EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 69, 2829:2835, October, 2023

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 08-06-2023 • Accept Date : 26-06-2023 • Available online: 15-10-2023 • DOI : 10.21608/EDJ.2023.215905.2585

EVALUATION OF GLASS CERAMIC BOND STRENGTH TO DIFFERENT FOUNDATION MATERIALS

Amal Al-Sohbani* , Noha El Wassefy** *and* Ahmed Attia***

ABSTRACT

Purpose: To determine the impact of core materials type on Lithium disilicate glass-ceramic shear bond strength when both are bonded using conventional resin cement.

Materials and Methods: Thirty-Two cylinders of IPS e-max Press were created, and core specimens including dentin, composite resin, zirconia, and RMGI were made following the recommendations of the manufacturer. The ceramic cylinders were bonded to core groups using (Multilink N) conventional resin cement, and all samples underwent artificial aging via water bath for 150 days and thermocycled for 5000 cycles. A universal machine was used to find the specimens' SBS, and a stereomicroscope was used for failure inspection. In addition, the SEM was utilized for further evaluation.

Results: According to the data, there was a noticeable statistical difference in the mean SBS values ($P<0.05$), and the performance of foundation materials. The composite resin groups came out on top with the highest mean SBS, while the dentin and zirconia groups had the lowest mean SBS.

Conclusion: When selecting a core material, it is important to remember that the type of material used can significantly impact SBS. While various options are available, composite resin is often preferred due to its superior properties and performance.

KEYWORDS: Lithium disilicate glass-ceramic, Core, resin cement

INTRODUCTION

Many ceramic systems have been introduced to tackle different clinical situations. These systems come in leucite, lithium disilicate, alumina, magnesia, and zirconia. In addition, various fabrication techniques are available, including CAD-CAM, pressing methods, and copy-milling. (1) Lithium Disilicate Glass Ceramic (LDGC) is incredibly strong. It is also known for its chemical endurance and aesthetic appeal, making it a popular choice in restorative dentistry. (2)

* Postgraduate Master student, Fixed Prosthodontic Department, Faculty of Dentistry, Mansoura University, Dakahlia Governorate, Egypt.

** Prof. Of Dental Biomaterials, Faculty of Dentistry, Mansoura University, Dakahlia Governorate, Egypt.

*** Professor and Chairman Department of Fixed Prosthodontics, Faculty of Dentistry, Mansoura University, Dakahlia Governorate, Egypt

Before crown preparation or fixation, it is essential to consider any potential sources of damage, such as caries or trauma. These issues can result in severe destruction of the tooth, making it challenging to fix the crown directly. In these situations, it is necessary to reconstruct any damaged dental structures before crown fixation to achieve the best possible outcome. [3] Various foundation materials can be used to restore missing tooth structures due to trauma, clinical procedures, or decay. Some options include amalgam, composite resin, glass ionomer, compomer, and porcelain. Depending on the specific situation, these materials can be used as direct or indirect core materials. [4]

The connection between fixed dental prostheses and core materials is critical for the success of ceramic restorations in the long run. This is because it improves marginal adaptation, reduces microleakage, and prevents secondary caries. In addition, the strong adhesion between the two components is essential for maintaining the integrity of the restoration and ensuring its longevity. [5,6]

Hence, assessing the bond effectiveness between the foundation material and prostheses is essential to minimize any potential complications or risk of debonding. Furthermore, proper evaluation of this bond can help ensure the longevity and effectiveness of the material. [7] Therefore, this research was done under the null hypothesis, which stated that the different foundation materials will not affect the lithium disilicate shear bond strength.

MATERIALS AND METHODS

Specimens preparation, grouping, and surface treatment

The sample size was calculated using G* (version 3.0.10). To detect the difference of 5% with an effect size of 1.72, a sample size of 8 specimens was needed in each group. The cylindrical samples (N=32) of lithium disilicate ceramics (IPS e-max Press, Ivoclar Vivadent) with a diameter of 4mm and length of 5mm were pressed under manufacturer instructions. Then, the four groups of foundation materials (n=8) including composite resin, zirconia, dentin, and RMGI were prepared following manufacturer instructions. First, three core materials (8mm diameter;3mm thickness) were constructed as follows: In group 1, zirconia specimens (IPS e.max ZirCAD, Ivoclar Vivadent) were milled using CAD/CAM technology. In groups 2 and 3, composite resins (Te-Econom Plus, Ivoclar Vivadent) and Resin-modified glass ionomer (Gc Fuji II Lc Capsules, Japan) were prepared using a particular mold with recommended dimensions. Next, in group 4, eight extracted permanent human molars free from caries were carefully cleaned and polished after extraction for periodontal problems before being stored in a 1.0% thymol solution. Once they were ready, the molars were embedded in self-curing acrylic resin, and each molar's occlusal surface was cut off to bare a flat and healthy dentin surface. This study was permitted and registered with a number (M31080622) by the Bioethical Committee of the College of Dentistry, Mansoura University, Mansoura, Egypt.

