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Research Article

Bonding Performance of Lithium Disilicate Veneers to Bioactive and Conventional Resin Cores using three types of luting agent: An in vitro study

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Abstract

Aims: The present study aimed to evaluate the shear bond strength (SBS) and internal adaptation of lithium disilicate veneers bonded to bioactive and conventional composite cores using various luting agents and bonding approaches.

Materials and Methods: A total of 96 specimens were fabricated from two core materials (Predicta Bulk Fill and 3M Filteks Z250 composites) and luted with three cements: Predicta Bioactive Cement, RelyX U200, and Variolink Esthetic LC, applied either with or without GC Premio Bond. Samples were then subjected to 5,000 thermocycles (5–55°C). SBS was measured using a universal testing machine, while internal adaptation was assessed with micro-CT. Failure modes were analyzed under stereomicroscopy. Statistical analysis involved three-way ANOVA with post hoc comparisons at $P \leq 0.05$. Core material and cement type significantly affected SBS outcomes.

Results: Predicta Bulk Bioactive cores demonstrated the highest SBS, particularly when luted with Predicta Bioactive Cement (320–330 MPa bonded; 300–310 MPa unbonded) or RelyX U200 (310–330 MPa). Filtek Z350 XT showed greater variability, with RelyX U200 unbonded samples achieving 280–300 MPa, while Variolink Esthetic LC consistently produced the lowest values (40–60 MPa). Application of GC Premio Bond improved SBS for Predicta and Variolink groups, whereas RelyX U200 performed strongly regardless of bonding protocol. Micro-CT analysis revealed uniformly small internal gaps (2–3 µm) across groups. RelyX U200 showed the best overall adaptation, while Predicta Cement exhibited slightly larger gaps, especially without bonding.

Conclusion: RelyX U200 provided the most favourable combination of bond strength and internal adaptation for lithium disilicate cementation.

Keywords: Dental Bonding; Dental Veneers; Resin Cements; Silicates; Tomography, X-Ray computer.

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INTRODUCTION

All-ceramic restorations represent a leading technology in contemporary dental practice, with lithium disilicate ($Li_2Si_2O_5$), particularly IPS E.max (Ivoclar Vivadent, Liechtenstein), being the most widely utilized form of adhesive glass ceramics in modern dentistry (1). Conventional resin composites are used widely for coronal build-up restorations and frequently serve as core materials for luting with $Li_2Si_2O_5$ restorations. However, growing clinical demands have led to the introduction of innovative alternatives. One of them is Predicta Bulk Bioactive (Parkell, New York, USA). This dual-cure resin composite eliminates the need for incremental layering and releases beneficial ions (calcium, phosphate, and fluoride) that enhance its bioactive potential (2).

The cementation process of $Li_2Si_2O_5$ is fundamental in ensuring reliable retention and formation of a durable seal between the restoration and the tooth structure or core materials. Consequently, the selection of suitable luting cement is a critical determinant of restoration longevity and performance (3). Luting agents play a crucial role in achieving mechanical retention, maintaining a marginal seal, and distributing functional stresses effectively (4,5). A wide range of luting systems is available, each with unique bonding mechanisms and clinical advantages. Dual-cure adhesive cements integrate chemical and light-activated polymerization, while self-adhesive cements simplify the bonding process[4]. Bioactive luting cements offer potential for ion exchange and chemical interaction with bioactive core materials (5).

The bonding of Li2Si2O5 is a multifactorial process influenced by numerous variables, including the surface treatment of both the ceramic and the core substrate, the type of core material, and the chemical as well as physical properties of the chosen luting agent (3,6). Despite technological advancements, there remains a scarcity of standardized data comparing shear bond strength, marginal seal, and internal adaptation across various core material-luting agent combinations. Moreover, the specific influence of luting agent bioactivity on bond strength and restorative material behavior has yet to be elucidated comprehensively. Addressing these knowledge gaps is essential to identify the most effective material combinations for achieving durable and esthetically favorable restorations, thereby enhancing clinical outcomes. This study aims to evaluate the effect of bioactivity of the luting agent and substrate upon the shear bond strength and the internal adaptation of the Li2Si2O5.

The null hypothesis of this *in vitro* investigation is that the bioactivity of the luting agent has no statistically significant effect on the interfacial bond strength or durability of Li2Si2O5 restorations.

MATERIALS AND METHODS

Ethical Approval

This study was approved by the Ethics Committee of the University of Mosul, College of Dentistry (Reference: **UoM.Dent/D.A/6943**, dated 31/12/2024) and conducted in accordance with institutional and international research standards. No living human participants or animals were involved. All experimental procedures and statistical analyses followed validated scientific and ethical guidelines, and the study adhered to the principles of the World Medical Association's Declaration of Helsinki.

Core materials included Predicta Bulk Bioactive resin composite containing bioactive glass fillers and conventional resin composite 3M Filtek Z350 XT (3M ESPE, USA). Three luting agents were evaluated: Predicta Bioactive Cement (Parkell, USA), RelyX U200 self-adhesive cement (3M ESPE, USA), and Variolink Esthetic LC (Ivoclar Vivadent, Liechtenstein). GC Premio Bond (GC Corp., Japan) was used as the adhesive system.

