EGYPTIAN
DENTAL JOURNAL

Vol. 63, 3915:3921, October, 2017

I.S.S.N 0070-9484

Fixed Prosthodontics, Dental materials, Conservative Dentistry and Endodontics

www.eda-egypt.org • Codex : 187/1710

SHEAR BOND STRENGTH AND FAILURE PATTERN OF TWO SELF-ADHESIVE RESIN CEMENTS TO HYBRID CERAMIC UNDER DIFFERENT MODES OF POLYMERIZATION

Mahmoud Abdel Salam Shakal*

ABSTRACT

Abstract: The purpose of this study was to evaluate the shear bond strength of two self-adhesive cements with different polymerization modes. cemented to a Hybrid-Ceramic CAD/CAM blocks (VITA ENAMIC® for CEREC®/ inLab®, VITA Zahnfabrik H. Rauter GmbH & Co.KG., Germany),

Methods: Two self-adhesive resin cements: Rely X U200 (RX, 3M ESPE,St. Paul, MN, USA) and G-CEM Link ACE (GC, GC corporation, Tokyo, Japan). RX and GC groups with different polymerization modes (photo-curing (*P*) and self-curing (*S*)), were used in this study on hyprid ceramic Vita Enamic CAD/CAM blocks. Shear bond strength (SBS) tests were performed on all the specimens.

Results: The highest SBS was recorded with RX S group whilst the lowest SBS values were recorded with the GC *S* groups. Based on Tukey's post hoc significance analysis test, significance differences were observed between the RX S group compared to the GC *S* group ($p < 0.05$). No significance differences were found between data obtained from different curing modes of neither, RX *S* and RX *P* nor GC *S* and GC P. Adhesive pattern of failure was predominantly for most of the groups except RX *S* that was presented as predominant cohesive form of failure with the CAD/CAM hybrid ceramic block.

Conclusion: Within the limitations of this in vitro study, polymerization modes had no significance, but more mixed failure patterns were observed when using the photo-curing mode than when using the self-curing mode.

Keywords: self-adhesive resin cement; polymerization mode; failure mode, hybrid ceramic.

INTRODUCTION

Aesthetic indirect restorative materials bonded with resin cement are used to simulate the natural tooth translucency and color, mask tooth discoloration, provide a the desirable aesthetic outcome , and durable long-term retention of the prosthesis [(1)].

* Assistant Professor of Fixed Prosthodontics, Department of Fixed Prosthodontics, Faculty of Dentistry, University of Tanta, Egypt

Resin cements are classified according to their setting reaction into chemical, photo, or dual-cured polymerization reaction. Resin cements with chemical polymerization reaction exhibit a shorter working time, but their completeness of polymerization is not affected by the thickness of the adherent restorative material. Photo-initiated polymerization reaction resin cements present a more favorable working characteristics with an adequate amount of light [(2)]. The photo-initiated polymerization of a cement may be affected by light intensity emitted by the light source, wavelengths emitted beyond the spectrum range of the photo-initiator within the resin material, and the thickness of the adherent indirect restoration[(3)]. Combining the desirable properties of chemical polymerization with those of light curing to assure enough working time and adequate polymerization, or degree of conversion, even in the deepest area of the preparation was presented with the developed dual cured resin cement [(4, 5)].

Optimizing the mechanical properties and adhesive capacity of the resin cement is dependent the completeness of monomers conversion into polymers during the polymerization reaction. Most of the available polymers exhibit a varying amount of residual monomer with degrees of conversion ranging from 55% to 75% with conventional irradiation conditions. Residual monomers present adverse consequences and may result in unfavorable biological tissues effects, mainly in the pulp and increase the incidence of marginal leakage and development of secondary caries because of insufficient resin cement polymerization [(5-6)] Inadequate polymerization of the resin cement as a result of Inadequate required light quality may compromises its physical properties by interfering with its resistance, hardness, water absorption, adhesion ability, and color stability.