After that, a permanent marker was used to mark one surface of LDGCs and other cores to distinguish the untreated surface easily. First, LDGCs' surfaces were etched using Hydrofluoric acid in 9.5% (Bisco, USA) for 20 seconds, rinsed for 30 seconds, and dried for 1 minute. Next, the dentin surfaces were etched with 37% (N-Etch etching gel, Ivoclar Vivadent) for 15 seconds, then rinsed the surface thoroughly with a strong stream of water for more than 5 seconds. Then, zirconia, composite resin, and RMGI surfaces were sandblasted using (Renfert Basic ECO Sandblaster 29492025, Germany) with 40μm aluminum oxide for 10 seconds from a distance of 5mm at a 90-degree angle and 0.2MPa pressure. After rinsing the surface thoroughly, proceed with ultrasonically cleaning all specimens using ethyl alcohol 95% and distilled water for the dentin group.

Bonding protocol

The ceramic surface was first treated with Universal ceramic primer (Monobond N, Ivoclar Vivadent) for 1 minute, then dried for another minute. The dentin surfaces were then rinsed carefully and dried with an oil-water-free air syringe. Afterward, they were coated and scrubbed using (Tetric N-bond universal, Ivoclar Vivadent) for at least 20 seconds. The surfaces were then dispersed with compressed air and cured for 10 seconds.

All specimens were deemed ready for bonding after the necessary surface treatment, cleaning, and drying procedures were completed. LDGC cylinders(N=32) were divided into four groups, each consisting of 8 specimens, based on the type of core materials that would be used. The bonding of ceramic cylinders to already prepared foundation materials was carried out in accordance with the manufacturer's instructions. Multilink N resin cement was auto-mixed and applied to the ready ceramic intaglio. Next, a loading device was utilized to bond the ceramic cylinder to the foundation specimen. Then, a (UniXS, Heraeus Kulzer, Wehrheim, Germany) device was applied to light-cure the bonded assembly from different sides for 40 seconds. Afterward, the specimens stayed under a 2 kg load for 5 minutes. The bonded specimens were illustrated in (Fig.1).

Artificial aging, shear bond strength test, and failure analysis

After five months of being stored in water, the samples underwent thermal cycling using the (Thermalcycler TC21, Robota, Egypt). The thermocycler device was cycled between 5-55°C for 5000 cycles, with a 40-second transfer and dwell time. After that, all samples were overloaded on the universal machine, using a compressive weight until separation appeared. The force at which failure occurred was documented, and the shear strength was determined for each sample. Next, a failure examination was conducted using a stereomicroscope at x20 amplification. Some examples were prepared for further analysis of the bonded interface using SEM (JEOL.JSM.6510LV, Japan, Faculty of Agriculture, Mansoura University).

