactive dentin substitute (Biodentine®) at different time intervals. Stomatolog Dis Sci 2017; 1: 116-22.
http://dx.doi.org/10.20517/2573-0002.2017.07

[59] Carretero V, Giner-Tarrida L, Peñate L, Arregui M. Shear bond strength of nanohybrid composite to biodentine with three different adhesives. Coatings 2019; 9(12): 783.
http://dx.doi.org/10.3390/coatings9120783

[60] Xavier MT, Costa AL, Caramelo FJ, Palma PJ, Ramos JC. Evaluation of the interfaces between restorative and regenerative biomaterials used in vital pulp therapy. Materials 2021; 14(17): 5055.
http://dx.doi.org/10.3390/ma14175055 PMID: 34501145

[61] Shin H, Kim M, Nam O, Lee H, Choi S, Kim K. Shear bond strength comparison of different adhesive systems to calcium silicate-based materials. J Korean Acad Pediatr Dent 2018; 45(4): 445-54.
http://dx.doi.org/10.5933/JKAPD.2018.45.4.445

[62] Akbiyik SY, Bakir EP, Bakir S¸. Evaluation of the bond strength of different pulp capping materials to dental adhesive systems: An *in vitro* study. J Adv Oral Res 2021; 12(2): 286-95.
http://dx.doi.org/10.1177/2320206821997983

[63] Nekoofar MH, Motevasselian F, Mirzaei M, Yassini E, Pouyanfar H, Dummer PMH. The micro-shear bond strength of various resinous restorative materials to aged biodentine. Iran Endod J 2018; 13(3): 356-61.
PMID: 30083206

[64] Sismanoglu S, Bilmez YZ, Gurcan AT, Gumustas B. Influence of application mode of universal adhesive on the surface morphology, elemental composition and bond strength of calcium silicate-based cements to composite resin: A SEM-EDX microanalysis study. J Adhes Sci Technol 2021; 0(0): 1-14.

[65] Alex G. Universal adhesives: The next evolution in adhesive dentistry? Compend Contin Educ Dent 2015; 36(1): 15-26.
PMID: 25822403

[66] Stuss KM, Nowak J, Rzepkowska BE. Bond strength of Biodentine to a resin-based composite at various acid etching times and with different adhesive strategies. Dent Med Probl 2019; 56(1): 39-44.
http://dx.doi.org/10.17219/dmp/103589 PMID: 30835973

[67] Abdullah HA, Al-Ibraheemi ZA, Hanoon ZA, Haider J. Evaluation of shear bond strength of resin-based composites to biodentine with three types of seventh-generation bonding agents: An *in vitro* study. Int J Dent 2022; 2022: 2830299.

[68] Li X, De Munck J, Van Landuyt K, Pedano M, Chen Z, Van Meerbeek B. How effectively do hydraulic calcium-silicate cements re-mineralize demineralized dentin. Dent Mater 2017; 33(4): 434-45.
http://dx.doi.org/10.1016/j.dental.2017.01.015 PMID: 28233602

[69] Rendzova V, Apostolska S, Kostadinovska E, *et al.* Evaluation of bond strength of one step and two steps self-etch adhesive agents with two different pulp-capping materials. Stomatol Glas Srb 2020; 67(2): 75-82.
http://dx.doi.org/10.2298/SGS2002075R

[70] Ha HT. The effect of the maturation time of calcium silicate-based cement (Biodentine™) on resin bonding: An *in vitro* study. Appl Adhes Sci 2019; 7(1): 1-13.
http://dx.doi.org/10.1186/s40563-019-0118-7

[71] Talwar S, Sultana N, Nawal RR, Chaudhry S, Sivakumar M. Effect of acid etching on the micro-shear bond strength of resin composite–calcium silicate interface evaluated over different time intervals of bond aging. J Conserv Dent 2018; 21(2): 194-7.
http://dx.doi.org/10.4103/JCD.JCD_167_17 PMID: 29674824

[72] Singla M, Wahi P. Comparative evaluation of shear bond strength of biodentine, endocem mineral trioxide aggregate, and theraCal LC to resin composite using a universal adhesive: An *in vitro* study. Endodontology 2020; 32(1): 14.
http://dx.doi.org/10.4103/endo.endo_7_19

[73] Mustafa RM, Al-Nasrawi SJ, Aljdaimi AI. The effect of biodentine maturation time on resin bond strength when aged in artificial saliva. Int J Dent 2020; 2020: 8831813.
http://dx.doi.org/10.1155/2020/8831813

[74] Palma P, Marques J, Falacho R, Vinagre A, Santos J, Ramos J. Does delayed restoration improve shear bond strength of different restorative protocols to calcium silicate-based cements? Materials 2018; 11(11): 2216.
http://dx.doi.org/10.3390/ma11112216 PMID: 30413054

[75] Palma PJ, Marques JA, Antunes M, Falacho RI, Sequeira D, Roseiro L. Effect of restorative timing on shear bond strength of composite resin / calcium silicate – based cements adhesive interfaces. Clin Oral Investig 2020; 25(5): 3131-9.
PMID: 33047203

[76] Çolak H, Tokay U, Uzgur R, Uzgur Z, Ercan E, Hamidi MM. The effect of different adhesives and setting times on bond strength between Biodentine and composite. J Appl Biomater Funct Mater 2016; 14(2): 0.
http://dx.doi.org/10.5301/jabfm.5000266 PMID: 27149941

[77] Samman M, Barakat O, Fares H. Bonding ability of different liners to bulk-fill resin composite using silane-containing adhesive. Egypt Dent J 2017; 63(4): 2905-13.
http://dx.doi.org/10.21608/edj.2017.76344

[78] Karadas M, Cantekin K, Gumus H, Ateş SM, Duymuş ZY. Evaluation of the bond strength of different adhesive agents to a resin-modified calcium silicate material (TheraCal LC). Scanning 2016; 38(5): 403-11.
http://dx.doi.org/10.1002/sca.21284 PMID: 26553783

[79] Alzraikat H, Taha NA, Qasrawi D, Burrow MF. Shear bond strength of a novel light cured calcium silicate based-cement to resin composite using different adhesive systems. Dent Mater J 2016; 35(6): 881-7.
http://dx.doi.org/10.4012/dmj.2016-075 PMID: 27680033