Surface treatment materials included: 37% phosphoric acid gel (Transene, USA), 10% hydrofluoric acid gel (FGM, Brazil), and Monobond N silane coupling agent (Ivoclar Vivadent, Liechtenstein).

Sample Preparation

Two core materials were used to fabricate disc-shaped specimens measuring 6 mm in diameter and 2 mm in height. A total of 96 specimens, 48 specimens were prepared from Predicta Bulk Fill composite, and another 48 specimens were fabricated using 3M

Filtek Z250, following standardized dimensions achieved through metallic molds. Each disc was then embedded in cold-cure acrylic resin blocks (ProBase® Cold, Ivoclar Vivadent, Liechtenstein) to provide rigid support and ensure specimen stability during surface preparation, luting procedures, and subsequent testing.

Lithium disilicate veneers (4 mm diameter × 2 mm thickness) were CAD-designed and milled from IPS E.max CAD blocks using a five-axis MAXX CAD/CAM device (Robots & Design, Korea), then crystallized according to the manufacturer's schedule (850°C for 20 min).

Surface Treatment Protocols

Intaglio surfaces of veneers were etched with 10% hydrofluoric acid gel for 40 seconds, rinsed for 120 seconds, air-dried, and coated with Monobond N silane coupling agent for 60 seconds before gentle air dispersion (7).

Core surfaces were flattened with a flat-end diamond bur (236 C Lusterdent Lusterdent Medical Instrument Co., Ltd., China) under water cooling (400 k rpm, 50–60 mL min^{-1}, 60 s) cooling using a survey to ensure even and standardized preparation, cleaned ultrasonically for 10 minutes, and air-dried. All cores were etched with 37% phosphoric acid for 30 seconds, rinsed for 30 seconds, and air-dried. Specimens were allocated randomly to 48 specimens bonded with (G-Premio Bond applied per manufacturer instructions) or 48 specimens unbonded subgroups.

Experimental Design

The sample size was established in accordance with previous in-vitro investigations on lithium-disilicate bonding and internal adaptation, which typically employed comparable subgroup distributions (3,6,7). A total of 96 specimens were prepared, with 48 specimens allocated to each core material (Predicta Bulk Fill composite and 3M Filtek Z250). For each core material, the 48 specimens were evenly divided into bonded (n = 24) and unbonded (n = 24) groups according to the application of GC Premio Bond. Each of these groups was further subdivided into three luting-agent subgroups: Predicta Bioactive Cement (n = 8), RelyX U200 (n = 8), and Variolink Esthetic LC (n = 8), resulting in eight specimens per cement type per **bonding condition**

This produced a balanced distribution across all experimental factors. Cements were mixed/dispensed per manufacturer instructions, applied to the veneer intaglio, and seated under 1 kg axial load for 10 seconds (8), using a custom surveyor jig to standardize film thickness. Excess was removed, and light polymerization was completed with an LED unit (1000 mW/cm^2; Eighttooth Curing pen-E unit Changzhou Sifary Medical Technology Co., Ltd) through the ceramic for 40 seconds per surface.

Aging Protocol

All samples were thermocycled for 5,000 cycles between 5°C and 55°C, with 30-second dwell time and 10-second transfer intervals, following ISO TR11405 standards[7].

Shear Bond Strength Testing

Sixty specimens (30 per core material, 5 per cement × bonding condition) were mounted in a jig and loaded with a chisel-shaped blade at 0.5 mm/min until failure using a universal testing machine (GT KS20, Gester, China). Shear bond strength (SBS; MPa) was calculated as: SBS = F/A, where F = failure load (N) and $A = \pi r^2$ (r = 2 mm).

Failure Mode Analysis

Debonded interfaces were inspected under stereomicroscopy at 20× magnification (Optika, Italy) and categorized as adhesive, cohesive, or mixed [1].

Micro-CT Evaluation

Thirty-six samples (18 per core material, 3 per cement/ bonding condition) were analyzed using a cone beam micro-CT scanner (LOTUS inVivo, Tehran, Iran). Scanning parameters: 80 kV, 90 μA, 25 μm voxel size, 30-minute duration. Three-dimensional reconstruction using an LOTUS inVivo-REC by a standard Feldkamp, Davis, Kress (FDK) algorithm allowed measurement of marginal and internal gap volumes (μm^3) using threshold-based segmentation.

Statistical Analysis

Three-way ANOVA was performed to evaluate the effects of core material, cement type, and bonding condition on SBS and internal adaptation. P*ost hoc* comparisons were conducted using Tukey's test. Chi-square analysis was used for failure mode distribution. Statistical significance was set at $p \leq 0.05$

RESULTS

Shear Bond Strength

Three-way ANOVA revealed that cement type was the dominant factor influencing shear bond strength, with RelyX U200 achieving the highest mean SBS values across both core materials (approximately 300–330 ± 15 MPa). Predicta Bioactive Cement also produced high values when used with Predicta Bulk Fill cores, particularly in bonded groups (325 ± 10 MPa) compared with unbonded specimens (305 ± 12 MPa). In contrast, Variolink Esthetic LC exhibited the lowest SBS values, especially with Filtek Z250 XT, where means ranged from 40–60 ± 15 MPa.

