Original Article

The Effectiveness of Various Functional Monomers in Self-adhesive Resin Cements on Prosthetic Materials

Tool Sriamporn[1], Niyom Thamronganankul[2], Awiruth Klaisiri[3,4]

[1]Department of Prosthodontics, College of Dental Medicine, Rangsit University, Pathumthani, [2]Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University, Bangkok, [3]Division of Restorative Dentistry, Faculty of Dentistry, Thammasat University, Pathumthani, [4]Thammasat University Research Unit in Restorative and Esthetic Dentistry, Thammasat University, Pathumthani, Thailand

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ABSTRACT

Aim: This study examined the influence of various functional monomers in two self-adhesive resin cements (SACs) on prosthetic materials. **Materials and Methods:** Base metal alloy, lithium disilicate glass-ceramic, and zirconia were used as bonding materials. Silicon carbide paper was used to polish the specimens. Two self-adhesive resin cements (Panavia SA luting multi, PAM, and Maxcem elite chroma, MAC) were used. Ten specimens for each material were produced and resin cements were bonded to each material. The specimens were stored in 37°C distilled water in an incubator for 24 hours. A universal testing machine was used to measure the shear bond strength. The data were statistically examined using one-way ANOVA and Tukey's test. **Results:** In all prosthetic materials, PAM had the highest bond strength. In lithium disilicate glass-ceramic, the lowest bond strength was found with MAC. **Conclusion:** The self-adhesive resin cement (PAM) containing 10-MDP monomer and long carbon-chain silane was performed the greatest outcome in the shear bond strength on the prosthetic materials and self-adhesive resin cement interface.

Keywords: *Base metal alloy, lithium disilicate glass-ceramic, self-adhesive resin cement, zirconia*

Introduction

The luting process for adhesive resin cement appears to have a more important role in bonding to indirect restorations. Cementation is an important step in guaranteeing indirect restorations' longevity and clinical success.[1] Certainly, in certain clinical situations, resin adhesive cements must be used. Resin cements are becoming more popular as a result of their superior mechanical characteristics, excellent retention, and color match.[2,3] However, adhesive resin cements requires multiple luting procedures. Accordingly, there have been reports of self-adhesive resin cements that need less clinical steps, designed at reducing the luting step of indirect restorations.[4,5]

Self-adhesive resin cements (SACs) combine the ease of use of conventional luting cements with enhanced mechanical properties and bonding potentiality of adhesive resin cements.[6,7] SACs bonds to prosthetic materials and tooth structures without requiring the pretreatment of substrates. Thus, SACs are very simple to apply and may be used in only one clinical luting step.[6]

SACs' bonding capabilities are influenced by their chemical characteristics. The cement's matrix, composing of acidic phosphate/carboxylate functional molecules such 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) and glycerol phosphate dimethacrylate (GPDM), results in chemical adherence to metal oxides, including such base metal alloy, zirconia.[8,9] Unfortunately, there is still some controversy. SACs matrix's contains of acidic functional methacrylate monomers. If a variety of acidic

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Address for correspondence: Dr. Awiruth Klaisiri, Division of Restorative Dentistry, Faculty of Dentistry, Thammasat University, Pathumthani, Thailand.
E-mail: Dentton@hotmail.com

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functional molecules interact with the prosthetic material and create a chemical interaction strong enough. The goal of this *in vitro* experiment was to examine the effect of various functional monomers in two SACs on prosthetic materials. The study's null research hypothesis was that the varied functional monomers of SACs have no effect on the shear bond strength of the different prosthetic materials and the SACs interface.

Materials and Methods

Specimen preparation

In this investigation, three different types of prosthetic materials were tested: 1) Base metal alloy (BMA, Alloy Name: N.P. (V) with <3% of Ferrum (Fe), Silicon (Si), Carbon (C), 1.8% Beryllium (Be), 2% Aluminium (Al), 9% Molybdenum (Mo), 15% Chromium (Cr), and 72% Nickel (Ni); Dental Art Lab, Bangkok, Thailand), 2) Lithium disilicate glass-ceramic (LDC, IPS e-max, Ivoclar-Vivadent, Schaan Liechtenstein), and 3) Zirconia (ZIR, VITA YZ HT, Zahnfabrik, Germany). All specimens (diameter is 6.0 mm, thickness is 4.0 mm) were placed within a polyvinyl chloride pipe filled with type IV dental gypsum. All samples had their surfaces polished using silicon carbide sandpaper of 600 grit (RS Components Co., Ltd., Bangkok, Thailand) after that 15 minutes distilled water ultrasonic cleaning and then using a triple syringe, dry for 10 seconds.

