Original Article

Measuring the resistance of different substructure materials by sticking them to dentine with two different resin cements *in vitro*

V Eratilla, AD Yildiz[1], S Guven[1], EA Eratilla[2], T Karaman[3], S Aguloglu[4], E Sumer

Department of Prosthodontics, Diyarbakir Oral and Dental Health Center, Departments of [1]Prosthodontics and [2]Endodontics, Faculty of Dentistry, Dicle University, [3]Department of Prosthodontics, Faculty of Dentistry, Firat University, [4]Department of Prosthodontics, Private Practice, Diyarbakir, Turkey

Abstract

Introduction: The resistance of three different substructure materials – metal (Cr-Co), zirconium (Zr), and ceramics (IPS Empress II) – was measured by sticking them to dentine with two different resin cements, a dual-cure resin cement (Panavia F 2.0 Light) and a self-adhesive resin cement (BisCem).
Materials and Methods: In an *in vitro* study, 72 central upper front teeth were selected with no decay or apparent breakage and with complete development, removed for periodontal reasons. Labial and incisal surfaces of all teeth were prepared. Molds were obtained to prepare metal (Co-Cr), Zr, and ceramic (IPS Empress II) blocks for use in the study. The compressive strengths of the obtained material infrastructures were examined after thermal cycle processing by performing cementation to the teeth with two different cements. The data obtained were analyzed statistically. The Mann–Whitney U-test was used for comparisons of the groups with two options, and Kruskal–Wallis variance analysis was used to compare more than two groups. P <0.05 were considered statistically significant.
Results: While the highest result between samples was 117.86 ± 47.94 N in the dual-cure (Panavia)-ceramic group, the lowest value was observed at 6.53 ± 3.12 N in the self-adhesive (BisCem)-metal group. There was a significant difference between dual-cure (Panavia) and self-adhesive (BisCem) groups.
Conclusion: In this study, we measured the bond strength; our most durable resistance groups were found to be, in order, Panavia-ceramics >Panavia-metal >Panavia-Zr >self-adhesive-ceramics >self-adhesive-Zr >and self-adhesive-metal.

Key words: Adhesive system, bond strength, thermal cycle, zirconium

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Introduction

The major objective of prosthetic dentistry is to treat the loss of a tooth, in terms of esthetics, function, and biology.[1] The use of adhesive materials in restorative dentistry is increasing. More esthetic restoration requests from patients have caused the development and usage of restorative materials closer to the natural color of teeth. Together with the development of these materials, current indications have shifted from the front teeth to the back teeth. In this way, dental fillings

Address for correspondence:
Dr. S Guven,
Department of Prosthodontics, Faculty of Dentistry, Dicle University, Diyarbakir, Turkey.
E-mail: dentistsedat49@hotmail.com

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have enabled a minimal interference principle in restorative operations, maintaining tooth structure as much as possible. The formation of a strong link between tooth structure and restoration material is very important in maintaining the clinical success of adhesive restorations. Successful connections between restorative materials and dental tissues will prevent microleakage and secondary caries, and will consequently lead to long-lasting restorations.[2,3] For these reasons, it is necessary to use suitable cements together with appropriate infrastructure materials.

Adhesion has special importance in the prosthetic process, because a tight connection between the tooth structure and the materials used is intended to minimize damage to the teeth. The teeth and tooth-contacting surface of the prosthetic structure can be considered the adherend, and the glue binding them is the adhesive. The status of the adherend surface and adhesive process needs to be understood.[4] Composite resin cements used in the dental cementing of prosthetic restorations include derivatives of bisphenol A-glycidyl methacrylate resin filler and other methacrylates. Resin composite cements can be classified into two groups, micro-filled cements and hybrid-filled cements, according to the type of filler.[5,6]

The aim of this study was to measure and compare the resistance of different substructure materials (Cr-Co, zirconium [Zr], and IPS Empress II) by sticking them to dentine with two different cements (Panavia F 2.0 Light and BisCem).