Color, thickness and type of the adherent restorative material and tooth structure through which the emitted light passes, the time length of light exposure, may influence the amount of light that is perceived by the resin cement, compromising the degree of conversion and their mechanical properties also the Dual-cured resin cement degree of polymerization, is affected by the amount of emitted light, since polymerization is not purely initiated by the chemical component of the reaction [(7-10)].

Hybrid ceramics are based on the concept of combining the positive characteristics of ceramics and composites [(11)].

VITA ENAMIC is a hybrid dental ceramic material with a dual-network structure. The dominant ceramic network is strengthened by a polymer network, with both networks fully integrated with one another, therefore combining the positive characteristics of a ceramic and a composite. This new material is highly heat cured through a controlled, proprietary manufacturing process, which eliminates the need for a firing step after milling. The material is easily machined chairside or in a dental lab, polishes quickly to an esthetic finish and if necessary, can be further adapted using light-cure restoratives.[(12 -14)]

It is well known that the composition of resin cements is the same as resin composite but with lesser filler content, the manufacturer of VITA ENAMIC stated that it can be corrected intraorally with resin composite so examining the bond strength of resin cement to hybrid ceramics is of great importance not only for achieving a better retention of restorations but also for understanding the intra oral repair of these materials.

Therefore, the aim of this in vitro study was to evaluate the impact of polymerization mode on the shear bond strength of two self-adhesive resin cements to hybrid ceramic.

MATERIALS AND METHODS

Samples preparation

A Total number of 24 blocks of VITA ENAMIC were included in the study, 3 blocks with equal thickness of 3mm were cut from each Vita ENAMIC blocks using a low-speed diamond saw under copious water cooling. Blocks were mounted in ring holders made of self-cured acrylic resin. The uppermost surface of all samples was etched using hydrofluoric acid (VITA CERAMICS ETCH) for 60 seconds washed and dried clean then salinized subsequently according the manufacturer recommendations.

The samples were then divided into two main groups (A and B groups) representing the self-adhesive cement type, each counting 36 samples. Each group were further subdivided into two subgroups (As, Ap, Bs and Bp) representing the polymerization reaction mode, each counting 18 sample (self or photopolymerization).

TABLE (1) Samples distribution (grouping and subgrouping)

Samples distribution (grouping and subgrouping)			
Total number of sample. (72 sample)			
Group A (Rely x resin cement) 36 sample		Group B (G-CEM resin cement) 36 sample	
Group As 18 sample Self-cured (RX S)	Group Ap 18 sample Photo-cured (RX P)	Group Bs 18 sample Self-cured (GC S)	Group Bp 18 sample Photo-cured (GC P)

Cement application

Transparent polyurethane tubes with an internal diameter of 2.4mm (so the surface area of adhesion is calculated from the equation πr^2 =3.14× 1.4= 4.4mm^2 , r is half the diameter) were fitted on the pre-cutted CAD/CAM Blocks) using wax, cement was mixed according to the manufacturer's recommendation and applied on the pretreated VITA ENAMIC surface thought the pre-fitted polyurethane tubes placed into the tube.[15]

Samples of group (Ap and Bp) were light-cured for 20 s with 1200 mW LED light-curing unit, while samples of groups (As and Bs) were left for 1 h at room temperature in darkness for self-cure. Before testing, all the specimens were kept in a 100% humid environment at room temperature for 24 h after cementation. [16]

Samples were mounted and jigged to a universal testing machine (Fig.1). Shear force was applied to the adhesive interface until fracture at a crosshead speed of 0.5 mm/min. The force (N) at which the bond failed was recorded and divided by the surface area of adhesion between resin cement and the block.