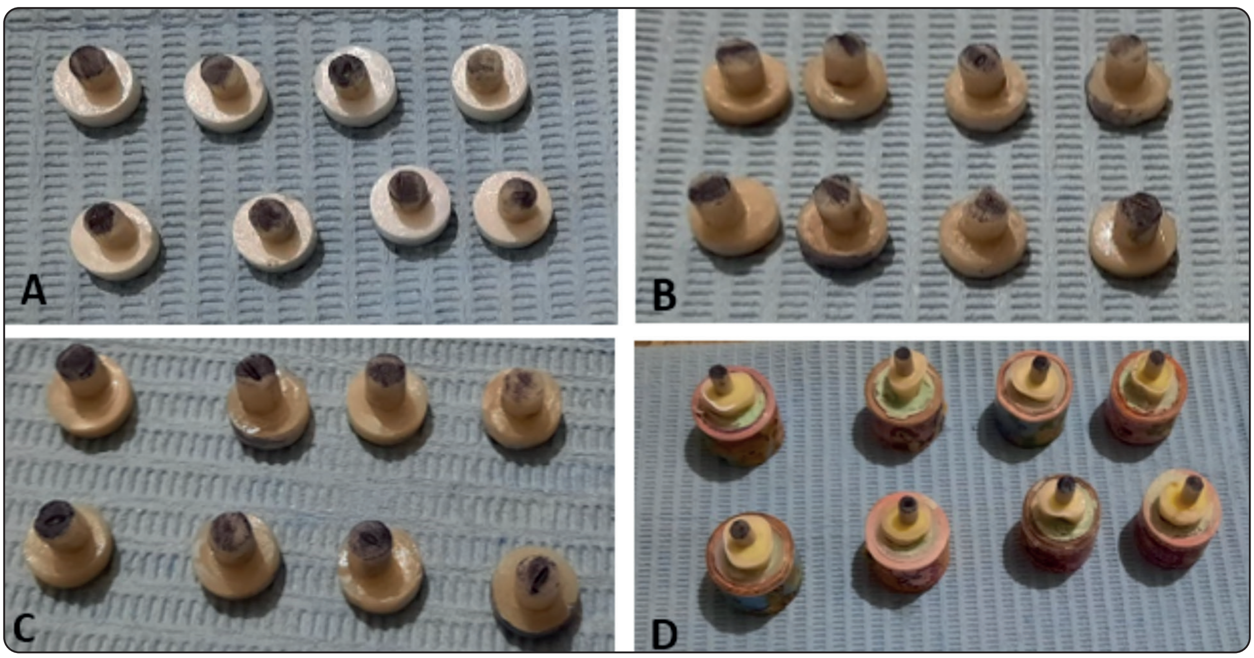

Fig. (1) The bonded ceramics to different core materials. A) Bonded ceramic to Zirconia. B) Bonded ceramic to RMGI. C)Bonded ceramic to composite resin. D) Bonded ceramic to flat dentin

Statistical analysis

The non-parametric test of normality (Kolmogorov-Smirnov Test) was performed. This test retained the normality hypothesis of shear bond strength relative to the groups and core. Thus, the parametric statistical tests become valid for groups and core. The statistical analysis for mean SBS was conducted using the IBM SPSS version 25.0 statistical software package. One-Way ANOVA was employed to analyze the data to determine any significance. The Post Hoc Tukey test was then utilized for comparing the mean values between groups that exhibited statistical significance at ($p \leq 0.05$).

RESULTS

Based on the analyzed data, the composite resin group had the superior SBS, with a mean value of 10.89 ± 0.79. The next highest SBS was recorded in the RMGI group, with a mean value of 08.67 ± 1.65. The zirconia group had a significantly lower SBS, with a mean value of 04.23 ± 1.75, and the dentin group had the lowest SBS, with a mean value of 03.48 ± 1.86. The One-Way analysis confirmed a statistically evident between the tested foundation materials with a p-value of 0.000. After conducting the Post Hoc Tukey test on different core materials, it was found that there was a statistically apparent in the SBS between most foundation groups with a p-value of 0.000. Nevertheless, there was no statistically stable between RMGI and composite resin with a p-value of 0.055, nor between zirconia and dentin, with a p-value of 0.779. (Table 1) and (Fig. 2)

It was found that when examining the separated samples at x20 using the stereomicroscope, different patterns of failure were noticed and recorded in (Table 1) and (Fig. 3).

TABLE (1) Tukey's Post Hoc test and failure pattern of core materials.

p-values of Tukey's Post Hoc test					Descriptive		Failure Mode		
Core	Z	CR	RMGI	D	N	Mean ± SD	AF	MF	CF
Z	—	**0.000***	**0.000***	0.779	8	04.23 ± 1.75	6	2	0
CR		—	0.055	**0.000***	8	10.89 ± 0.79	1	2	5
RMGI			—	**0.000***	8	08.67 ± 1.65	4	3	1
D				—	8	03.48 ± 1.86	5	2	1

** Mean difference is significant at 0.05 level;* ***N: Sample size;***

Z: Zirconia, CR: Composite Resin, RMGI: Resin-Modified Glass Ionomer, D: Dentin; AF: Adhesive Failure, MF: Mixed Failure, CF: Cohesive Failure.