Materials and Methods

At Dicle University (Turkey), in the Faculty of Dentistry and Oral and Maxillofacial Surgery Department, and at the Diyarbakır Oral and Dental Health Center Surgery, School of Dentistry (Turkey), 72 central upper front teeth with no apparent fractures or decay, but with complete development and extracted for periodontal reasons, were selected. These teeth were immersed in 0.9% isotonic sodium chloride (NaCl) and BIOSEL solution (Vacoliter; Eczacıbaşı-Baxter Hospital Products Industry and Trade Corporation, Istanbul, Turkey) until cleaning. Before cleaning, the teeth were kept in distilled water for 12 h with a disinfectant (1:100, Savlex Concentrated Solution; Drogsan Pharmaceutical Industry and Trade Joint Stock Company, Ankara, Turkey) containing 15% cetrimide and 1.5% chlorhexidine gluconate. During cleaning, tartar and any soft tissue residue remaining on the teeth was cleared away using a cavitron device and lancet. All parts of the teeth were brushed using a medium-hard toothbrush in the same disinfectant solution. After rinsing under running water, teeth were placed in isotonic sodium chloride. The 72 teeth were divided into 6 groups of 12 teeth [Table 1].

A diamond fissure bur was used to reveal the dentine surfaces of the teeth using high-speed and water-cooled aerators. In this process, 2 mm and 1.5 mm abrasions were made on the incisal and labial surfaces, respectively. When making use of the ruler during incisal surface abrasion, burs of 1.5 mm in diameter were used for labial surface abrasion [Figure 1].

After abrasion of the labial and incisal surfaces of all teeth, a mold was obtained for the preparation of metal, Zr, and ceramic blocks for use in our study. First, the shape and dimensions of the mold were prepared on the computer. With the help of a CAD-CAM device, metal (Co-Cr), Zr, and ceramic (IPS Empress II) infrastructures to be used for the cementation of tooth surface were produced [Figure 2].

To ensure better adhesion of the resin cement to the metal in the cementation of metal models, an adhesive metal preparatory agent (AlloyPrimer; Kuraray, Okayama, Japan) including MDP active phosphate-based monomer in the structure was applied to the models. Then, a preparatory agent (Bisco; Z-Prime REF Biscoinc, ABD) was applied to ensure better adhesion of Zr models to the resin cement. Finally, a surface wetting agent (Clearfil Ceramic Primer; Kuraray Noritake Dental Inc., Okayama, Japan) was applied to improve the adhesion of the ceramic mold [Figure 3].

The teeth were washed thoroughly and dried. Then, the labial surfaces of the teeth were treated for 10 s with a gel including 40–60% phosphoric acid (K-Etchant Gel; Kuraray Medical Inc.). The acid gel was then removed with an air-water spray and tooth surfaces were dried thoroughly with air after washing with plenty of water.

Then, the adhesive system, which included adhesive MDP active phosphate-based monomer (Clearfil Cement; ED Prime Liquid Ave. B 4 ml; Kuraray Medical Inc.) was prepared. Liquids A and B were added drop-wise into a mixing vessel in equal amounts, and were mixed immediately prior to the application. The mixture was applied to the entire labial surface of the tooth with a disposable brush tip, and was allowed to stand for 30 s. The treated surface was allowed to not come in contact with anything for at least 30 s. After preparing the tooth surface for 30 s, volatile content was evaporated by a light air stream. Primary accumulation was avoided. The particular amount of stirring, drying method, and treatment time were chosen by paying attention to the manufacturer's advice to ensure proper adhesion. We took care to not ouch the treated surface, and these operations were performed in a dark environment. Light-emitting diode (LED) lighting was applied for 20 s [Figure 4].

Then, the dual-cure adhesive resin cement (Panavia F 2.0 Light; Kuraray Medical Inc.), including adhesive MDP active phosphate‑based monomer, was prepared by mixing the two pastes for 20 s with a plastic spatula on mixing paper, after which it was immediately applied to the relevant surface of the prepared models. All of the models were placed individually on full labial surfaces of the teeth, and excess cement was removed with a disposable brush. Subsequently, cavity areas were placed twice beneath the LED light source for 10 s, and dual‑cure adhesive cement polymerization was achieved.

Groups with the self‑adhesive resin cements were prepared on the second day of the cementation process. The same process was applied to the metal, ceramic, and Zr models in the cementation of the samples. Direct self‑adhesive resin cement (BisCem; Bisco Inc.) was applied to the models without applying acid or primary to the tooth, and was attached to the labial surface of the tooth in accordance with the manufacturer's instructions. Overflowing cement was removed with a disposable brush. Subsequently, model surfaces were placed twice under the LED light source for 10 s, allowing self‑adhesive resin cement polymerization to be achieved. Models with a complete cementation process were placed in fresh isotonic sodium chloride solution.