A significant cement × bonding interaction indicated that GC Premio Bond produced a greater improvement in SBS for Predicta Bioactive Cement and Variolink Esthetic LC than for RelyX U200. For example, SBS increased from ~90 MPa to ~110 ± 25 MPa in Predicta–Variolink groups after bonding, whereas RelyX U200 showed minimal differences between bonded and unbonded specimens (320 ± 15 MPa vs. 310 ± 15 MPa). Bonding condition as a main effect was significant, with bonded specimens consistently demonstrating higher SBS than their unbonded counterparts. Core material type and higher-order interactions showed no statistically significant effect

P*ost hoc* comparisons revealed that unbonded Variolink Esthetic LC exhibited significantly lower SBS compared to both bonded and unbonded RelyX U200 configurations across both core materials ($p < 0.001$). Bonded Predicta Bioactive Cement also demonstrated superior performance compared to unbonded Variolink Esthetic LC ($p < 0.001$). Notably, RelyX U200 showed no statistically significant differences between bonded and unbonded conditions within the same core material ($p > 0.05$). The regression analysis demonstrated a strong positive correlation between predicted and actual SBS values ($R^2 = 0.59$, RMSE = 87.807, $p < 0.0001$), confirming the model's predictive validity.

Table (2): *Three-way ANOVA results for shear bond strength.* Cement type ($p < 0.0001$, $\eta^2 = 0.3718$) and cement/ bonding interaction ($p = 0.0032$, $\eta^2 = 0.1120$) showed significant effects, while bonding alone had a smaller but significant effect ($p = 0.0468$, $\eta^2 = 0.0359$). Composite type and higher-order interactions were not statistically significant.

Source	-log(p-value)	p-value	F Ratio	η^2 Effect Size
Cement	6.679	0.00000	21.5513	0.3718
Cement *Bonding	2.495	0.00320	6.4913	0.1120
Bonding	1.330	0.04677	4.1656	0.0359
Composite	0.802	0.15794	2.0575	0.0177
Composite *Cement *Bonding	0.610	0.24545	1.4466	0.0250
Composite *Cement	0.569	0.26967	1.3470	0.0232
Composite *Bonding	0.060	0.87168	0.0264	0.0002

Composite	Cement	Bonding	-Composite	-Cement	-Bonding	P-Value
Filteks Z250 XT	Variolink Esthetic	Unbonded	Filteks Z250 XT	Relyx u250	Unbonded	<.0001
Predicta	Predicta	Bonded	Filteks Z250 XT	Variolink Esthetic	Unbonded	<.0001
Predicta	Relyx u250	Unbonded	Filteks Z250 XT	Variolink Esthetic	Unbonded	0.0001
Predicta	Relyx u250	Bonded	Filteks Z250 XT	Variolink Esthetic	Unbonded	0.0015
Filteks Z250 XT	Predicta	Bonded	Filteks Z250 XT	Variolink Esthetic	Unbonded	0.0015
Filteks Z250 XT	Variolink Esthetic	Unbonded	Filteks Z250 XT	Relyx u250	Bonded	0.0035
Filteks Z250 XT	Variolink Esthetic	Bonded	Filteks Z250 XT	Relyx u250	Unbonded	0.0256
Predicta	Variolink Esthetic	Unbonded	Filteks Z250 XT	Relyx u250	Unbonded	0.0387
Predicta	Predicta	Bonded	Filteks Z250 XT	Variolink Esthetic	Bonded	0.0430
Filteks Z250 XT	Variolink Esthetic	Unbonded	Filteks Z250 XT	Relyx u250	Unbonded	<.0001
Predicta	Predicta	Bonded	Filteks Z250 XT	Variolink Esthetic	Unbonded	<.0001
Predicta	Relyx u250	Unbonded	Filteks Z250 XT	Variolink Esthetic	Unbonded	0.0001
Predicta	Relyx u250	Bonded	Filteks Z250 XT	Variolink Esthetic	Unbonded	0.0015