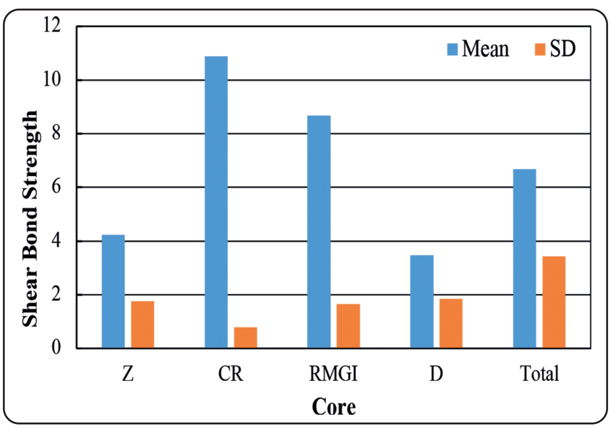

Fig. (2) Mean and standard deviation of shear bond strength of core materials. Z: Zirconia, CR: Composite Resin, RMGI: Resin-Modified Glass Ionomer, D: Dentin.

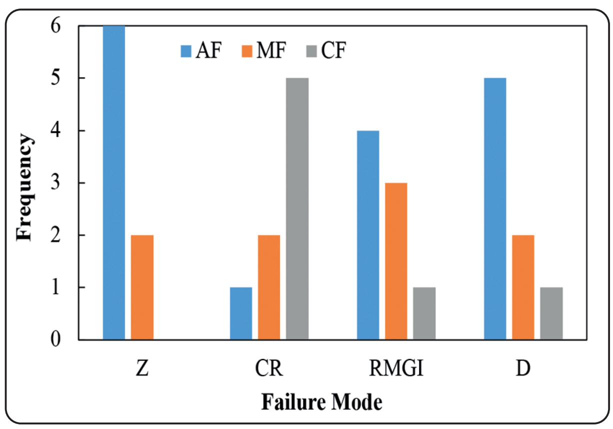

Fig. (3) Failure mode in groups. Z: Zirconia, CR: Composite Resin, RMGI: Resin-Modified Glass Ionomer, D: Dentin.

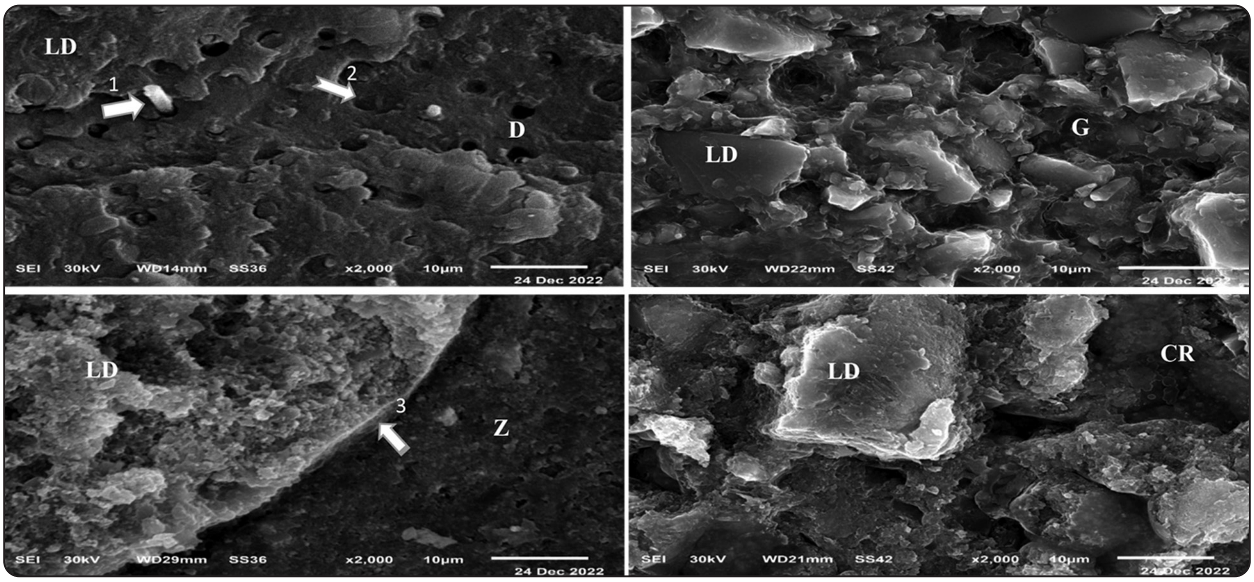

Fig. (4) SEM micrographs at x2000 showing the core/ceramic/resin interface characterization. (LD = Lithium disilicate glass-ceramic, CR = composite resin, D = Dentin, Z = zirconia, G = RMGI, 1 = odontoblastic process, 2 = opened dentinal tubules, 3 = resin cement).