The acrylic‑embedding process of the teeth after cementation was performed at Dicle University Faculty of Dentistry, Department of Prosthodontics. First, a matchbox was agreed on for preparation of the model, and each tooth was kept in a matchbox. Teeth were embedded in acrylic resin (Imicryl S.C., Imicryl Dental Supplies Industry and Trade Limited Company, Konya, Turkey) in the previously prepared matchboxes [Figure 5].

Teeth were held until the self‑curing acrylic solidified during the embedding process. The same molds were used for all of the samples, and the embedding was performed by two experienced physicians. In this way, in total, 72 samples were prepared.

The 72 prepared samples were stored in distilled water at 37°C for 24 h. Subsequently, all specimens were subjected to thermal cycling (custom‑made thermal cycling machine; Eppendorf Mastercycler Gradient Authorized Thermal Cycle, Hamburg, Germany) for 6,000 cycles between 5 and 55°C with a transfer time of 2 s and dwell time of 30 s. Thermal cycle processing was performed at the Erciyes University Faculty of Dentistry Research Laboratory (Kayseri). Models were placed immediately in a universal testing machine (Instron 6022; Instron Corp., High Wycombe, England) after the thermal cycling and were measured. A special apparatus was made for the measurements, and the same apparatus was used for all of the models. The apparatus was fixed by placing it into the universal testing machine (Instron 6022; Instron Corp., High Wycombe, England) [Figure 6]. Models were placed horizontally on the device, one by one. Then, the wire in the apparatus was positioned on the teeth in the models. The tests were carried out under displacement control, at a crosshead speed of 0.5 mm/min for all specimens until failure occurred.

Force was applied until teeth disengaged from the model, and the obtained values of Panavia and self‑adhesive groups (Panavia‑metal, Panavia‑Zr, Panavia‑ceramic, self‑metal, self‑Zr, self‑ceramic) were recorded [Table 2].

This study was approved by the ethical committee of Medical School, Dicle University‑226‑30.09.10.

Statistics

The IBM SPSS software (version 15.0 for Windows) was used for statistical evaluations (SPSS Inc., Chicago, USA). The Mann–Whitney U‑test was used for comparisons of the groups with two options, and Kruskal–Wallis variance analysis was used to compare more than two groups. Hypotheses were bidirectional and P values that are <0.05 were considered statistically significant.

Results

Maximum resistance values obtained from measuring the strength of the samples were calculated, and these averages were recorded in Newton [Figure 7] and Megapascal‑MPa [Table 3]. In an evaluation after the statistical results were obtained, the highest value was 117.86 ± 47.94 N in the Panavia‑ceramic group, and the lowest value was 6.53 ± 3.12 N in the self‑metal group [Table 4]. There was a significant difference between Panavia and self‑adhesive groups [Table 5]. Furthermore, comparisons of all groups were made in twos, threes, and finally in sixes. In these comparisons, there was a significant difference in all matchings.

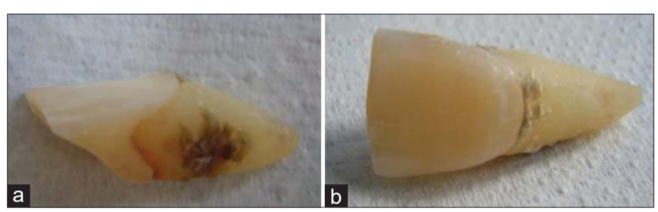

Figure 1: (a and b) Teeth with uncovered dentine surfaces

Table 1: Classification of teeth according to the infrastructure material and resin cement type

Groups	Pan‑1	Pan‑2	Pan‑3	Self‑1	Self‑2	Self‑3
Ingredients	Panavia‑metal	Panavia‑zirkonium	Panavia‑ceramic	Self‑adhesive‑metal	Self‑adhesive‑zirkonium	Self‑adhesive‑ceramic
Number of teeth	12	12	12	12	12	12

Table 2: Data resulting from the applied force (N)

Groups	Pan-1	Pan-2	Pan-3	Self-1	Self-2	Self-3
Ingredients	Panavia-metal	Panavia-zirkonium	Panavia-ceramic	Self-adhesive-metal	Self-adhesive-zirkonium	Self-adhesive-ceramic
Number of teeth	1	2	3	4	5	6
1	116.35	22.41	82.64	1.40	45.83	2.14
2	86.34	17.65	12.67	8.46	7.46	30.26
3	79.87	19.85	135.40	7.63	5.12	11.08
4	144.23	9.56	28.16	4.90	6.63	22.14
5	135.87	49.75	119.94	10.23	13.75	19.07
6	100.17	23.49	172.73	3.86	8.17	16.85
7	80.78	19.02	85.64	7.65	6.27	16.85
8	85.43	21.17	115.77	8.17	7.83	7.45
9	113.47	11.22	132.82	11.06	17.43	21.22
10	143.67	40.19	147.14	5.43	23.87	16.87
11	92.26	24.13	144.63	4.65	15.18	4.26
12	94.78	26.12	99.39	1.62	14.92	12.12

