Bond strength evaluation of two bioactive liners and glass ionomer cement, bonded to resin composite: A comparative study

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الخلاصة

الغرض من هده الدراسة هي مقارنة الربط القصي بين الحشوات (الراتنجية) والمواد العازلة (البطائن) وهي: البايودنتين و الثريكال (وهما مادتان ذات نشاط حيوي) ومادة الكلاس ايونومر التقليدي.

ابتدا العمل بهدا البحث بعمل (٣٠) قالب اكريليكي يحتوي على فجوة وسطية بقطر (٥)ملم وارتفاع (٢)ملم، قسمت الى ثلاثة مجاميع وكما يلي:

١) المجموعة الاولى (A): ملئت بمادة البايودنتين.
٢) المجموعة الثانية (B): ملئت بمادة الثريكال.
٣) لمجموعة الاولى (C): ملئت بمادة الكلاس ايونومر التقليدي.

بعد ذلك تم طلي الفجوات المملوئة بالمواد السنية العازلة(البطائن)، بالمادة السنية الرابطة (نظام الربط العام)، وبعد تصلبه (باستعمال الجهاز الضوئي) وضع الراتنج في وسط المواد التي ملئت الفجوات ولجميع العينات باستعمال انبوب بلاستيكي بارتفاع (٢)ملم وبقطر (٤)ملم ، ثم تم تصليب الراتنج لمدة (٢٠) ثانية باستعمال الجهاز الضوئي التصلبي.

لقد تبين من النتائج الاحصائية، ان قوة الربط القصي لمادة الثريكال هو الاعلى (وجود فرق احصائي كبير).بينما كانت قوة الربط القصي لمادة البايودنتين هو الاقل احصائيا. كما اوضحت النتائج الاحصائية بان قوة الربط القصي في مجاميع الثريكال ومجاميع الكلاس ايونومر هي اعلى بكثير من مجاميع البايودنتين ، بينما كانت مجموعة الثريكال (B) اعلى احصائيا من المجموعة (C) الكلاس ايونومر وكما يلي:

١. مجموعة (B) هي اعلى بكثير من مجموعة (A).
٢. مجموعة (C) هي اعلى بكثير من مجموعة (A).
٣. مجموعة (B) هي اعلى من مجموعة (C).

كلمات المفتاح:

قوة الربط القصي،الثريكال، البايودنتين، نظام الربط العام، الراتنج

A b s t r a c t

Aims: The mechanical properties of cements, as well as their adhesive properties, are important factors that influence the durability of restorations in the oral cavity. So the aim of this study is to compare and evaluate the bond strength of resin composite to underlying bioactive materials (Biodentine & Therecal) and conventional Glassionommer cement using single bond adhesive system and characterizing their failure modes with (10X magnification).

Materials and Methods: 30 acrylic blocks containing a central hole with a 5mm diameter and a 2mm height were prepared and divided into three groups of 10 samples each based on the liner used as Group A Biodentine (BD), Group B Therecal (TLC), and Group C chemical cure glassionomer cement (GIC). The resin composite of 4 mm diameter and 2 mm height was then bonded to each sample using universal adhesive. Shear bond strength (SBS) analysis was performed at a cross-head speed of 0.5 mm/min.

Statistical Analysis: Statistical analysis was performed with one-way analysis of variance (ANOVA) and least significant difference (LSD) tests were $P>0.05$ (Non-significant), $P<0.05$ (significant), $P<0.001$ (highly significant) using Statistical Package for the Social Sciences (SPSS) version 19.

Results: The results showed that the highest mean of SBS was in group B (TLC) (21.79 Mpa). While the lowest mean of SBS was scored by group A (BD) (6.5490 Mpa). Both group B (TLC) and group C(GIC) showed a very high significant difference ($p=0.000$) more than group A (BD) while group B(TLC) showed a significant difference ($p=0.001$) higher than group C (GIC) . The observed mode of failure were predominately cohesive in group A (BD), in group B (TLC) were adhesive and mixed while group C (GIC) were shown cohesion and a mixed mode of failure

Conclusions: This present study concludes that; Both TLC and GIC showed adequate bond strength to be used immediately as a direct liner beneath composite resin in single appointment. While newly set BD showed weak bond strength with composite, which mean it is better to use it in two-stage filling procedure.