Upon examination, the SEM observations of the core surfaces at x2000 show a mixture of the ceramic/core interfaces, with the remaining resin cement still detectable. Additionally, surface irregularities were noticeable among all treated surfaces, whether by etching or sandblasting. The SEM analysis for dentin surfaces displayed large opened dentinal tubules, contiguous with some odontoblastic processes. (Fig. 4)

DISCUSSION

Ensuring a durable bond between the core and the restoration is essential for restorative procedures. The ideal core materials should have good strength, durable bonding, dentin-like properties, and biocompatibility. The foundation materials in the current research were reported in many literatures. [3,8–10]

Based on the result of this research and analysis, it has been determined that the null hypothesis is invalid. This means that the bond strength of LDGC has been affected by the various types of core materials used. This finding is in agreement with previous researches, as it has significant implications for dentistry, and emphasizes the importance of selecting core materials that meet the patient's functional and aesthetic needs while maintaining the bond strength of the ceramic.[8,11,12]

The oral environment can impact ceramic restorations, as it can lead to material failure. In this study, water storage and thermocycling were used to test the bond degradation with adhesive resin cement to simulate this effect. It was found that the resin cement exhibited bond deterioration similar to clinical aging, particularly if stored in water for 90 days. [13] In this study, artificial aging was achieved through water storage for five months and thermocycling 5000 cycles.

The distinction at adhesion interfaces related to the coefficient of thermal expansion (CTE) should be considered, particularly after artificial aging. This can increase the undesirable effect of water storage and impact the bond effectiveness of used resin cement. The poorly matched CTE between materials can elevate the stress intensity and resin deprivation. However, an identical CTE, mechanical characterization, and water uptaking capability at the core/resin boundary can result in nearly similar reactions to thermal stress. This may explain why the extreme SBS was the composite resin group and the minimal was the dentin group. [14] Moreover, according to Bozogullari et al. 2009[15], resin-based core materials have been found to have superior SBS compared to ceramic foundation materials. This is consistent also with the studies conducted by Hewlett et al.2010 [8] and Al-Manei et al. 2020[16], which also displayed that the composite group had the greatest SBS.

On the other hand, in the present study, the dentin group had the lowest SBS, while Al-Manei et al. 2020[16] reported the dentin group as the second highest group next to the composite resin group. Additionally, they also described the RMGI group next to the dentin which is different from the finding of the current study. Shipla et al. (2019) [7] evaluated the SBS of ceramic to zirconia core and found a high SBS in the zirconia group compared to the findings of this study. The justification for these variances might be a variation in study design and methodology, such as the number of thermal cycles and long-term water storage that were not applied in the earlier studies.

The failure mode can provide valuable insight into the material's ability to withstand force and tolerance. Through stereomicroscope examinations, it was retrieved that the composite resin test group primarily experienced cohesive failure. This can be attributed to the durable bond between the materials and cement interfaces. In addition, the mechanical properties, composition, and chemical interaction contributed to a favorable merging achievement. These findings align with the research of Bozogullari et al. 2009. [15] They stated that the resin cores demonstrated cohesive failure, while ceramic cores presented adhesive failure. This could be explained by Zirconia's advanced modulus of elasticity and unique composition that lead to fracture prevention, which appears to be an adhesive failure. On the other hand, dentin and RMGI groups show the mostly adhesive mode of failures. Hitz et al.2012 [17] disagree with this study's finding as they displayed that dentin group failure was just adhesive, while Al-Manei et al. 2020[16] found dentin and RMGI groups mostly were a mixed failure. The variances in the mode of failures between the recent study and preceding reports might be interpreted as consequences of the differences in the experimental procedures or universal testing machine type.

Considering the limitations of in-vitro reports, as many studies lack standardization methods or identical conditions, it can be challenging to compare results. Therefore, conducting further clinical assessments may be beneficial before making any clinical applications based on this evidence.