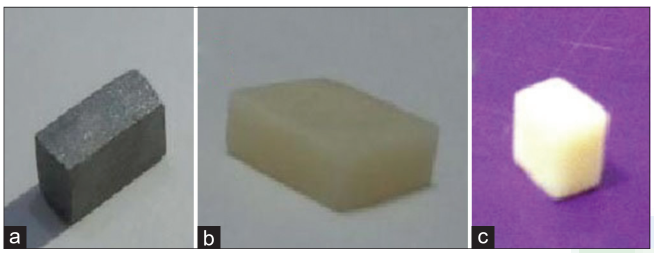

Figure 2: (a) Metal (Co-Cr), (b) Zirconium, and (c) Ceramic (IPS Empress II) infrastructures

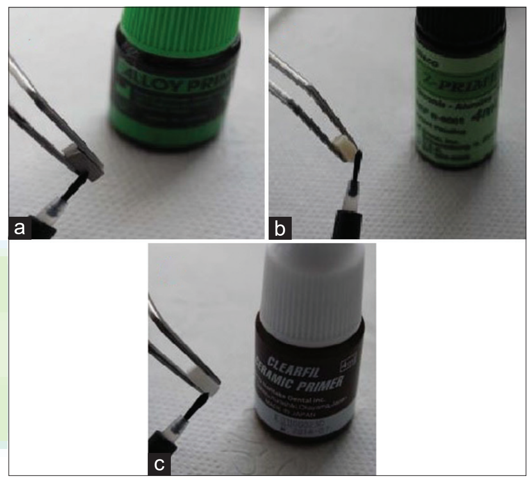

Figure 3: Primary implementation to (a) Metals, (b) Zirconium, and (c) Ceramic models

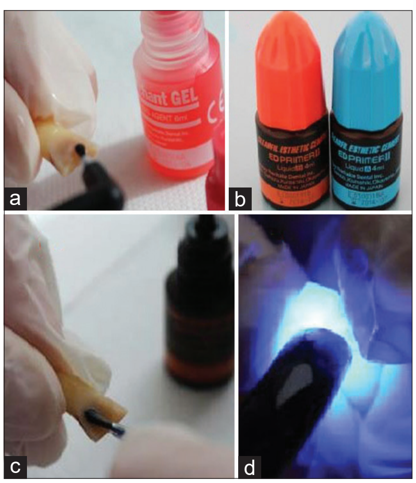

Figure 4: (a) Applying acid gel, (b) Bonding system, (c) Applying bonding system, and (d) Polymerization process applied to the teeth

Figure 5: Example of teeth embedded in acrylic

Figure 8 shows the force-displacement curve of the six groups.

In order, the most durable resistance was found in Panavia-ceramic >Panavia-metal Panavia-Zr > self-ceramic >self-Zr >self-metal.

In looking at the separation of the models from the teeth during the experiment, only the separations of four in the self-Zr group and eight in the Panavia-metal group were observed at the model cement border. In the models, in four, breaking was seen in the cement. Separation in the others

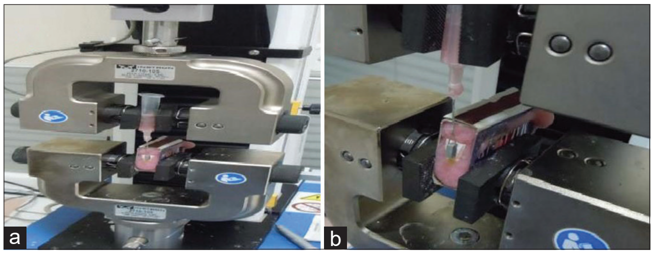

Figure 6: (a and b) Snapshot while measuring in the universal testing machine (Instron 6022; Instron Corp, High Wycombe, England)

