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Original article

SHEAR BOND STRENGTH OF LITHIUM DISILICATE AND HYBRID CERAMIC WITH THREE TYPES OF LUTING CEMENT (A PILOT STUDY)

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ABSTRACT

The present pilot study aimed to determine the bond strength between dentin and two types of ceramics cemented using three types of luting agents.

The purpose of this pilot study was to determine the bond strength between dentin and two types of ceramics cemented using three types of luting agents.

Materials and Methods: Seventy-two dentin discs were prepared from extracted teeth with intact dental crowns. Ceramic cylinders of two types, lithium disilicate (IPS emax CAD) and hybrid Ceramic (Vita Enamic), were cut and sintered to dimensions of 6/6 mm. Test specimens (dentin – cement – ceramic) were distributed into six groups (n = 12), depending on the ceramic material used and the cement used for adhesive fixation (eCEMENT, Variolink Esthetic DC, Panavia V5). They were subjected to shear bond strength testing. The results were statistically analyzed using IBM SPSS Statistics 26 with a significance level of 0.05.

Results: In Vita Enamic, the highest shear bond strength was observed with Panavia V5 cement (18.87±0.89 MPa), followed by Variolink Esthetic DC (14.03±4.45 MPa) and e-CEMENT (11.40±5.19 MPa) ($p < 0.05$). In IPS emax CAD, the best bond was again with Panavia V5 cement (17.53±3.39 MPa), followed by Variolink Esthetic DC (17.30±4.49 MPa) and eCEMENT (14.33±5.27 MPa), however without statistical significance ($p > 0.05$).

Conclusions: Within the limitation of the presented study, the composite cement Panavia V5 demonstrates better adhesive properties than the other two types of cement.

Keywords: hybrid ceramic, lithium disilicate ceramic, luting cements, shear bond strength,

INTRODUCTION

The recent advances in dental technologies have increased the popularity of CAD/CAM (Computer-Aided Design; Computer-Aided Machining) in everyday dental practice, as they have enabled the automated production of high-quality restorative and prosthetic ceramic restorations.

Ceramic materials for CAD/CAM constructions are generally divided into glass-based, polycrystalline, and resin-based materials. Glass-based (lithium disilicate) and polycrystalline (zirconia) ceramics are widely used in dentistry due to their low degradation, biocompatibility, and favourable aesthetic appearance. Currently, lithium-based and zirconium-based ceramics are the main materials considered for monolithic CAD/CAM restorations. Materials such as leucite-reinforced glass ceramics, feldspathic ceramics, resin composite materials, polymer-infiltrated ceramics (hybrid ceramics), and titanium are also frequently used [1].

The first developed ceramic material based on lithium (IPS e.max CAD Ivoclar Vivadent, Lichtenstein) consists mainly of lithium disilicate (LD) and has high flexural strength (≈360 MPa) [2]. Due to its excellent optical and mechanical properties, this ceramic can be used for restorations in the frontal and distal areas of the tooth, including inlays, onlays, implant constructions, and three-unit bridge prostheses up to the second premolar [3]. Glass ceramics, feldspathic ceramics, lithium disilicate ceramics, and lithium disilicate reinforced with zirconia possess superior qualities but are prone to fracture. Hybrid and nanoceramics have been developed to overcome this and other disadvantages of glass ceramics, combining the advantages of composites and ceramics. Vita Enamic (Vita Zahnfabrik, Germany) is a recently developed material known as hybrid ceramic, consisting of a feldspathic ceramic network (86 wt%) infiltrated with polymer (14 wt%). This polymer-infiltrated ceramic network has increased flexibility and fracture resistance compared to conventional ceramics while maintaining its mechanical properties – ≈160 MPa flexural strength [2].