CONCLUSION

Regarding the outcomes of this study mentioned earlier, it can be concluded that the type of core material used impacts the shear bond strength of bonded LDGC. So, it may be preferable to use composite resin or RMGI as core materials for achieving higher SBS values.

Abbreviations

LDGC = Lithium disilicate glass-ceramic

SBS= Shear bond strength

HF= Hydrofluoric acid

RMGI= Resin-modified glass ionomer

REFERENCES

1. Maruo Y, Nishigawa G, Irie M, Yoshihara K, Matsumoto T, Minagi S. Does acid etching morphologically and chemically affect lithium disilicate glass-ceramic surfaces? Vol. 15, J Appl Biomater Funct Material. 2017. p. e93–100.
2. Song XF, Ren HT, Yin L. Machinability of lithium disilicate glass-ceramic in vitro dental diamond bur adjusting process. J Mech Behav Biomed Mater. 2016;53:78–92.
3. Cvikl B, Filipowitsch R, Wernisch J, Raabe M, Gruber R, Moritz A. Immediate shear bond strengths of a composite,

a compomer, and a glass ionomer to a ceramic substrate. J Adhes Dent. 2013;15(4):385–91.

4. Stober T, Rammelsberg P. The failure rate of adhesively retained composite core build-ups in comparison with metal-added glass ionomer core build-ups. J Dent. 2005;33(1):27–32.

5. Tavakolizadeh S, Dehghan M, Ghoveizi R, MScD D, Fayyazi A. Shear Bond Strength of Zirconia Ceramic to Four Different Core Materials, An in vitro Study. [Internet]. Vol. 22, Journal of Dentistry (Shiraz, Iran). 2021. p. 138–43.

6. Gundogdu M, Aladag LI. Effect of adhesive resin cements on bond strength of ceramic core materials to dentin. Niger J Clin Pract. 2018;21(3):367–74.

7. Shilpa P, Narendra R, Reddy S. Shear bond strength of ceramic bonded to different core materials and their pattern of failure: An in vitro study. Cureus. 2019;11(11):138–43.

8. Hewlett S, Wadenya RO, Mante FK, Sandra Hewlett, Wadenya RO, Mante FK. Bond strength of luting cements to core foundation materials. Compend Contin Educ Dent. 2010;31(2):140–6.

9. Saka M, Yuzugullu B. Bond strength of veneer ceramic and zirconia cores with different surface modifications after microwave sintering. J Adv Prosthodont. 2013;5(4):485–93.

10. Çakırbay Tanış M, Kılıçarslan MA, Bellaz İB. In vitro evaluation of bond strength between zirconia Core and CAD/CAM-produced veneers. J Prosthodont. 2020;29(1):56–61.

11. Capa N, Özkurt Z, Canpolat C, Kazazoglu E. Shear bond strength of luting agents to fixed prosthodontic restorative core materials. Aust Dent J. 2009;54(4):334–40.

12. Altintas S, Eldeniz AU, Usumez A. Shear bond strength of four resin cements used to lute ceramic core material to human dentin. J Prosthodont. 2008;17(8):634–40.

13. El Mourad AM. Assessment of bonding effectiveness of adhesive materials to tooth structure using bond strength test methods: A review of literature. Open Dent J. 2018;12(1):664–78.

14. Guarda GB, Correr AB, Gonçalves LS, Costa AR, Borges GA, Sinhoreti MA C-SL. Effects of surface treatments, thermocycling, and cyclic loading on the bond strength of a resin cement bonded to a lithium disilicate glass-ceramic. Oper Dent. 2013;38(2):208–17.

15. Bozogullari N, Inan O, Usumez A. Bond strength of adhesively luted ceramic discs to different core materials. J Biomed Mater Res - Part A. 2009;89(2):466–71.

16. Al-Manei KKK, Owaiwid AB, Dhafiri R AL, Al-Manei KKK, Harran S AL, Alsulaimani RS. Shear bond strength of E. Max ceramic restoration to hydraulic calcium silicate-based cement (Biodentine): An in vitro study. Eur Endod J. 2020;5(3):288–94.

17. Hitz T, Stawarczyk B, Fischer J, Hämmerle CHF, Sailer I. Are self-adhesive resin cements a valid alternative to conventional resin cements? A laboratory study of the long-term bond strength. Dent Mater. 2012;28(11):1183–90.