[Table 1] summarizes the SACs that were examined in this investigation. In this research, two self-adhesive resin cements (PAM, Panavia SA luting multi, Kuraray Noritake Dental Inc., Okayama, Japan and MAC, Maxcem elite chroma, Kerr Corporation, California, USA) were used. The manufacturers' guidelines were followed for mixing SACs. Custom-built silicone mold (Honigum putty, DMG GmbH, Hamburg, Germany, diameter is 2.0 mm, thickness is 2.0 mm) were put over the prosthetic material. The silicone mold was injected with self-adhesive resin cement, followed by the application of a steady force of 1,000 grams for 30 seconds utilizing a custom-built apparatus, and then kept in yellow box at room temperature for 10 minutes. After that, the silicone molds were removed. The total of ten specimens (n = 10) were utilized in each group; 1) PAM + BMA, 2) PAM + LDC, 3) PAM + ZIR, 4) MAC + BMA, 5) MAC + LDC, and 6) MAC + ZIR. Before testing, all bonded samples were stored in 37°C distilled water in an incubator for 24 hours. (CN-25C, Matsuyoshi and Co., Ltd., Tokyo, Japan).

Testing for shear bond strength and surface analysis

Universal testing equipment (EZ-S 500N, Shimadzu Corporation, Kyoto, Japan) with a cross-head speed of 0.5 mm per minute was also utilized to assess the shear bond strength. The maximum load of fracture and surface zone for bonding were utilized to obtain the shear bond strength value in megapascal (MPa).[10]

To investigate failure types, the fracture prosthetic surfaces were analyzed by a stereomicroscope (1013369, 3B Scientific GmbH, Hamburg, Germany) at 40 times (x40) magnification. The types of failure were categorized within three classes: 1) adhesive failure at the prosthetic surface and self-adhesive resin cement interface, 2) cohesive failure inside the self-adhesive resin cement, and 3) mixed failure occurred caused by a combination of the both.

Analytical statistics

To analyze the data statistically, one-way ANOVA and Tukey's test were utilized. Statistically significant difference was determined when the p-value was less below 0.05 ($p < 0.05$).

Results

The shear bond strength ranged from the highest to the lowest as follows: 1) PAM + LDC, 2) PAM + ZIR, 3) PAM + BMA, 4) MAC + BMA, 5) MAC + ZIR, and 6) MAC + LDC. However, there was no statistical difference between PAM + LDC, PAM + ZIR, and PAM + BMA ($p > 0.05$). In this study, all prosthetic materials showed predominantly adhesive failure. Details were summarized in [Table 2].

Table 1: Self-adhesive resin cements used in this investigation

Material	Composition
Maxcem elite chroma (Kerr Corporation, California, USA) Lot: 7430106 Shade: Clear	Methacrylate ester monomers, GPDM, proprietary self-curing redox activator, camphorquinone, fluoraluminosilicate glass filler, silica, barium glass filler, activators, stabilizers
Panavia SA luting multi (Kuraray Noritake Dental Inc., Okayama, Japan) Lot: 7M0082 Shade: Translucent	10-MDP, Bis-GMA, TEGDMA, hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, long carbon chain silane, di-camphorquinone, benzoyl peroxide, initiator, silanated colloidal silica, silanated barium glass filler, accelerators, surface treated sodium fluoride, pigments

Abbreviations: GPDM; glycerol phosphate dimethacrylate, 10-MDP; 10-methacryloyloxydecyl dihydrogen phosphate, Bis-GMA; bisphenol A-glycidyl methacrylate, TEGDMA; triethylene glycol dimethacrylate.

Table 2: The mean SBS values (MPa) (X±SD, n = 10). Failure mode percentage (adhesive/mix/cohesive)

	BMA	LDC	ZIR
PAM	19.36 ± 2.63^{A}	20.11 ± 2.85^{A}	19.84 ± 1.96^{A}
	(70/30/0)	(70/30/0)	(70/30/0)
MAC	13.14 ± 3.01^{B}	7.73 ± 3.41^{C}	12.97 ± 2.23^{B}
	(90/10/0)	(100/0/0)	(90/10/0)

Abbreviations: SBS, shear bond strength; MPa, megapascal; SD, standard deviation.

The value with identical letters indicates no statistically significant difference ($p < 0.05$).

Discussion

This research tested the effect of various functional monomers in two SACs on prosthetic materials. The results demonstrate that the shear bond strength from each group is significantly different. As a result, the null research hypothesis was disproved.