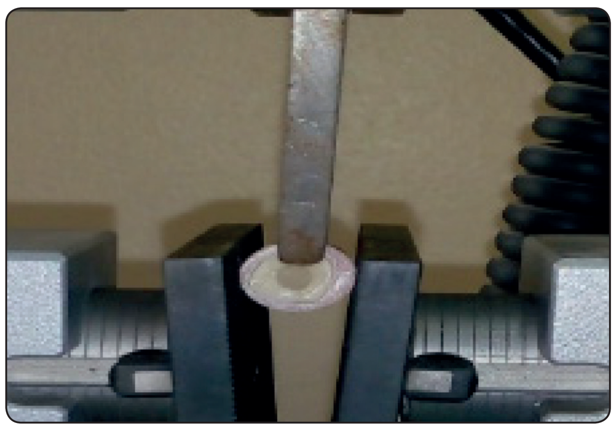

Fig. (1)

The shear bond strength (SBS) was calculated in MPa. Data were analyzed using one-way analysis of variance (ANOVA) with Tukey's post hoc test.

Hybrid ceramic sample deboned surface were examined for mode of failure under digital stereo microscope at magnification (80X), the type of failure was considered as "cohesive failure in resin cement or the CAD/CAM block" and "adhesive failure at the interface cement - hybrid ceramic" and "mixed failure".

RESULTS

The mean shear bond strength and standard deviations (SD) are mentioned in Table 2. The Relay X S group has recorded the highest shear bond strength, while the G-Cem *S* group has recorded the lowest Shear bond strength. Based on Tukey's post hoc significance analysis test, significance differences was observed between the Relay X S group compared to the G-Cem *S* group ($p < 0.05$). No significance differences were found between data obtained from different curing modes of neither, RX *S* and RX *P* nor GC *S* and GC.

TABLE (2) Shear bond strength mean values and standard deviations.

Group	RX S	RX P	GC S	GC P
SBS ± SD Mpa	10.9± 4.9	9.5± 4.3	6.5± 2.8	9.5± 4.5

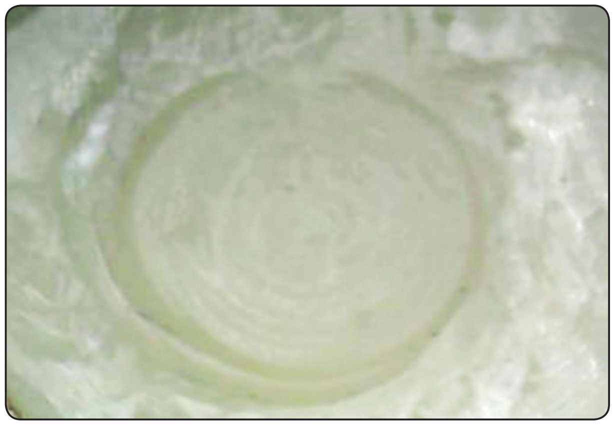

Fig. (2) Cohesive failure

Fig. (3) Mixed failure

Microscopic analysis of the bonding joint failure pattern

Adhesive failure was the predominant pattern along the adhesive joint between the resin cement-hybrid ceramic interface. A predominant cohesive mode of failure in the CAD/CAM block was noted with Relay X S group (Figure. 2). While a mixed form of failure was observed for the Relay X *P* and G-Cem *P* groups, at the block-cement interface, resin remnants were seen on the failed bonding interface. (Figure.3). The GC *S* group has shown an adhesive mode of failure with complete separation of the resin cement at the bonding interface with the hybrid /ceramic blocks (Figure. 4).

Fig. (4) Adhesive failure

DISCUSSION

The VITA-ENAMIC (Hyprid- Ceram) presents a three-dimensionally interconnected pre-sintered ceramic network of 86 vol% that is infiltrated with a monomer mixture; thus, intertwined networks of polymers and ceramics are created. Clinical reliability of the material adhesion of the restoration is very important. However, information about bonding protocols to this new composite and polymer-infiltrated ceramic materials is still scarce[17].

The results of this study showed that the RX exhibited significantly higher shear bond strength than GC-cem when self-cured, without any significant difference between the shear bond strength recorded for both self-adhesive resin cements when cured by photo-curing mode. This could be attributed to the lower viscosity of RX as a result of lower filler content [18].