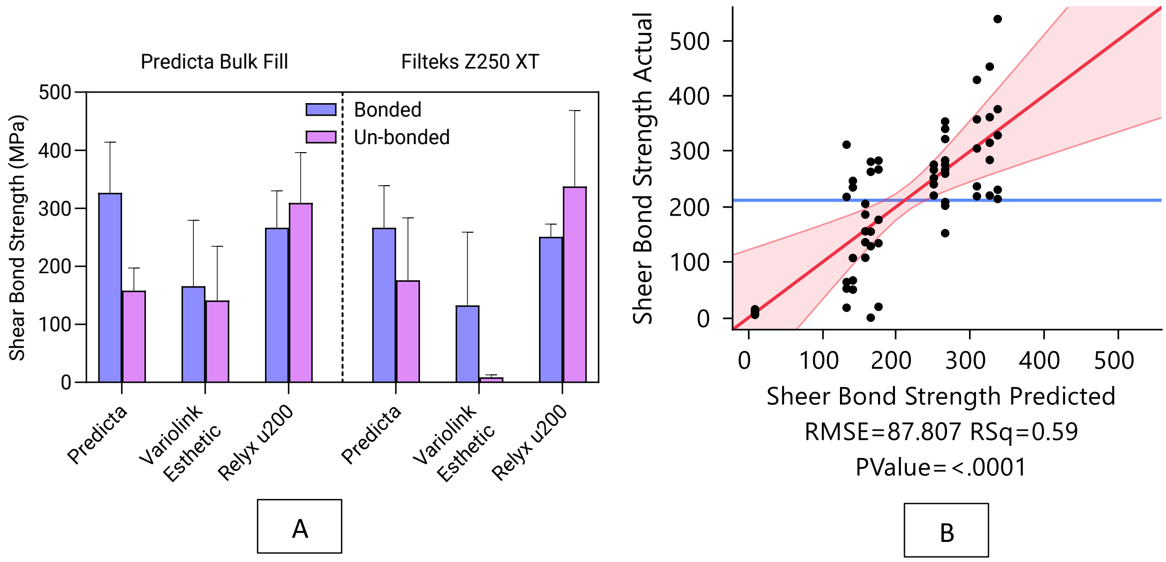

Figure (1): Shear bond strength analysis of Li2Si2O5 veneers bonded to core materials. (A) Mean shear bond strength values (MPa ± SD) for Predicta Bulk Fill and Filtek Z350 XT core materials with three luting cements under bonded and unbonded conditions. RelyX U200 demonstrated superior performance across both core materials, while Variolink Esthetic LC showed the lowest values, particularly in unbonded conditions. (B) Regression analysis showing correlation between predicted and actual SBS values with 95% confidence interval ($R^2 = 0.59$, RMSE = 87.807, $p < 0.0001$), validating the statistical model's predictive accuracy.

Failure mode

Chi-square analysis revealed that the failure mode distribution varied significantly with cement type ($\chi^2 = 82.21$, $p < 0.0001$), while resin composite type and bonding condition showed no statistically significant effect ($p = 1.000$ for both). Variolink Esthetic LC exhibited predominantly adhesive failures (approximately 95% of specimens), indicating failure at the cement-substrate interface. In contrast, RelyX U200 and Predicta Bioactive Cement demonstrated more balanced distributions with higher proportions of cohesive failures within the cement body and admix (mixed) failures combining both interfacial and cohesive characteristics.

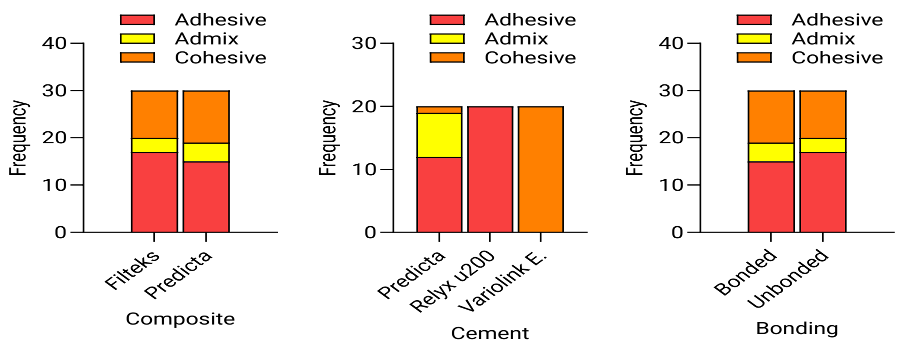

Figure (2): Distribution of failure modes following SBS testing. Stacked bar charts showing frequency of adhesive (red), admix (yellow), and cohesive (orange) failures by composite core material, luting cement type, and bonding condition. Variolink Esthetic LC demonstrated predominantly adhesive failures, while RelyX U200 and Predicta Bioactive Cement exhibited more balanced distributions with higher proportions of cohesive and mixed failures, indicating superior interfacial bonding.

Internal Adaptation

Three-way ANOVA demonstrated that the cement type influenced internal gap formation significantly ($F = 18.80$, $p = 0.00022$, $\eta^2 = 0.1899$), with RelyX U200 consistently producing the smallest marginal gaps across all experimental conditions. As illustrated in Figure 4A, RelyX U200 achieved mean gap measurements ranging from 1.7 to 2.4 μm for both core materials, demonstrating superior marginal adaptation regardless of bonding protocol. The cement/bonding interaction proved highly significant ($F = 17.50$, $p < 0.00001$, $\eta^2 = 0.3537$), indicating that adhesive bonding application improved marginal adaptation substantially, with the most pronounced effects observed in Predicta Bioactive Cement and Variolink Esthetic LC groups.

Predicta Bioactive Cement exhibited the largest internal gaps, particularly in unbonded configurations, where mean values exceeded 2.9 ± 0.3 μm in Predicta Bulk Fill specimens. The application of GC Premio Bond significantly reduced these gaps to approximately 2.0 ± 0.2 μm ($p < 0.001$), representing a ≈ 31% improvement in internal adaptation. Similarly, Variolink Esthetic LC demonstrated intermediate performance, with gap dimensions decreasing from 2.9 ± 0.4 μm (unbonded) to 1.9 ± 0.3 μm (bonded), also showing a statistically significant enhancement ($p < 0.001$). The effect of bonding on gap volume was confirmed by the significant cement/bonding interaction ($F = 17.50$, $p < 0.00001$, $\eta^2 = 0.3537$), indicating that adhesive application markedly improved marginal adaptation in Predicta and Variolink systems.

The three-way interaction (core material/cement/bonding) reached statistical significance ($F = 7.34$, $p = 0.0033$, $\eta^2 = 0.1483$), demonstrating that the beneficial effects of bonding varied considerably depending on the specific combination of core material and luting cement employed. This interaction was particularly evident in the differential response between core materials when used with Predicta Bioactive Cement.