Silicate, hybrid, and feldspathic ceramics are usually pretreated by etching with hydrofluoric acid (HF) to create micromechanical retention and increase the surface area for bonding between the substrate and the cement [4]. Chemical bonding to silicate and hybrid ceramics is achieved by applying silane [5]. When processing CAD/CAM composite materials such as RNC (Lava Ultimate, 3M ESPE, USA) and hybrid ceramics (Vita Enamic, Vita Zahnfabrik, Germany), reliance is placed on their specific composition, and airborne abrasion with aluminium oxide or etching with HF acid is recommended [1, 6, 7].

The adhesive cementation of all-ceramic constructions is carried out with composite cements. Composite cements can be dual-curing, light-curing, or self-curing, with a slight decrease in pH allowing for self-adhesion and hydrolysis resistance [1, 8].

The micromechanical bond of the composite cement to dentin is based on the infiltration and polymerization of small monomers into the network of collagen fibres, called the hybrid layer. To achieve the hybrid layer, traditional etching and rinsing are used. Cements that use total etching have superior clinical performance in terms of resistance and durability. These systems are preferred for indirect restorations when enamel is still present [2].

The clinical application of self-adhesive composite cements is significantly simplified compared to other cements, reducing the risk of errors. Self-etching primers containing non-rinsing acidic monomers such as 10-methacryloyloxydecyl dihydrogen phosphate (MDP) have been created, which can simultaneously etch and prime dental tissue [7]. Therefore, the separate etching of the dental substrate with phosphoric acid can be omitted. These adhesive systems are recommended when a larger portion of the substrate is dentin.

Adhesion to ceramic materials is improved by creating a microretentive surface using sandblasting or HF etching, followed by applying a monobond primer to enhance chemical bonding [2, 6, 9, 10].

The product line (Kuraray Noritake, Okayama, Japan) has a separate bonding primer for dental tissues (PV5 Tooth Primer) and a different primer to be used on prosthetic constructions (Clearfil Ceramic Primer Plus). PV5 Tooth Primer is a self-adhesive primer with a pH of 2.03, containing HEMA and MDP, which, according to the manufacturer's instructions, can etch dentin and enamel without the need for conventional phosphoric acid use. Clearfil Ceramic Primer Plus contains silane for bonding to silicate ceramics and MDP for pre-treatment of zirconia [7]. There is a trend towards higher bond strength to enamel and dentin with universal adhesives containing MDP than those without MDP [11]. Such cements also include Variolink Esthetic DC (Ivoclar Vivadent, Lichtenstein) and RelyX Universal (3 M; Neuss, Germany), which use a universal bond [7, 9].

The bond strength between two materials can be assessed using various methods - shear bond strength (SBS), micro-shear bond strength (μSBS), tensile bond strength (TBS), and micro-tensile bond strength (μTBS), but the most popular of these is Shear Bond Strength (SBS). The bond strength values documented in the scientific literature when using different types of cement and different CAD/CAM materials range from 12.1±1.2 MPa to 25.5±2.5 MPa while adhering to the manufacturers' recommendations for their use [12, 13, 14, 15]. The relationship between dental tissues, CAD/CAM ceramics, and various composite cements has been the subject of research by a number of authors, but there is still no consensus on the combination that yields the best results [9, 16].

The aim of this pilot study was to determine the bond strength between dentin and two types of ceramics cemented using three types of luting agents.

The tested null hypothesis in this study was that there would be no difference in the mean levels of bond strength between the three types of cement and the two types of ceramics.

MATERIALS AND METHODS

Specimen Preparation

In the study, 80 extracted teeth with intact crowns were used. The teeth were extracted from patients aged 30 to 50. The patients also filled out an informed consent form, agreeing to have their teeth used for the scientific research. Teeth with intact crowns without caries and cracks were selected. A preliminary radiograph was done to determine the level of cuts. From the middle part of the tooth crown of the teeth, 80 dentin discs with a thickness of 2.0 ± 0.3 mm were cut using a microtome, Leica SP1600 (Leica Biosystems, Germany). All dentin discs were examined under a stereomicroscope "Leica S6" to exclude those with cracks and artifactual damage, and 72 defect-free discs were selected. The dentin discs (n=72) were embedded in epoxy resin.