Viscosity changes during the auto-polymerization reaction possibility has reduced radicals migration and continuing the conversion reaction process ability [19], also the self-curing mode slow polymerization could have been impaired by water produced during the neutralization reaction of the phosphate monomers with basic filler within the self-adhesive resin cement[20].

The low shear bond strength recorded for the self cured group of G-CEM than that of the light-cured group with no significant differences ($p > 0.05$) are in agreement with previous studies evaluated the flexural strength, hardness and the degree of conversion of dual-cured resin cements and stated that self-curing components of this type of resin cements were not enough for compensating for light intensity attenuation or its total absence and the self-curing mode of resin cements is less effective than the dual-cured or photo-cured cements [21-24].

The results of this study also agrees with Suk Shim et al. (25) who concluded that self-chemical polymerization is not sufficient to cause the resin cement to achieve the highest polymerization in both early and late stage of polymerization.

However, this result is not agreed with the manufacturer data who stated that they used a new innovative chemical initiator system offering the highest polymerization in the self-curing mode. They claimed that it polymerizes within four minutes in self-curing mode and provides the maximum bond strength after 20 min.

In contrary to GC- CEM, the recorded shear bond strength of the self-cured group of Rely X U200 was slightly higher than that of the light-cured group but also with no significant differences ($p > 0.05$), this could be attributed to the deleterious consequences of polymer stiffens resulting from immediate light application, limiting the processes of chemical activation during polymerization preventing the cement from achieving its maximum degree of conversion and compromising its mechanical properties as stated by Manso AP etal [26].

The light-activation delay to allow more time for the chemical activation to occur before light-activation seems to affect the dual-cured resin cement properties depending on the material's composition and the time interval between the mixture until light-activation. Light-activation delay of 5 min, was suggested as being advantageous to reduce shrinkage stress during polymerization, without impairing the degree of conversion, the extent of polymerization and hardness of some dual-cured cements [27-29].

It was also demonstrated that a 6-minute delay after the manipulation of resin cements may result in increased color stability[30], but a 10-minute delay may be harmful [31]

Most of the groups except RX S revealed adhesive failure patterns along the resin cement-hyprid ceram block interface. The RX S group showed a predominant cohesive failure pattern in its hyprid- ceram (50%). These results are indicative of more efficient interfacial polymerization. while comparing RX S with RX P and GC S with GC P, a higher percentage of mixed failure was observed in the RX P and GC P groups. In microscopic observation, the RX S group showed a predominant cohesive failure pattern in the hybrid ceramic, that goes with the statement of Toledano et al. who reported that cohesive and mixed failure patterns are desirable in a clinical situation when analyzing the fracture patterns of specimens[32].

The RX P and G-Cem P group of samples has presented an adhesive pattern of failure along the block-cement interface with remnants of resin cements. While samples of the GC S group, complete separation of the luting cement from the CAD/CAM blocks was observed. This variation in failure pattern observed in this study could be attributed to the analysis of Fischer et al. who reported that bonding strength can be influenced by the internal strength of the cements and the strength between the adhered materials and cements[33].

Also in Accordance with Asmussen et al., who stated that the physical property of the resin cements can be influenced by the type of monomer, filler content, structure, and degree of conversion[34].

CONCLUSION:

Within the limitations of this in vitro study, polymerization modes had no significance, but more mixed failure patterns were observed when using the photo-curing mode than when using the self-curing mode.