Micro-CT analysis (Figure 5,6) provided a detailed visualization of these quantitative findings. The 3D reconstructions with orange interface demarcation clearly demonstrate the superior marginal adaptation achieved by RelyX U200 (figure

5,6), with minimal visible gaps and uniform cement distribution. In contrast, Predicta Bioactive Cement specimens (Figure 5,6) showed pronounced interfacial separations, particularly visible in the 3D reconstructions of unbonded specimens. The 2D cross-sections revealed detailed internal cement distribution patterns, confirming the quantitative measurements and demonstrating how bonding application improved cement flow and reduced void formation.

The regression analysis confirmed strong model validity with excellent correlation between predicted and actual internal adaptation values ($R^2 = 0.76$, RMSE = 0.3767, $p < 0.0001$), as demonstrated in Figure 4B, validating the statistical model's predictive accuracy and supporting the reliability of the quantitative gap measurements obtained through threshold-based segmentation.

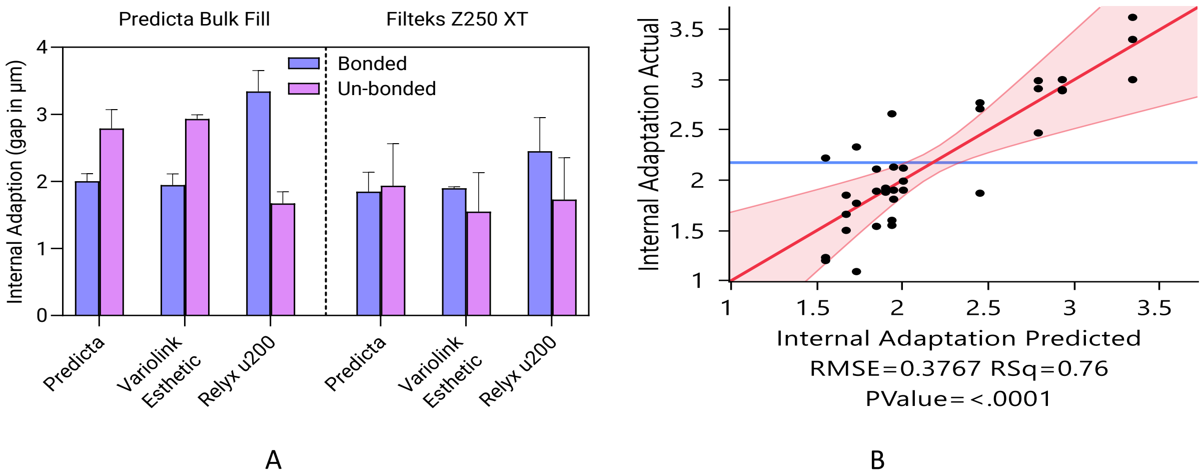

Figure (4): Internal adaptation analysis of Li2Si2O5 veneers. (A) Mean internal gap measurements (µm ± SD) for different cement-core combinations under bonded and unbonded conditions. RelyX U200 consistently achieved the smallest gaps, while Predicta Bioactive Cement showed the largest gaps, particularly in unbonded configurations. (B) Regression plot showing correlation between predicted and actual internal adaptation measurements with 95% confidence interval, demonstrating strong model predictive accuracy ($R^2 = 0.76$, RMSE = 0.3767, $p < 0.0001$). Bonding application improved adaptation significantly for all cement types except RelyX U200, which maintained consistently low gap values regardless of bonding protocol