Keywords: BiodentineTM (BD); Theracal(TLC) ; universal adhesive; glass ionomer (GIC);

Introduction:

A major drawback of traditional self-cured CaOH materials is high solubility and dissolution over time (within one to 2 years after application) in tissue fluids. Fluids from restoration leakage, dentinal tubules ,or the pulp may cause the disappearance of this type of lining material and the formation of voids/defects in reparative dentine underneath the capping.[1] This can lead to a failure of the definitive seal against bacterial invasion and restoration failure.[2] and may cause a decrease in bonding strengths of the restoration to the tooth.[3]

Bioactivity refers to apatite-forming ability while bio mineralization is the ability to get anchored to the underlying dentin by the formation of a mineral-rich interfacial layer and a tag-like structure extending from the interfacial layer to the dentinal tubules.[4]

Newer resin-based materials based on the MTA and other high calcium releasing materials have superior long-term sealing ability and they have the potential for greater stimulation of reparative dentin.[5]

TheraCal LC and Biodentine (Septodont) is a base materials have the potential to seal dentin, stop microleakage, almost eliminate sensitivity, and even promote pulpal healing. So, instead of merely replacing tooth, we hope to stimulate the formation of tooth.[6]. They are calcium silicate-based bioactive liners that are proposed as alternatives to glass ionomers (GIs).

Biodentine was developed by Septodont‘s Research Group as a new class of dentin material which could conciliate high mechanical properties, excellent biocompatibility and bioactive behavior. It is a two-component material. The powder part include tricalcium silicate (80%), zirconium oxide, calcium carbonate, and oxide. Liquid part is an aqueous solution containing calcium chloride which accelerates the system and partially modifid polycarboxylate as super plasctizing agent to reduce the water content, which decreases the setting time to harden within 9 to 12 minutes. Biodentine is claimed to possess mechanical properties sufficient to withstand occlusal load when protected with composite resin material**.**[7]

TheraCal LCTM (TLC) is a novel light-cured mineral trioxide aggregate (MTA)-filled, resin-modified (RM) calcium silicate cement and was given approval as a liner under composite

restorations aiming to achieve a bond between the different layers of materials and as a pulp protectant. The chemical and physical properties of TLC were reported more calcium release than ProRoot MTA and Dycal. It was reported that calcium silicate-based materials showed apatite formation at a faster rate than calcium hydroxide-based materials. Recently, studies proved that the bond strength of TheraCal methacrylatebased composite was significantly higher than that with silorane-based composites and GI cement. [4]

Glass ionomer cement (GIC) was developed and first presented by Wilson and Kent in 1972[8]. GICs exhibit several clinical advantages such as physico-chemical bonding to tooth structures[9], fluoride release, and low coefficient of thermal expansion[10]. However, these materials have some clinical limitations, such as prolonged setting time, moisture sensitivity during initial setting, dehydration, and rough surface texture, which can hamper mechanical resistance **[**11**]**

One of the most recent adhesive system in dentistry is 'universal' or 'multi-mode' adhesives. These materials are simplified adhesives, usually containing all bonding components in a single bottle. Universal adhesives may be applied either in etch-and-rinse or self-etching bonding approaches, according to manufacturers' claims. [12]

In this study we evaluated the bond strength of methacrylate-based composites, with Theracal after polymerization (20s), new set (after12minute) Biodentine and a new set GIC (after6 minut) using universal adhesive system as a self-etch technique.

MATERIALS AND METHODS

The materials used in this study included Resin modified Cal calcium silicate cement TheraCal LCTM, Bisco, tricalcium silicate-based cement (Biodentine®, ZiZine, France), GIC(chemical cure promedica Germany), Meth acrylate based composite resin (Filtek™ Z350XT, 3m ESPE, USA), universal universal dental adhesive system (single bond universal, 3m ESPE, USA).The composition and the mode of application of Biodentine®, Theracal, resin composites ,GIC, as well as universal dental adhesive system are listed in Table (1).

Specimens Fabrication.

In this in vitro study, 30 acrylic blocks containing a central hole with a 5mm diameter and a 2mm height were prepared and categorize as follow:

Group A: 10 blocks were fully filled with Biodentin(BD) according to manufacturer instruction and wait (12min.) for setting.

Group B: 10 blocks were fully filled with Theracal(TLC) according to manufacturer instructions.