REFERENCES

1. Umetsubo ls, yui kck, borges ab, barcellos dc, gonçalves sedp. Additional chemical polymerization of dual resin cements: reality or a goal to be achieved? Revista de Odontologia da UNESP. 2016;45(3):159-64.
2. Helvatjoglou-Antoniadi M, Papadogianis Y, Koliniotou-Kubia E, Kubias S. Surface hardness of light-cured and self-cured composite resins. The Journal of prosthetic dentistry. 1991;65(2):215-20.
3. Hofmann N, Papsthart G, Hugo B, Klaiber B. Comparison of photo-activation versus chemical or dual-curing of resin-based luting cements regarding flexural strength, modulus and surface hardness. Journal of Oral Rehabilitation. 2001;28(11):1022-8.
4. El-Mowafy OM, Rubo MH. Influence of composite inlay/onlay thickness on hardening of dual-cured resin cements. Journal-canadian dental association. 2000;66(3):147-51.
5. Ferrari M, Dagostin A, Fabianelli A. Marginal integrity of ceramic inlays luted with a self-curing resin system. Dental materials. 2003;19(4):270-6.
6. HARASHIMA I, NOMATA T, HIRASAWA T. Degree of conversion of dual-cured composite luting cements. Dental Materials Journal. 1991;10(1):8-17, 97.
7. Chan KC, Boyer DB. Curing light-activated composite resins through dentin. The Journal of prosthetic dentistry. 1985;54(5):643-5.
8. El-Mowafy O, Rubo M, El-Badrawy W. Hardening of new resin cements cured through a ceramic inlay. Operative dentistry. 1999;24:38-44.
9. Göhring T, Zehnder M, Sener B, Schmidlin P. In vitro microleakage of adhesive-sealed dentin with lactic acid and saliva exposure: a radio-isotope analysis. Journal of dentistry. 2004;32(3):235-40.
10. Soares C, Silva N, Fonseca R. Influence of the feldspathic ceramic thickness and shade on the microhardness of dual resin cement. Operative dentistry. 2006;31(3):384-9.
11. Coldea A, Swain MV, Thiel N. Mechanical properties of polymer-infiltrated-ceramic-network materials. Dental Materials. 2013;29(4):419-26.
12. Awada A, Nathanson D. Mechanical properties of resin-ceramic CAD/CAM restorative materials. The Journal of prosthetic dentistry. 2015;114(4):587-93.
13. Della Bona A, Corazza PH, Zhang Y. Characterization of a polymer-infiltrated ceramic-network material. Dental Materials. 2014;30(5):564-9.
14. Fasbinder DJ, Neiva GF. Surface evaluation of polishing techniques for new resilient CAD/CAM restorative materials. Journal of Esthetic and Restorative Dentistry. 2016;28(1):56-66.
15. Kim J-Y, Cho G-Y, Roh B-D, Shin Y. Effect of curing mode on shear bond strength of self-adhesive cement to composite blocks. Materials. 2016;9(3):210.

16. Aleisa K, Al-Dwairi Z, Alghabban R, Glickman G, Hsu M-L. Effect of cement types and timing of cementation on the retentive bond strength of fiber posts. Journal of Dental Sciences. 2012;7(4):367-72.

17. Frankenbergera R, Hartmannb V, Krechc M, Krämerd N, Reiche S, Braunf A, et al. Adhesive luting of new CAD/CAM materials Adhäsive Befestigung neuer CAD/CAM-Materialien. International journal of computerized dentistry. 2015;18(1):9-20.

18. Youm S-H, Jung K-H, Son S, Kwon Y-H, Park J-K. Effect of dentin pretreatment and curing mode on the microtensile bond strength of self-adhesive resin cements. The journal of advanced prosthodontics. 2015;7(4):317-22.

19. Rueggeberg F, Caughman WF. The influence of light exposure on polymerization of dual-cure resin cements. Operative Dentistry. 1993;18(2):48-55.

20. Yoshida K, Tsuo Y, Atsuta M. Bonding of dual-cured resin cement to zirconia ceramic using phosphate acid ester monomer and zirconate coupler. Journal of Biomedical Materials Research Part B: Applied Biomaterials. 2006;77(1):28-33.

21. Arrais CA, Rueggeberg FA, Waller JL, Mario F, Giannini M. Effect of curing mode on the polymerization characteristics of dual-cured resin cement systems. Journal of Dentistry. 2008;36(6):418-26.