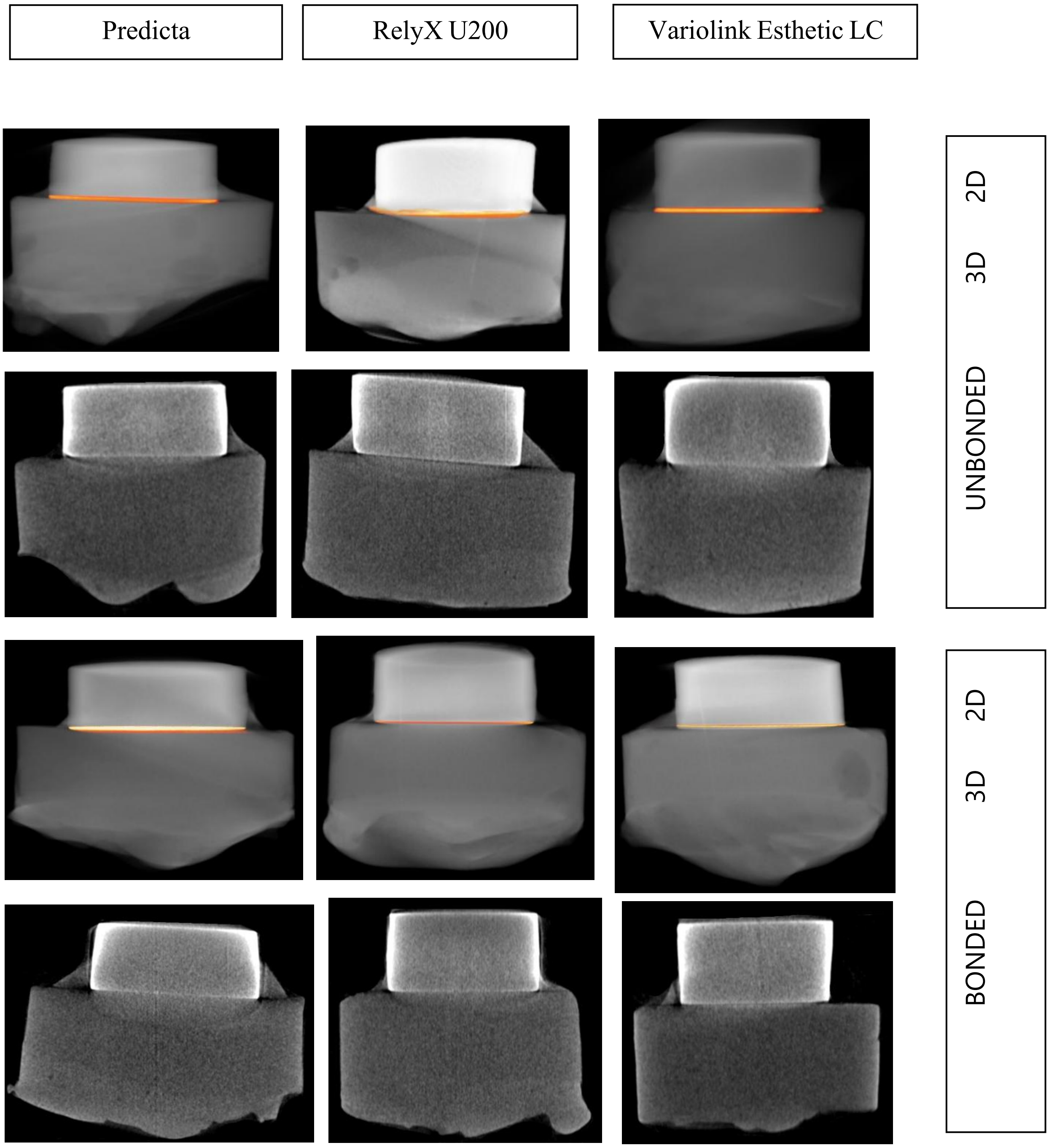

Figure (5): Representative micro-CT images illustrating the internal adaptation of lithium-disilicate veneers luted to predicta bulk fill bioactive composite using three resin cements under bonded and unbonded protocols.Columns display Predicta Bioactive, Variolink Esthetic LC, and RelyX U200. For each cement, the upper image is a false-colour three-dimensional reconstruction (orange = cement layer); the lower image is the corresponding sagittal two-dimensional slice. The upper block shows bonded specimens, the lower block unbound specimens. Scale bar = 1 mm.