Afterwards, the 72 ceramic cylinders with dimensions of diameter and height, respectively 6mm/6mm, were cut using a five-axis CAD-CAM milling machine (Ceramill Motion 2, Amann Girrbach). The sintering of the lithium disilicate specimens was performed according to the manufacturer's specified temperature program in a sintering furnace Ceramill Therm 3 (Amann Girrbach).

The ceramic cylinders were distributed into two groups (n = 36) depending on the ceramic material used (IPS e.max CAD, Ivoclar-Vivadent, Lichtenstein and Vita Enamic, Vita Zahnfabrik, Germany) and into three subgroups (n = 12) depending on the cement used for adhesive fixation (e-CEMENT, Bisco Inc, USA; Variolink Esthetic DC, Ivoclar-Vivadent, Lichtenstein; Panavia V5, Kuraray Noritake, Japan).

All test specimens (n = 72) from the six combinations of dentin - Ceramic - cement (Fig. 1) were stored in distilled water for a period of 24 hours.

Fig. 1. The test specimens, composed of a dentin base to which a ceramic cylinder is bonded using a cement

To standardize the methodology of adhesive fixation, a 3D printed model was created using a 3D stereolithography printer Form 2 SLA (Formlabs Inc., USA) for precise positioning of the ceramic cylinder and dentin disc.

The adhesive fixation was performed with equal force, using a standardized 500 g weight (according to the Bulgarian State Standard, BSS), which was positioned at the precisely designated location in the 3D-printed model (Fig. 2a, b).

Etching, Silanization and Bonding Procedure

The ceramic cylinders and dentin discs were cemented according to the manufacturer's instructions for each type of cement and each type of Ceramic (Table 1 a, b).

Fig. 2. Experimental model of fixation of the test body to the dentin disc **a)** standardized 500g weight **b)** placed in the experimental 3D printed model

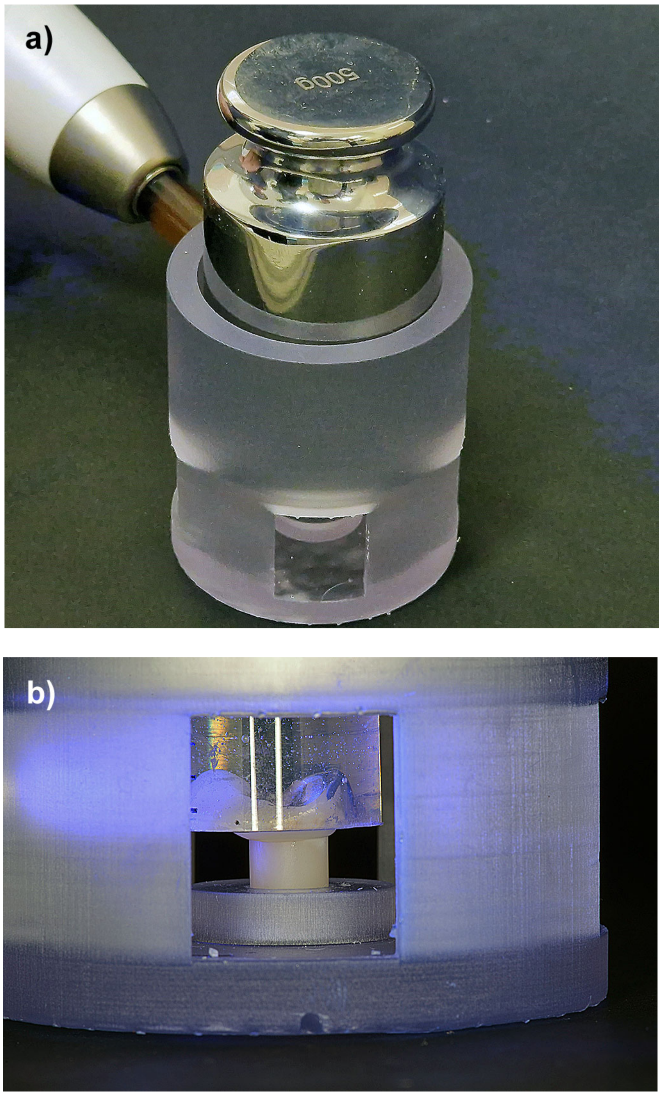

Table 1a. Etching, Silanization, and Bonding Procedure - according to manufacturer's requirements by IPS emax CAD (Ivoclar Vivadent, Lichtenstein) - Lithium disilicate ceramics