Group C: 10 blocks were fully filled with chemical cure glassionomer cement(GIC) according to manufacturer instruction and wait (6min.) for setting,

Universal adheasive,(singl bond universal 3m ESPE, USA) was applied on BD/TLC/CGIC surfaces according to the manufacturers' instructions as (Apply adhesive with micro brush and rub it in for 20 s, then direct a gentle stream of oil free air for 5 s until the adhesive no longer moves and solvent has evaporated, and light-cured for 10 s.)

After the bonding procedure, the resin composite (Filtek™ Z350XT – shade A2, 3M ESPE Dental Products, MN, USA) was applied at the center of the liners material by placing the composite into transparent plastic hole (2 mm high and 4 mm in diameter), so that the composite can be packed into the hole in one increment (2mm thickness) using small burnisher, the composite was then covered with a celluloid strip and microscopic glass slide, (200 gm.) pressure had been applied for one minute to expel excess material from the mold and to reduce voids .The tip of the light-curing unit should be in intimate contact with the glass slide. The composite specimens were cured with a light-emitting diode light cure (china) with an intensity of 1,200 mW/cm2 for 20 seconds from the top surface.

The specimens were stored at 37C in 100% humidity for 24 hours in incubator. All the samples were then loaded into a universal testing machine to measure the shear bond strengths.

Shear bond strength test:

Each block was secured in a universal testing machine (Laryee, China). Using a stainless steel chisel-shaped rod with across head speed 0.5 mm/min' until bond failure were occurred in Newton , then converted to MPa by dividing the peak break load by the cross-sectional area of the bonded interface (12.57mm^2).

Types of failure analysis:

The specimens and broken parts were examined with 10X magnification to determine the mode of failure between composite and BD/TC/CGIC surfaces. Failure was assessed as either adhesive failure showing a completely smooth surface of composite, cohesive failure appearing as small particles of materials (BD/TLC/CGIC) was attached to all composite interface or mixed (combination of adhesive failure and cohesive failure) [13] .

Statistical analysis:

Data were analyzed using the Statistical Package for the Social Sciences statistical software(SPSS ,version 19).The effect of intermediate agents on the shear bond strength were compared using one-way analysis of variance (ANOVA) and least significant difference (LSD) tests were $P>0.05$ (Non-significant), $P<0.05$ (significant), $P<0.001$ (highly significant).

Result

The means, the maximum (Max) and minimum (Min) and standard deviation (SDs) values of shear bond strength (SBS) are shown in table (2), the least significant differences (LSDs) ($p= P<0.000$) are shown in table (3) and were analyzed using one-way ANOVA test.

The results showed that the highest mean of Shear bond strength was group B (TLC) (21.79 Mpa). While the lowest mean of Shear bond strength was scored by group A (BD) (6.5490 Mpa). (Fig 1). Both group B(TLC) and group C(GIC) showed a very high significant difference ($p=0.000$) more than group A (BD) while group B(TCL) showed a significant difference ($p=0.001$) higher than group C (GIC) . The observed mode of failure were predominately cohesive in group A (BD), in group B (TCL) were adhesive and mixed while group C (GIC) were shown cohesion and a mixed mode of failure (Fig 2)

Table 1: Composition of materials used in this study

Material	Manufacturer	Composition	**Mode of application**
calcium silicate-based capping materials	Biodentine®, ZiZine, France	Tricalcium silicate,calcium carbonate(filler),Zirconium oxide(radiopacifier) and a water based liquid composed of calicium chloride as a water-reducing agent for shorter initial and final setting time, as it also accelerates the rate of early strength development.	Mixing premeasured unit doses capsules in a high-speed amalgamator for 30 s
Resin modified calcium silicate cement	TheraCal LCTM, Bisco, Inc. Schamburg,IL USA	Portland cement type III. <60% MA, polyethleneglycol dimethacrylate <50%Barium zirconate <10%	Inject the material into the cavity in 1 mm increments Light cure each increment for 20s Light polymerization for 20s
calcium silicate cement	Glass ionemer cement chemical cure promedica Germany	powder: Ca Aluminum silicat containing fluoride and phosphate. Liquid: polyacrylic acid 5o%,itatonic acid co-polymerand water	mixing 1 scoop powder with 1 drop liquid for 40s
Nanofill composite resin	Filtek™ Z350XT, 3M ESPE, USA	The fillers contain: 20 nm nanosilica fillers, 5.00–20.00 nm agglomerates zirconia/silica particles, 0.60–1.40 um clusters particle size The monomers contain :Bis-GMA, UDMA TEGDMA, PEGDMA, Bis-EMA	Light polymerize for 20 s
Universal dental adhesive system	Single bond universal 3M ESPE, , USA	MDP phosphate monomer, dimethacrylate resins, HEMA, vitrebond copolymer, filler, ethanol, water, initiators, silane, pH=2.7	Scrub in for 20 s, air dry for 5 s or until the adhesive does not move Light cure for 10 s