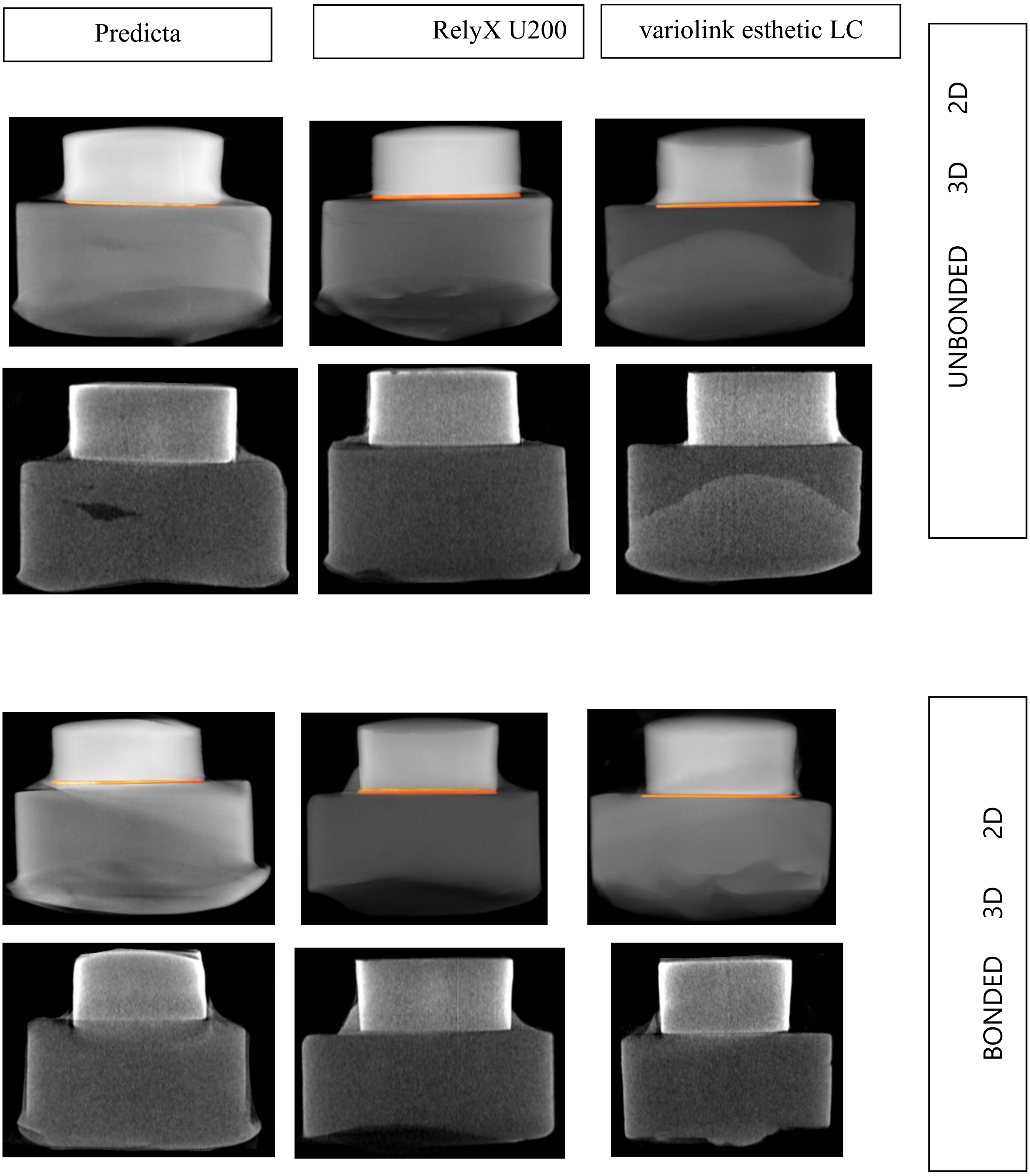

Figure (6): Representative micro-CT images illustrating the internal adaptation of lithium-disilicate veneers luted 3M Filtek Z250 using three resin cements under bonded and unbonded protocols. Columns display Predicta Bioactive, Variolink Esthetic LC, and RelyX U200. For each cement, the upper image is a false-colour three-dimensional reconstruction (orange = cement layer); the lower image is the corresponding sagittal two-dimensional slice. The upper block shows bonded specimens, the lower block unbound specimens. Scale bar = 1 mm.

DISCUSSION

This study evaluated the shear bond strength and internal adaptation of Li2Si2O5 veneers bonded to two core materials: a bioactive resin composite (Predicta Bulk Fill) and a conventional resin-based composite (3M Filtek Z350 XT). The results revealed significant differences across groups, highlighting the influence of core material composition, luting agent type, and bonding protocol.

The application of an adhesive bonding agent significantly improved SBS, which can be attributed to the adhesive layer's rich supply of functional monomers, which create a chemically active interface between the core material and cement. GC Premio Bond contains 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP), a functional monomer capable of forming stable nano-layers through chemical interaction with calcium ions, producing MDP-Ca salts. These salts balance hydrophilicity/hydrophobicity, reduce water sorption, and improve the durability and aging resistance of the adhesive interface (9-11).

Lithium disilicate veneers are inherently bioinert and therefore do not undergo chemical alterations that could enhance bonding to resin cements. As a result, the adhesion mechanism is predominantly dependent on micromechanical interlocking [1]. To optimize this interface, surface conditioning with 10% hydrofluoric acid has been widely recommended (3,7). Hydrofluoric acid etching produces a micro-retentive surface morphology, facilitating the effective coupling of silane molecules, which promotes durable chemical interaction between the resin cement and ceramic substrate (1). When Predicta Bulk Fill was used as the core and luted with Predicta Bioactive Cement, high SBS values were recorded, but with the largest gap volume among the other luting agents. This can be explained by the chemical compatibility between the two materials, both developed by the same manufacturer (Parkell, USA) and containing bioactive glass fillers that release calcium and phosphate ions(13). Whilst these fillers primarily promote remineralization at the tooth-restoration interface, they may also contribute to interface stability by forming apatite-like mineral phases (14,15).

The subgroup that received GC Premio Bond achieved even higher SBS, likely due to the formation of MDP-Ca salts between the adhesive's phosphate groups and the calcium ions from the bioactive cement and resin composite, providing additional chemical retention and protecting the hybrid layer from hydrolysis (9,10,16).

For RelyX U200, Filtek Z350 XT cores demonstrated the highest SBS values, particularly in the unbonded subgroups. This can be attributed to the shared resin matrix components (Bis-GMA, UDMA, TEGDMA) between the resin composite and cement, which promoted efficient resin-resin copolymerization (6,17). These findings align with previous studies that advocate the use of RelyX U200 without an additional bonding agent (18).

In contrast, Predicta Bulk Fill cores exhibited lower SBS values with RelyX U200, a result of compositional mismatches. While RelyX U200 contains conventional resin monomers (19), Predicta Bulk Fill incorporates unconventional monomers (such as bicyclo(2,2,1) heptane monomers) and ion-releasing fillers, reducing the proportion of reactive methacrylate groups and producing a more hydrophilic and less densely crosslinked polymer matrix (20,2). This reduced copolymerization potential explains the diminished bond strength. However, when GC Premio Bond was applied prior to RelyX U200 cementation, SBS values improved substantially. The presence of additional methacrylate groups and the formation of 10-MDP-Ca salts provided an alternative adhesion mechanism, reinforcing the cement-core interface(10,11).

Of the three luting agents evaluated, Variolink Esthetic LC demonstrated the lowest shear bond strength values, with the reduction being most pronounced in the unbonded subgroups. This may be due to its dependence on adequate light exposure for complete polymerization. Given that the Li2Si2O5 veneers used in this study were 2 mm thick - a dimension known to limit light transmission, insufficient curing at the cement interface may have occurred, thereby compromising bond strength (21). Variolink Esthetic LC replaces Bis-GMA with Urethane Dimethacrylate (UTEDMA) to improve viscosity and MDP compatibility (21). When used with Predicta Bulk Fill composite, calcium ion release from the core allows Ca-MDP salt formation, enhancing adhesion (14). This may explain why Predicta Bulk Fill cores bonded with Variolink Esthetic LC achieved higher SBS values compared to Filtek Z350 XT.