Among of the most recent developments in restorative and prosthetic dentistry was the development of SACs. Because most SACs are composed of particular carboxylate and/or phosphate functional molecules, the composition is a significant consideration. For instance, the acidic functional monomer 10-MDP is present in several SACs.[11] It's a functional monomer that's hydrophilic with mild self-etching properties, with a proven ability to bond to the tooth,[12] base metal alloy, titanium,[13,14] and zirconia.[15,16]

The mild self-etching capability is ascribed to the appearance of the acidic functional monomers, which might vary based on resin cement category. Even though these two SACs have relatively comparable filler and resin matrix compositions, significant variances on shear bond strength were detected among the 10-MDP specimen and the GPDM specimen. It's possible that the discrepancy is related to the acidity functional monomer found in each self-adhesive resin cement. PAM contains methacrylated phosphoric esters as 10-MDP and long carbon-chain silane (LCCS), whereas MAC contains methacrylated phosphoric esters as GPDM. In the present study, in all of the groups, PAM had the strongest shear bond. PAM containing 10-MDP can create strong shear bond strength to base metal alloy and zirconia. The 10-MDP chemical reaction with the oxide layer of the base metal alloy or zirconium oxide may explain the high shear bond strength on base metal alloys and zirconia. 10-MDP is an acidic phosphate functional monomer along a lengthy chain spacer of - $(CH2)_n$ than GPDM.[17] The long chain spacer of - $(CH2)_n$ might increase the self-adhesive resin cement's hydrophobicity, its binding strength was deemed to be superior to that of other SACs containing various acidic phosphate functional monomers. Moreover, Nagaoka *et al.*,[18] found that there may be increased chemical adhesion if there is a large quantity of 10-MDP. PAM appears to have more 10-MDP than any other self-adhesive resin cement.[19] Furthermore, PAM exhibited the strongest shear bond strength in lithium disilicate glass-ceramic. PAM containing LCCS can create strong shear bond power with lithium disilicate glass-ceramic. The LCCS is characterized with a bifunctional adhesion function; (a) chemical bonding with lithium disilicate glass-ceramics through siloxane bonds; (b) co-polymerization of the monomers within the self-adhesive resin cement through methacrylate groups.[20] In addition, Mano *et al.*,[21] reported that after 5,000 thermocycles of age, the presence of LCCS in self-adhesive resin cement is important for achieving long-term bond ability in lithium disilicate glass-ceramic.

In the present investigation, MAC showed lower shear bond strength than PAM in all prosthetic materials as its GPDM acidic functional monomer composition. A MAC containing GPDM can make weak shear bond strength to base metal alloy and zirconia. GPDM is an acidic phosphate functional monomer along a shorter chain spacer of - $(CH2)_n$ and higher hydrophilicity compared to 10-MDP.[22] The acidic phosphate functional monomer of MAC becomes deficient for stimulating chemical adhesion, and therefore, strong shear bond strength will not be achieved. It's reasonable to assume that GPDM's chemical adhesion efficacy is inferior to that of 10-MDP. However, GPDM also has two methacrylate polymerizable groups, which is a unique feature. Thus conduces to bond with the other monomers within SACs and prosthetic substrate more greatly than other acidic functional monomers with only one polymerizable group. The polymer structure's quality and the mechanical characteristics of SACs are both enhanced when the degree of polymerization is increased.[23] Regarding, the lithium disilicate glass-ceramic, MAC had the weakest shear bond ability of all the samples. MAC not containing LCCS has not the ability to create a bond to lithium disilicate glass-ceramic.

In terms of fracture mode, shear bond strength testing can reveal primarily adhesive and mixed failure mechanisms. All of the groups had a high rate of adhesive failures. High shear bond strength was frequently associated with mixed failure modes. This could be due to the self-adhesive resin cement's improved chemical bond. In the case of MAC in lithium disilicate glass-ceramic, adhesive failure was observed in all specimens, because it had lower shear bond strength than the other groups relatively, which caused in adhesive failures of all specimens.

Conclusion

The research's limitations are contained inside the area of the study, the self-adhesive resin cement (PAM) containing 10-MDP monomer and LCCS was performed the greatest outcome in the shear bond strength on the prosthetic materials and self-adhesive resin cement interface.

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Conflicts of interest

The authors declare no conflict of interest.

Authors' contribution

TS, NT, and AK designed the study. TS and AK performed the study and collected data. TS, NT, and AK analyzed and interpreted the data. AK drafted the article. TS, NT, and AK revised the article. TS, NT, and AK approved the final version of the article and agree to be accountable for all aspects of the work.

Ethical policy and institutional review board statement

Not applicable.

Patient declaration of consent

Not applicable.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

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