Table (2): Shear bond strength in (Mpa) for all groups:

Group	N	Mean	SD	Min	Max
A	10	6.5490	.45703	5.88	7.15
B	10	17.3790	2.74239	14.31	21.79
C	10	13.5520	5.57416	13.52	18 .92

Table (3): LSDs for all groups

Between groups	P value	Sig.
A&B	0.000	HS
A&C	0.000	HS
B&C	0.001	S

Figure (1): Bar-chart of mean shear bond strength values among groups

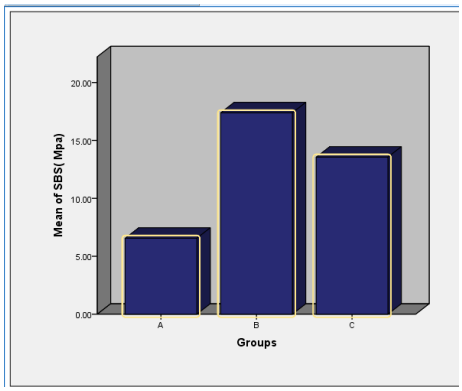
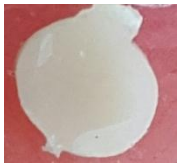


Figure (2) mode of failure

Complete cohesion 90% BD

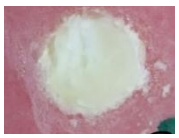
mixed cohesion BD



90% Adhesive TLC

50% mixed TLC

Complete cohesion (GIC)



Mixed (GIC)60%

Discussion:

Although the cement is applied beneath a restoration, the cement layer is exposed to stress through the restoration during chewing. Therefore, the mechanical properties of cements, as well as their adhesive properties, are important factors that influence the durability of restorations in the oral cavity [14].

In this study the two bioactive liners (TLC/BD) releases calcium and silicon ions into the underlying dentin , silica is a stronger inducer for dentin matrix remineralization than fluoride ions of GIC. So the use of TLC/BD as a liner and an alternative to GIC in laminate restorations is better, provided the bond to composite is adequate to withstand polymerization stresses. The bond strength between TLC/BD/GIC liners and composite depend on the types of adhesive used. In the this study, methacryloyloxydecyl dihydrogen phosphate (MDP)-based, universal adhesive with silanes was selected ,which shows chemical bonding to Ca ions, and Al and zirconium oxides. The bifunctional silane molecule bonds chemically to silica-containing materials and has methacrylate functionality that allows chemical union with resinous substrate which allow additional chemical bonding with Ca releasing bio active liners.[4]

The result of this study showed that the highest mean of Shear bond strength was group B (Theracl) (21.79 Mpa), this is because Theracal, in addition it is Ca releasing material, resin-based light cure cements that attain early cohesive strength on photo activation and this is agreed with Velagala et al [4]. This result bear relevance that TLC is an etchable surface material and suggested to do more studies to evaluate its bonding strength to resin composite in different mode of acid application. The failure mode of (TLC) were adhesive and mixed (predominately adhesion), this could be due to the fact that TLC is a calcium silicate cement which is a combination of a HEMA/TEGDMA-based resin and calcium-silicate powder; on light activation, HEMA and TEGDMA monomers create a polymeric network that is able to stabilize the outer surface of the cement. Thus formed poly-HEMA is hydrophilic and favors the absorption of moisture and triggers a second setting reaction that is hydration of calcium silicate particles with liberation of calcium ions.[4]

Group A (BD) showed the least SBS means (5.666 MPa), which may have been due to low early strength of the material *per sec* and this was in agreement with previous studies. (BD is a porous material that needs at least 2 weeks' time for crystallization of hydrated calcium silicate gel to attain bulk strength adequate to withstand the polymerization stresses [15],[16].

In the present study, bonding was performed to BD immediately after 12 min to depict a single appointment clinical procedure, and this is the same reason which make group C (GIC) showed higher bond strength(HS) than group B(BD) **.**[17]

The failure mode of (BD)were predominately cohesive, while for (GIC) were mixed, this could be due to the fact that (BD) releases more Ca ions than GIC. Hence, a strong chemical bonding among adhesive and Ca, Al, Zr, and silicon ions of BD could stabilized the outer surface of the cement while the inner layers of BD is still weak and need more time to get strong bulk.