Luting agent	Treatment of the tooth surface	Treatment of the ceramic surface	Fixation and polymerization
e-CEMENT dual-cure	1. Etching (SELECT HV ETCH) - 15 s	1. Etching of porcelain with 4% HF (PORCELAIN ETCHANT) - 25 s	1. Application of cement
	2. Rinsing and drying	2. Rinsing and drying	2. Polymerization for 2 s on each side of the prosthetic structure
	3. Application of 2 layers of ALL-BOND UNIVERSAL®	3. Application of 1 layer of PORCELAIN PRIMER	3. Removal of excess
	4. Drying - 10 s	4. Waiting-30 s and drying-3-5 s	4. Final polymerization-40 s
	5. Polymerization - 10 s		

Variolink Estethic DC self-etching adhesive	1. Etching (optional) - 15-30 s and rinsing for 1 min., 5 s drying	1. Monobond Etch & Prime by rubbing for 20 s	1. Application of cement
	2. Application of Adhese Universal (VivaPen) by rubbing - 20 s	2. Waiting - 40 s	2. Polymerization for 2 s
	3. Polymerization-10 s	3. Rinsing - 10 s	3. Removal of excess
			4. Final polymerization-10 s
Panavia V5 self-etching adhesive dual-cure	1. Application of PANAVIA V5 Tooth Primer	1. Etching of porcelain with 4.5% HF or K-ETCHANT-20 s	1. Application of cement
	2. Waiting-20 s	2. Rinsing and drying	2. Polymerization for 3-5 s on each side of the prosthetic structure
	3. Drying	3. Application of CLEARFIL CERAMIC PRIMER PLUS and drying	3. Removal of excess
			4. Final polymerization-20 s

Table 1 b. Etching, Silanization, and Bonding Procedure - according to manufacturer's requirements by Vita Enamic, Vita Zahnfabrik, Germany

Luting agent	Treatment of the tooth surface	Treatment of the ceramic surface	Fixation and polymerization
e-CEMENT dual-cure	1. Etching (SELECT HV ETCH)-15 s	1. Etching of porcelain with 4% HF (PORCELAIN ETCHANT) - 60 s	1. Application of cement
	2. Rinsing and drying	2.Rinsing and drying	2.Polymerization for 2 s on each side of the prosthetic structure
	3. Application of 2 layers of ALL-BOND UNIVERSAL®	3. Application of 1 layer of PORCELAIN PRIMER	3.Removal of excess
	4. Drying-10 s	4. Waiting-30 s	4. Final polymerization-40 s
	5. Polymerization-10 s	5. Drying 3-5 s	
Variolink Estethic DC self-etching adhesive dual-cure	1. Etching (optional) - 15-30 s, rinsing for 1 min., 5 s. drying	1. Monobond Etch & Prime by rubbing for 20 s	1. Application of cement
	2. Application of Adhese Universal by rubbing-20 s	2.Leaving for activation-40 s	2. Polymerization for 2 sonds on each side of the prosthetic structure
	3. Polymerization-10 s	3. Rinsing-10 s	3. Removal of excess
			4. Final polymerization-10 s
Panavia V5self-etching adhesivedual-cure	1. Application of PANAVIA V5	1. Etching of porcelain with 4.5% HF or K-ETCHANT-60 s	1. Application of cement
	2. Tooth Primer	2. Rinsing and drying	2. Polymerization for 3-5 s on each side of the prosthetic structure
	3. Waiting-20 s	3. Application of CLEARFIL CERAMIC PRIMER PLUS and drying	3. Removal of excess
	4. Drying		4. Final polymerization-20 s

Shear Bond Strength (SBS) Test

A physical mechanical testing machine (MultiTest 2.5-i, Macmesin Ltd, West Sussex, England) was used to conduct the shear bond strength test. All tests were conducted at a knife movement speed of 1 mm/min.