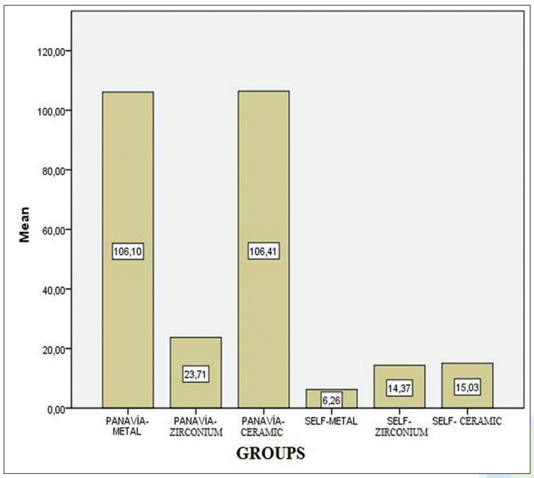

Figure 7: Graphical display of results

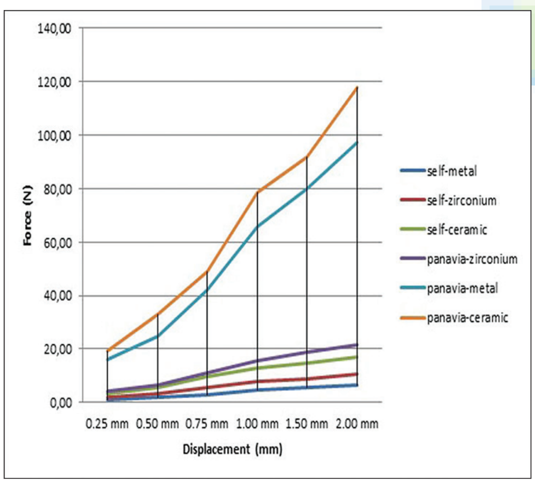

Figure 8: Graphical display of results

occurred in the dental tissue boundaries. The results showed that no damage such as separation or fracture of the teeth observed. While adhesive separation was observed in 68 teeth in our study, in 4, cohesive separation was observed. Two of the cohesive separations were in the Panavia-metal group, and the other two were in the Panavia-ceramic group.

Table 3: Translating the results into MPa

Groups	MPa
Panavia-metal	12.18
Panavia-ceramic	14.73
Panavia-zirconium	2.73
Self-metal	0.81
Self-ceramic	2.10
Self-zirconium	1.37

Table 4: Average statistical values of data obtained

Groups	Mean±SD (*n*)	*P*
Panavia-metal	97.48±24.14	0.013
Panavia-zirkonium	21.79±11.26	
Panavia-ceramic	117.86±47.94	
Self-metal	6.53±3.12	
Self-zirkonium	10.96±11.40	
Self-ceramic	16.85±8.03	

SD=Standard deviation

Table 5: Average statistical values of Panavia and self-adhesive (self) groups

Groups	Mean±SD (*n*)	*P*
Panavia group	85.54±27.7	0.000
Self-group	8.32±7.51	

SD=Standard deviation

Discussion

Methods and materials are constantly being developed for demand of the esthetic and mechanical stability in dentistry. Even if good results can be obtained in metal-supported restoration in terms of the mechanical aspects, problems are encountered in the esthetic and biological point. When full ceramic restoration is compared with metal-ceramic restoration, it gives excellent esthetic results particularly in anterior teeth. It provides color depth and has the ability to reflect light. It has a thermal expansion coefficient and thermal conductivity similar to natural tooth tissue. It has a good biocompatibility and it is particularly preferred in patients with metal allergy. It causes less plaque buildup. It does not give metallic taste in the mouth. Discoloration and reflection of the metal color does not appear in this restoration.[7-12]

On the other hand, full ceramic system that keep pace with the developments offered by advanced technology is known to have several disadvantages like the increase in production costs and hosting the tensile stress generated by the plastic deformation of materials and lack of dissemination of stress around the crack or defect. Researchers are turning to other infrastructure options owing to these disadvantages.[13]

New techniques are being developed every day as an alternative to restorative techniques with fully proven success for many years. The structure of porcelain changes over time in order to strengthen the material. Zr has been used in dentistry along with porcelain material owing to having a less grain diameter and high tensile strength.[14]

Now-a-day, adhesive systems put forward that dentin bonding forces were higher at the beginning but they began to drop over time depending on degradation formed on tooth-restoration interface. Along with mechanical factors such as occlusal and thermal stresses in the mechanism of degradation on binding interface, mainly chemical factors may play a role. The most important chemical reactions are hydrolysis of resin components and plasticization occurring depending on the diffusion related water inlet.[15]