While the result in this study showed that group B(TLC) higher bond strength(SD) than groupC(GIC). This is due to the fact that GIC is a chemical cure, and not a resin-based light cure cement to attain early cohesive strength on photo activation as in (TLC).

CONCLUSION

Within the limitations of this study, the following conclusions are made:

1) Although TLC showed significance difference higher than GlC Both of them have an adequate bond strength to with stand the contraction force from overlying composite resin.
2) Both TLC and GIC can be used immediately as a direct liner beneath composite resin in single appointment
3) Newly set BD showed weak bond strength with composite resin in single appointment.
4) It is better to delay BD (2 weeks) for complete setting before applying composite resin (two-stage clinical procedure)

Reference:

1. Desai S, Chandler N. Calcium hydroxide-based root canal sealers: a review. *J ndod.*2009;35:475-480.
2. Hørsted-Bindslev P, Løvschall H. Treatment outcome of vital pulp treatment. *Endodontic Topics.*2002;2:24-34.
3. Wang Y, Liao Z, Liu D, et al. 3D-fEA of stress levels and distributions for different bases under a Class I composite restoration. *Am J Dent.*2011;24:3-7.

4. Velagala L Deepa, Bhargavi Dhamaraju, Indira Priyadharsini Bollu1, Tandri S Balaji.
Shear bond strength evaluation of resin composite bonded to three different liners: TheraCal LC,Biodentine, and resin-modified glass ionomer cement using universal adhesive J Conserv Dent 2016;19:166-7
5. Witherspoon DE. Vital pulp therapy with new materials: new directions and treatment perspectives—permanent teeth. *Pediatr Dent.*2008;30:220-224.
6. Colon P, Bronnec F, Grosgogeat B, et al. Interactions between a calcium silicate cement (Biodentine) and its environment. *J Dent Res.*
    a. 2010;89. Abstract 401.
7. Dammaschke T, Leidinger J, Schäfer E. Long-term evaluation of direct pulp capping-treatment outcomes over an average period of 6.1 years. Clin Oral Investig 2010;14:559-67.)
8. Wilson AD, Kent BE. A new translucent cement for dentistry: the glass ionomer cement. Br Dent J. 1972;15(4):133-135.
9. De Munck J, Van Meerbeek B, Yoshida Y, Inoue S, Suzuki K, Lambrechts P. Four-year water degradation of a resin-modified glass ionomer adhesive bonded to dentin. Eur J Oral Sci. 2004; 112: 73-76.
10. Mitra SB. In vitro fluoride release from a light-curred glass-ionomer liner/base. J Dent Res. 1991; 70: 75-78.
11. Sabah A. Ismail BDS, MSc.Shaymaa SH. Hassan BDS, MSc. Tikrit Journal for Dental Sciences 1(2012)27-32
12. Ilie N, Jelen E, Clementino-Luedemann T, Hickel R.Low rinkagecomposite for dental application. Dent Mater 2007; 26:149-55)
13. Saleh RS, Gallab OH, Zaazou MH, Niazi HA. The Influence of different surface of pretreatments on the shear bond strength of repaired composite. J Am Scien 2011; 7(7): 705-11.
14. Yamazaki A, Hibino Y, Honda M, Nagasawa Y, Yoshiaki Hasegawa Y, et al. Effect of Water on Shear Strength of Glass Ionomer Cements for Luting. Dent Mater J. 2007; 26 (5): 708-712.
15. Tunç ES, Sönmez IS, Bayrak S, Eğilmez T. The evaluation of bond strength of a composite and a compomer to white mineral trioxide aggregate with two different bonding systems. J Endod 2008;34:603-5) (Bayrak S, Tunç ES, Saroğlu I, Eğilmez T. Shear bond strengths of different adhesive systems to white mineral trioxide aggregate. Dent Mater J 2009;28:62-7)
16. Bayrak S, Tunç ES, Saroğlu I, Eğilmez T. Shear bond strengths of different adhesive systems to white mineral triox-ide aggregate. Dent Mater J 2009;28:62-7)
17. Dammaschke T, Leidinger J, Schäfer E. Long-term evaluation of direct pulp capping-treatment outcomes over an average period of 6.1 years. Clin Oral Investig 2010;14:559-67