Analysis of Failure Mode

After the shear bond strength test, the test specimens underwent stereomicroscopic examination (Leica S-6, Leica Microsystems IR GmbH, magnification x4), and the failures of the dentin/cement/ceramic bond were characterized into three types: adhesive, cohesive, and mixed.

Statistical Analysis

For processing the obtained results, the following **statistical methods** were used:

Descriptive statistics - arithmetic mean (Mean) – a measure to assess the average force applied within a given group; - standard deviation (SD) – a measure to determine the average dispersion of forces within a given group; - absolute (N) and relative values (%) – measures to determine the number of test specimens and their percentage representation.

Kolmogorov-Smirnov test (One sample Kolmogorov-Smirnov Test) – to check the normality of the shear bond strength distribution in the groups.

Non-parametric test for two independent samples (Mann-Whitney Test) – when comparing two means of two groups where the shear bond strength distribution is not normal.

Non-parametric test for three independent samples (Kruskal-Wallis Test) – when comparing three means of three groups where the shear bond strength distribution is not normal. If a difference between groups is found, a post-hoc analysis for unequal variances will be conducted to determine exactly which groups there is a significant difference. All tests were conducted at a 5% risk of error. The statistical methods were applied using IBM SPSS Statistics 26 (IBM SPSS Statistics for Windows, SPSS Inc., Chicago, IL, USA), and graphical representation was carried out using Excel 2015.

RESULTS

In the group of test specimens with a ceramic base of hybrid ceramic, the results showed the highest shear bond strength with Panavia V5 cement (18.87±0.89 MPa), followed by Variolink Esthetic DC (14.03±4.45 MPa) and e-CEMENT (11.40±5.19 MPa). In the group of test specimens with a ceramic base of lithium disilicate, the highest shear bond strength was again observed with Panavia V5 cement (17.53±3.39 MPa), followed by Variolink Esthetic DC (17.30±4.49 MPa) and e-CEMENT (14.33±5.27 MPa).

Panavia exhibited the highest shear bond strength values in both groups. Variolink Esthetic DC ranked second, while e-CEMENT ranked third. After analysis, it was found that the shear bond strength levels were not normally distributed, and the non-parametric Kruskal-Wallis test was used for verification. The results of the analysis are presented in Table 2.

In the test specimens with a ceramic base of IPS e.max CAD (lithium disilicate ceramic), no statistically significant difference was found in the shear bond strength among the three types of cement.

Table 2. Results of checking the difference in shear bond strength among the three types of cement.

Tested groups	Tested variable	Charecteristics	Type of cement: e-CEMENT	Type of cement: Panavia V5	Type of cement: Variolink Esthetic DC	Total	Kruskal-Wallis Test
Shear bond strength [MPa]	Hybrid ceramic (Vita Enamic)	Mean	11.40 ^{B}	18.87 ^{A}	14.03 ^{AB}	14.77	$p < 0,05$
		SD	5.19	1.89	4.45	4.99	
		N	12	12	12	36	
	Lithium disilicate (IPS e.max CAD)	Mean	14.33 ^{A}	17.53 ^{A}	17.30 ^{A}	16.39	$p > 0,05$
		SD	5.27	3.39	4.49	4.45	
		N	12	12	12	36	

*For groups with the same letter, no statistically significant difference was observed.

In the test specimens with a ceramic base of Vita Enamic (hybrid ceramic), Panavia V5 cement exhibited a statistically significantly higher shear bond strength compared to e-CEMENT. Variolink Esthetic DC cement showed no significant difference in shear bond strength compared to either e-CEMENT or Panavia V5.