The present study's limitations include the *in vitro* design, which may not fully replicate clinical conditions, and the focus on immediate bond strength without long-term aging evaluation. Future research should investigate the long-term stability of these bonding systems under clinical conditions.

CONCLUSIONS

Within the limitations of the current study, it is possible to conclude that:

- The performance of lithium disilicate veneers is influenced significantly by the type of luting agent, core material, and bonding protocol used:

1- Adhesive bonding (GC Premio Bond) improved shear bond strength and internal adaptation, especially with Predicta Bioactive Cement and Variolink Esthetic LC.

2- RelyX U200 achieved the highest SBS values overall, particularly with Filtek Z350 XT cores, even without an adhesive agent, due to their chemical compatibility.

3- Predicta Bioactive Cement showed strong SBS values with Predicta Bulk Fill cores due to their shared bioactive chemistry, but displayed larger internal gaps compared to RelyX U200.

4- Variolink Esthetic LC consistently exhibited the lowest SBS values, particularly in unbonded subgroups due to insufficient polymerization under the 2 mm thick lithium disilicate veneers.

5- Micro-CT analysis confirmed that RelyX U200 achieved the best internal adaptation, while adhesive application notably improved gap volume for Predicta and Variolink systems

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Authors' Contribution

Muhammad MJ completed the conceptualization, data curation, formal analysis, methodology, finding acquisition, investigation, resources, software, validation, visualization, writing- original draft, and editing. Dawood AE and Manton DJ completed the supervision, visualization, review & editing.

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Ethical statement: This study was approved by the Ethics Committee of the University of Mosul, College of Dentistry (Reference: **UoM.Dent/D. A/6943**, dated 31/12/2024) and conducted in accordance with institutional and international research standards. No living human participants or animals were involved.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript

Availability of data and materials: All data generated or analyzed during this study are included in this published article and its supplementary information files.

Declaration of Generative AI and AI-assisted technologies

During the preparation of this work, the authors used ChatGPT to improve the readability of the manuscript. The authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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أداء ربط قشـــور ثنائي ســـيليكات الليثيوم باللب الراتنجي الحيوي والتقليدي باســـتخدام ثلاثة أنواع من عوامل التثبيت: دراسة مختبرية

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الملخص

الأهداف: تهدف هذه الدراسة إلى تقييم تأثير النشاط الحيوي لمادة التثبيت والركيزة على قوة رابطة القص والتكيف الداخلي لـ Li2Si2O5. **المواد والطرائق العمل**: تم تحضـــير ســـتةٍ وتســـعين عينة باســـتخدام مادتين قاعديتين وثلاث مواد تثبيت: Predicta Bioactive Cement، وRelyX U200، وVariolink Esthetic LC، مع وبدون استخدام مادة الربط GC Premio Bond. تم تخريش فينيرات الليثيوم ديســـيلكات بحمض الهيدروفلوريك بتركيز 10% ثم معالجتها بالســـيلان. بعد إجراء عملية المحاكاة الحرارية (5000 دورة)، تم اختبار قوة الارتباط القصـــوى باســـتخدام جهاز اختبار الشـــد العام، كما تم تقييم التكيف الداخلي بواســـطة تقنية الميكرو-CT. تم فحص أنماط الفشـــل بالمجهر الاســـتيريوســـي. أُجري التحليل الإحصـــائي باســـتخدام تحليل التباين الثلاثي (Three-way ANOVA) مع اختبار المقارنات البعدية عند مســـتوى دلالة ($p \leq 0.05$).
النتائج: أظهر نوع الإسمنت تأثيراً معنوياً على قوة الارتباط القصـــوى ($F = 21.55, p < 0.0001$)، حيث سـجّل RelyX U200 أعلى القيم. كما كان للتفاعل بين نوع الإســـمنت وتطبيق مادة الربط تأثير معنوي ($F = 6.49, p = 0.0032$)، مما يشـــير إلى أن تطبيق مادة الربط حسّـــن قوة الارتباط في إســـمنتي Predicta وVariolink Esthetic أكثر من RelyX U200. أما بالنسبة للتكيف الداخلي، فقد كان لنوع الإسمنت ($F = 18.80, p = 0.00022$) والتفاعل بين الإسمنت والربط ($F = 17.50, p < 0.00001$) تـأثير معنوي، حيـث أظهر RelyX U200 أقـل الفجوات. بينمـا أظهر Predicta Bioactive Cement مع القواعد من نوع Predicta Bulk Fill قوة ارتبـاط جيـدة ولكن مع فجوات أكبر مقـارنـةً بـ RelyX U200. **الاســـتنتاجات**: وفر RelyX U200 المزيج الأمثل من قوة الترابط والتكيف الداخلي لتثبيت الليثيوم ثنائي السيليكات.

الكلمات المفتاحية: ربط الأسـنان؛ قشـور الأسـنان؛ الأسـمنت الراتنجي؛ السـيليكات؛ التصـوير المقطعي، التصـوير بالأشـعة السينية المحوسب.