The reaction time of resin cements cured chemically is short and control is difficult. Early polymerization can lead to loss of fitting of the restoration. Light-curing resin cements are influenced by the light transmittance of the ceramic. In general, they are used to glue laminate veneer restorations. As the restoration thickness increases, the amount of polymerization is reduced. Dual-cure resin cements have long been studied and offer some control. However, the light intensity, time of light application, and appropriate wavelength selection are important variables in hardening.[16]

Various studies recommend that dual-cure-resin cements be used when the thickness of full-ceramic restorations exceeds 2 mm. Not all types of full-ceramic restorations have the same light transmittance. For example, even if full zirconia and alumina-based ceramics have thicknesses of 0.5–0.7 mm, cement polymerization may not be complete because of less light transmittance when used with light-curing resin cements. If an adhesive cementation is used, dual-cure resin cements must be used.[17,18] Because of its advantages, a dual-cure resin cement was used in our study for the cementation of full-ceramic, Zr, and metal-based restorations.

Watanabe *et al.*[19] indicated that shear strength values in the group with a self-etch bonding system were lower than those in the groups with a total-etch bonding system. This may be a result of the application technique with the self-etch system. While treatment of dentine with phosphoric acid removes the smear layer and smear plugs, a self-etch system that lacks acid treatment partially demineralizes the smear layer and carries residues into a hybrid layer. Self-etch systems are affected by the thickness of the smear layer, intensity, and quality.[20]

Frankerberger and Franklin used a three-stage total-etch and a single-stage self-etch adhesive in their study comparing adhesive systems.[21] While less space was encountered in the margins of the total-etch adhesive surface (9%), the ratio was 55% with the single-stage adhesive. A similar result was reported in another study that reviewed the literature between 1998 and 2004.[22] Although innovations aimed toward simplifying the implementation phase of adhesives were described, they were reported to reduce the binding activity.

Ernst *et al.*[23] used Zr crowns cemented with compomer, resin-modified glass ionomer, self-adhesive resin cement, Panavia, and glass ionomer cement in their study. The resin cements had higher values than the resin-modified glass ionomer and glass ionomer cements. In addition, Panavia had higher values than self-adhesive resin cements. The results in our study were consistent with this.

Yang *et al.*[24] reported that dual-cure resin cements had higher binding strengths than self-adhesive cements in their study. Self-adhesive resin cements were shown to have lower binding strength due to their high viscosity, preventing demineralized dentine penetration. However, Chai *et al.*[25] found no significant difference in binding strength among self-adhesive resin cement and dual-cure resin cement and Ni-Cr metal-dentine in their study.

Kanehira *et al.*[26] found that dual-cure resin cement had higher binding strength to dentine than self-adhesive resin cement in their study, in which they compared the binding strength of dual-cure resin cement and self-adhesive resin cement to dentine. Fonseca *et al.*[27] compared dual-cure resin cement, zinc-phosphate cement, and chemical curing resin cements in their study. Only chemical curing was used, and there was no treatment with light to prevent photoactivation. The dual-cure resin cement had the highest binding strength. Farrokh *et al.*[28] compared three self-adhesive resin cements and one dual-cure resin cement in their study in 2012, and concluded that dual-cure resin cement had significantly higher binding strength.

We consider that longer-term studies, supported by *in vivo* studies, may more accurately and clearly reveal the stability of adhesive systems. Given that adhesive systems have developed rapidly in recent years, we believe that systems that enable stronger binding will be developed in the near future, and the performance of these adhesive systems can be evaluated with more advanced techniques.

Within the limitation of this study, dual-cure resin cement especially combined with ceramic shows the best binding strength.

Conclusion

The results and recommendations reached within the limitations of this study are:

- Panavia 2.0 F (dual-cure) resin cement was shown to have higher binding strength than BisCem (self-adhesive) resin cement
- The highest binding strength found was in the Panavia-Ceramic group among the infrastructure materials stuck on dentine with Panavia 2.0 F
- The highest binding strength was found in the Self-Ceramic group among the infrastructure materials

stuck on dentine with BisCem
- Dual-cure cements have significant advantages for use in many cementation processes beyond the reach of LED lights due to their chemical hardening properties
- Panavia 2.0 F (dual-cure) cement is recommended as the first choice compared to BisCem (self-adhesive) cement based on this study.

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Conflicts of interest

There are no conflicts of interest.

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