Additionally, a check was conducted on the difference in the applied force during the assessment of shear bond strength between the two types of ceramics. Overall, the mean force for shear bond strength amounted to 440.4±133.6 N. For Vita Enamic hybrid ceramic, the mean force during shear bond strength was 417.5±140.9 N, while for lithium disilicate ceramic IPS e.max CAD, the mean force was 463.3±125.6 N.

The test specimens underwent stereomicroscopic examination (Leica S-6, Leica Microsystems IR GmbH, magnification x4), and the failures of the dentin/cement/ceramic bond were characterized into three types: adhesive, cohesive, and mixed.

Adhesive type of destruction - along the dentin-cement border (d/c), along the cement – Ceramic border (c/C)

Cohesive type of destruction – in dentin (d), in cement (c), in Ceramic (C)

Mixed type of destruction - in dentin and cement (d+c), in cement and ceramic (c+C), in dentin, cement and ceramic (d+c+C)

Table 3. Predominant type of bond failure

		Type of destruction*		
		Adhesive type	Cohesive type	Combined type
		d/c - c/C*	d – C*	d+c - d+c+C*
Types of cements	Total	66,7%	16,7%	16,7%
	e-CEMENT	100,0%	0,0%	0,0%
	Panavia V5	57,1%	21,4%	21,4%
	Variolink Esthetic DC	71,4%	28,6%	0,0%

** d-dentin, c- cement, C-ceramic*

For e-CEMENT, there was the highest concentration of bond failures, with 100% of the failures being of the adhesive type. Variolink Esthetic DC cement had the second-highest concentration of failures, with a predominant portion of them also being of the adhesive type. With Panavia V5, approximately 20% of failures were of both cohesive and mixed types, but again, over 50% of the failures were of the adhesive type (Table 3).

Table 4. Predominant place of bond failure

		Place of destruction*							
		d/c	c/C	d	c	C	d+c	c+C	d+c+C
Types of cements	Total	38,9%	27,8%	0,0%	19,4%	0,0%	0,0%	13,9%	0,0%
	e-Cement	100,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
	Panavia V5	42,9%	14,3%	0,0%	25,0%	0,0%	0,0%	17,9%	0,0%
	Variolink Esthetic DC	35,7%	35,7%	7,1%	21,4%	0,0%	0,0%	0,0%	0,0%

**d-dentin, c-cement, C-ceramic*

Additionally, the predominant location of bond failure was determined. Most commonly, the bond failure occurred at the dentin-cement interface (Table 4). For e-CEMENT, there was the highest concentration, with 100% of the failures occurring at the dentin-cement interface. With Variolink Esthetic DC cement, there were approximately 36% failures at the dentin-cement interface and the cement-ceramic interface. With Panavia V5, the concentration was observed at failures occurring at the dentin-cement interface and cohesive failures within the cement.

DISCUSSION

The results of the present study rejected the null hypothesis regarding hybrid ceramics. For Vita Enamic hybrid ceramic (Vita Zahnfabrik, Germany), shear bond strength (SBS) values ranged from 11.4±5.19 to 18.8±1.89 MPa with statistical significance ($p < 0.05$). The highest shear bond strength values were obtained when using the composite cement Panavia V5 (Kuraray Noritake, Japan).

Vita Enamic consists of feldspathic ceramic infiltrated with resin (TEGDMA/UDMA), which can be stained. Clearfil Ceramic Primer Plus is unable to bond to the resin matrix; therefore, bonding to Vita Enamic with Panavia V5 is achieved through silanization via covalent Si-O-Si bonds to the feldspathic ceramic. Based on the data presented by Rohr N, et al. [7], the use of Panavia V5 is recommended for restorations relying on adhesive bonding with large areas of dentin, such as partial or full crowns. Other authors have also reported these findings [17]. High dentin shear bond strength values with Panavia V5 cement of 18.0 ± 4.2 MPa have been reported by other authors and are consistent with the results obtained in the present study (17.53±3.39 – 18.87±1.89 MPa) [5,7]. A possible explanation is the presence of MDP, which provides better bonding [18]. Additionally, MDP prevents the hydrolysis of γ-MPTS and ensures stronger bonding of more silane molecules to the glassy phase [19]. From a clinical perspective, Panavia V5 (with its Tooth Primer) is preferred as phosphoric acid etching is not necessary [7]. The lower values obtained in the present study are likely due to the fact that fixation was performed only on dentin, which is consistent with the findings of Rohr N, et al. [7]. When examining two composite cements (Panavia V5 and RelyX Universal), the authors report a shear bond strength of around 18 MPa for dentin and around 21 MPa for enamel.