22. Lührs A-K, De Munck J, Geurtsen W, Van Meerbeek B. Composite cements benefit from light-curing. Dental Materials. 2014;30(3):292-301.

23. Arrais CA, Giannini M, Rueggeberg FA, Pashley DH. Microtensile bond strength of dual-polymerizing cementing systems to dentin using different polymerizing modes. The Journal of prosthetic dentistry. 2007;97(2):99-106.

24. Aguiar T, Di Francescantonio M, Ambrosano G, Giannini M. Effect of curing mode on bond strength of self-adhesive resin luting cements to dentin. Journal of Biomedical Materials Research Part B: Applied Biomaterials. 2010;93(1):122-7.

25. Shim JS, Kang JK, Jha N, Ryu JJ. Polymerization Mode of Self-Adhesive, Dual-Cured Dental Resin Cements Light Cured Through Various Restorative Materials. Journal of Esthetic and Restorative Dentistry. 2017.

26. Manso AP, Silva NR, Bonfante EA, Pegoraro TA, Dias RA, Carvalho RM. Cements and adhesives for all-ceramic restorations. Dental Clinics of North America. 2011;55(2):311-32.

27. Faria-e-Silva A, Boaro L, Braga R, Piva E, Arias V, Martins L. Effect of immediate or delayed light activation on curing kinetics and shrinkage stress of dual-cure resin cements. Operative dentistry. 2011;36(2):196-204.

28. Ramos MB, Pegoraro TA, Pegoraro LF, Carvalho RM. Effects of curing protocol and storage time on the microhardness of resin cements used to lute fiber-reinforced resin posts. Journal of Applied Oral Science. 2012;20(5):556-62.

29. Soares C, Bicalho A, Verissimo C, Soares P, Tantbirojn D, Versluis A. Delayed photo-activation effects on mechanical properties of dual cured resin cements and finite element analysis of shrinkage stresses in teeth restored with ceramic inlays. Operative dentistry. 2016;41(5):491-500.

30. Furuse AY, Santana LOC, Rizzante FAP, Ishikiriama SK, Bombonatti JF, Correr GM, et al. Delayed Light Activation Improves Color Stability of Dual-Cured Resin Cements. Journal of Prosthodontics. 2016.

31. Da Rocha SVIZERO N, Silva MS, ALONSO RCB, Rodrigues FP, Di Hipolito V, Carvalho RM, et al. Effects of curing protocols on fluid kinetics and hardness of resin cements. Dental materials journal. 2013;32(1):32-41.

32. Toledano M, Osorio R, Osorio E, Aguilera FS, Yamauti M, Pashley DH, et al. Durability of resin–dentin bonds: effects of direct/indirect exposure and storage media. Dental Materials. 2007;23(7):885-92.

33. Fischer J, Grohmann P, Stawarczyk B. Effect of zirconia surface treatments on the shear strength of zirconia/veneering ceramic composites. Dental materials journal. 2008;27(3):448-54.

34. Asmussen E, Peutzfeldt A. Influence of UEDMA, bisgma and TEGDMA on selected mechanical properties of experimental resin composites. Dental Materials. 1998;14(1):51-6.

35. Lee IB, An W, Chang J, Um CM. Influence of ceramic thickness and curing mode on the polymerization shrinkage kinetics of dual-cured resin cements. Dental materials. 2008;24(8):1141-7.

36. Valentino TA, Borges GA, Borges LH, Vishal J, Martins LRM, Correr-Sobrinho L. Dual resin cement knoop hardness after different activation modes through dental ceramics. Brazilian dental journal. 2010;21(2):104-10.

37. Tauböck TT, Buchalla W, Hiltebrand U, Roos M, Krejci I, Attin T. Influence of the interaction of light-and self-polymerization on subsurface hardening of a dual-cured core build-up resin composite. Acta Odontologica Scandinavica. 2011;69(1):41-7.