The results of the present study regarding the lack of significant differences when using different cements, in terms of lithium disilicate ceramic, are consistent with the findings of Irie et al. [16]. The authors analyzed 33 types of self-adhesive and dual-cure composite cements regarding SBS to lithium disilicate and did not find a significant difference in SBS in 70% of the analyzed materials. The mean shear bond strength reported by the authors was 17.87±0.17 MPa.

The clinical use of universal self-adhesive systems such as Adhese Universal VivaPen (Ivoclar Vivadent, Lichtenstein), Clearfil Universal Bond (Kuraray Noritake, Japan), and G-Premio Bond (GC Dental Products, Japan) can be recommended as they demonstrate good shear bond strength values compared to other adhesive systems. Shear bond strength values ranging from 6.0±1.9 MPa to 22.8±4.9 MPa for enamel and from 5.0±2.4 MPa to 13.5±4.3 MPa for dentin when using different adhesive systems have been reported by several authors [14,17]. Two of the composite cements (Panavia V5 (Kuraray Noritake, Japan) and Variolink Esthetic DC (Ivoclar Vivadent, Lichtenstein)) used in the present study can be classified as self-adhesive adhesive systems. The results of the present study confirm the above-cited findings, as better results were obtained with Variolink Esthetic DC (Ivoclar Vivaden, Lichtenstein), using Adhese Universal VivaPen, and with Panavia V5 (Kuraray Noritake, Japan), using Clearfil Universal Bond, compared to using All Bond Universal with the composite cement e-CEMENT, although total etch technique is used with it.

The data obtained in the current study with the third cement, e-CEMENT (Bisco, USA) – 11.40±5.19 MPa, contradicts the data published by Ashy & Marghalani [20]. The authors report better internal and marginal adaptation and, consequently, better bonding with e-CEMENT with the Lava Ultimate hybrid ceramic (3M ESPE, USA) than with Variolink Esthetic DC. They also observe weaker bonding of composite cements to dentin compared to enamel. According to Lu Y, et al. [13], the use of self-etching primers yields satisfactory results for IPS e.max CAD lithium disilicate ceramic (Ivoclar Vivadent, Lichtenstein), as with Panavia V5 composite cement (Kuraray Noritake, Japan) – 19.28±5.99 MPa, and Variolink Esthetic DC composite cement (Ivoclar Vivaden, Lichtenstein) – 17.15±4.79 MPa. Regarding the two investigated cements, Variolink Esthetic DC and Panavia V5, other authors also observe no substantial differences in SBS for LD. They report values ranging from 22.5 to 32.5 MPa, as well as values close to those obtained in the present study [17].

Some authors believe that the presence or absence of HEMA and other solvents is the reason. HEMA is a small hydrophilic monomer that aids in the penetration of other monomers into dentinal tubules and also serves as a solvent, facilitating the formation of a hybrid layer [8, 11]. The presence of HEMA in cements is more critical for lithium disilicate Ceramic. In the present study, all three cements used contain HEMA and showed sufficiently good SBS values for lithium disilicate ceramic.

Variolink Esthetic DC composite cement (Ivoclar Vivaden, Lichtenstein) ranked second in the current study in terms of bond strength (14.03±4.45 MPa – 17.30±4.49 MPa). Weaker bonding with Variolink Esthetic DC composite cement (Ivoclar Vivaden, Lichtenstein) is observed by Tribst et al. [15] with both Vita Enamic hybrid ceramic (Vita, Germany) and IPS e.max CAD lithium disilicate (Ivoclar Vivadent, Lichtenstein). The authors explain their findings by the use of a self-etching primer with this cement, which bonds more weakly to dentin but is a good alternative for fixing prosthetic constructions because it is not as harmful as HF acid.

The importance of ceramic surface treatment with HF acid and subsequent silanization, performed in the present study, is confirmed in a publication by Cinar et al. [5] The authors report shear bond strength (SBS) values for Vita Enamic hybrid ceramic (Vita Zahnfabrik, Germany) ranging from 8.09±0.78 MPa without any surface treatment to 21.76±1.56 MPa with HF treatment and subsequent silanization. For lithium disilicate IPS e.max CAD (Ivoclar Vivadent, Lichtenstein), values range from 4.48±0.51 MPa without treatment to 18.21±1.22 MPa with HF and silane use. The authors demonstrate that the sandblasting (SB) of these CAD-CAM materials reduces the bond strength to dental tissues. They report values for IPS e.max CAD of 9.02±0.98 MPa after sandblasting and 12.09±2.45 MPa after adding silane, and for Vita Enamic hybrid ceramic, respectively, 16.54±1.54 MPa after SB and 18.59±1.44 MPa after SB and S. Lu Y, et al. [13] report that surface treatments with HF, followed by silanization, increase the bond strength of CAD-CAM materials, especially lithium disilicate ceramic and that sandblasting is not suitable for them but is suitable for hybrid ceramics.

Analysis of the results for the type of bond failure reported by several authors reveals a relationship between the type of failure and the surface treatment of CAD-CAM materials. Adhesive failure is commonly observed at low SBS values, while cohesive and mixed failures are more frequent with materials where the adhesive bond strength exceeds the inherent strength of CAD-CAM materials [5, 18]. Several authors observe mainly adhesive failures with Variolink Esthetic DC (Ivoclar Vivaden, Lichtenstein). This higher frequency of adhesion failure at the cement-dentin interface registered for this material is a result of lower bond strength values compared to Panavia V5 (Kuraray Noritake, Japan) [13, 17]. In the present study, failures were 100% adhesive in nature with e-CEMENT (Bisco Inc., USA), which showed the lowest SBS values. For the composite cement ranked second in SBS values, using Adhese Universal VivaPen in combination with Monobond Etch and Primer, mainly adhesive (≈70%) and a small amount (≈30%) of cohesive bond failure were recorded. The least adhesive failures (≈57%) were observed with Panavia V5 cement, which showed the highest SBS values. These results are consistent with the cited authors and the findings of Maqbool B, et al. [21] for improving bonding with Monobond Etch and Primer.

This in vitro study had its limitations, similar to other investigations. It did not account for contamination with oral fluids, occlusal loading of the structure, marginal microleakage and adaptation, changes in pH and temperature in the oral cavity, and factors that could potentially influence the bond strength. The ageing of the materials was also not analyzed in this study as a potentially influential factor that deserves attention, considering the impact of the oral environment over time. All of these factors may influence the findings and applicability of the results in this study in a broader context. Further research in a controlled clinical setting is necessary. The clinical importance of this study is the ability of the dentist to choose which luting protocol to apply when using different types of CAD/CAM prosthesis.

CONCLUSIONS

The highest shear bond strength values were obtained when using the composite cement Panavia V5 (Kuraray Noritake, Japan). The least adhesive failures (H"57%) were observed with Panavia V5 cement, which showed the highest SBS values. The use of self-etching and self-adhesive systems (Panavia V5 (Kuraray Noritake, Japan) and Variolink Esthetic DC (Ivoclar Vivadent, Lichtenstein)) with hybrid ceramics (Vita Enamic; Vita Zahnfabrik, Germany) creates a stronger bond compared to total etching techniques used with composite cement e-CEMENT (All Bond Universal).

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