Original Article

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# The effect of a silane-SIO$_2$ nanocomposite coating on a provisional restorative material on surface roughness

Thamonwan Langlongsathit, **Pranithida Kamonwanon**

*Department of Prosthodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*

**Objective:** To investigate the effect of a silane-coating material on the surface roughness of a provisional fixed prosthodontic material and compare the changes in surface roughness after brushing.
**Materials and Methods:** Specimens were produced from four commercial provisional restorative materials (GC Unifast Trad™, Major C&B dentine, Protemp™ 4, Luxatemp® star) and a silane-coated provisional restorative material (coated-GC Unifast Trad™) and randomly divided into control and brushing groups. A profilometer was used to determine the surface roughness of each group's specimens. The surface morphology of the specimens from each group was examined using a scanning electron microscope (SEM).
**Result:** The roughness of the control groups was not significantly different. In the brushing groups, the coated-GC Unifast Trad™ roughness was significantly lower than that of GC Unifast Trad™. Furthermore, the coated-GC Unifast Trad™ roughness was not significantly different compared with Protemp™ 4 and Luxatemp® star.
**Conclusion:** The surface roughness of acrylic resin coated with a silane-SiO$_2$ nanocomposite film is similar to that of conventional acrylic resin and bis-acryl composite resin. In contrast, the roughness of conventional acrylic resin is higher compared with coated acrylic resin after brushing, and acrylic resin coated with a silane-SiO$_2$ nanocomposite film also has a roughness similar to that of bis-acryl composite resin.

**Keywords:** provisional restorative material, silane surface coating agent, surface roughness

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## Introduction

Before the final restoration is fabricated, provisionalization provides significant diagnostic functions, esthetics, and improves the periodontal status around the tooth. Interim restoration functions include preserving pulpal and periodontal tissues, generating an emergence profile, preventing abutment movement, and ensuring correct occlusion. Provisional restorations can be used for a long time (6–12 weeks) in oral rehabilitation cases to maintain the vertical dimension and can be monitored and adjusted to develop suitable final restorations [1-3].

Polymethyl methacrylate (PMMA) is a commonly used material for fabricating provisional crowns and fixed partial dentures. Their popularity is due to their low cost, acceptable esthetics, and adaptability. However, bis-acryl composites have been demonstrated to have superior marginal adaptability, color stability, and repairability with other composites compared with PMMA [4]. Bis-acrylate composite resins have become more frequently used as direct provisional prosthetics in the oral cavity due to their properties. However, this material is brittle, which makes finishing and polishing difficult, and is expensive [5].

Correspondence author: Pranithida Kamonwanon
Department of Prosthodontics, Faculty of Dentistry, Mahidol University
6 Yothi Road, Ratchathewi, Bangkok 10400, Thailand
Tel.+66 2200 7816 Fax. +66 2200 7818
E-mail: pranithida.kam@mahidol.ac.th
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Minimizing dental bacterial plaque attachment is a key component in the success of definitive fixed prostheses. Rough-surfaced dental materials have been demonstrated to increase bacterial adhesion and reduce oral hygiene [6]. The surface of a provisional restoration should be smooth, esthetic, comfortable, and be stain and plaque resistant. The rough surface of a temporary restoration results in biofilm formation and bacterial adhesion that cause inflammation at the gingiva and bone resorption [7].

The surface of a restorative material in the oral environment can become rougher over time due to several factors, such as masticatory forces, friction, fatigue, erosion, and toothbrushing. Several studies found that the surface roughness of a restoration is related to how the tooth is brushed [8-10]. Another study revealed that provisional resin restorations demonstrate increased roughness over a long period during the evaluation of the outcomes of periodontal and endodontic treatment, as well as during the restorative phase of implant placement [11].

Dental glazes and coating materials were created to improve a material's mechanical properties, such as changing the surface energy, altering the roughness, and reducing surface degradation. Moreover, a surface coating can improve a material's surface properties, resulting in a better marginal seal, decreased roughness, and increased wear and stain resistance. For temporary crowns and fixed partial dentures, regular multiphase polishing can achieve minimal roughness on acrylic resins. However, applying a coating on the restoration has been advised by dental product manufacturers and specialists as an alternative to polishing [12].

Silanes have been used in dentistry used for many purposes. Silanes have an important role in providing adhesion at the interface and added $SiO_2$ nanoparticles to increase the strength of the film [13]. In the present study, a silane-$SiO_2$ nanocomposite coating was applied to the PMMA surface to improve its mechanical properties, including roughness.

The aim of this study was to determine the roughness of a silane-$SiO_2$ nanocomposite-coated PMMA provisional restorative material compared with 4 commercially available provisional restorative materials before and after brushing. The null hypothesis was that coating the PMMA provisional restorative material with a silane-$SiO_2$ nanocomposite would not affect the roughness before and after brushing.

## Materials and methods

Two commercially available PMMA provisional restorative materials (GC Unifast Trad ™ and Major C&B dentine) and two commercially available bis-acryl provisional restorative materials (Protemp™ 4 and Luxatemp® star) were used in this study. The types, manufacturers, and compositions of the materials used for the experiments are listed in Table 1.

The 5 x 10 x 2 mm bar-shaped specimens (n=15 per material in each group) were prepared using an epoxy mold per EN ISO 4049:2009 and the manufacturer's instructions. A polishing machine and 600, 800, 1000, and 2000 grit wet abrasive paper discs were used to polish each specimen. A commercially available PMMA provisional restorative material (GC Unifast Trad™) was coated with a silane-$SiO_2$ nanocomposite film.

The coating solution was prepared by mixing 7.5 g methyl trimethoxysilane (MTMS) with 0.9 mL acetic acid and 8.1 g $SiO_2$ nanoparticles, followed by 10.5 mL solvent. The GC Unifast Trad™ specimens were cleaned using isopropanol for 30 sec. The hard-coating solution was applied to the pretreated specimens using a motorized dip coater at a withdrawal speed of 30 cm/min. The solvent in the coated specimens was evaporated by preliminary curing at 65°C for 20 min and heating at 110°C for 2 h [14].

Table 1 Specifications of the tested samples.

| Material | Types | Manufacturer | Compositions |
|---|---|---|---|
| GC Unifast Trad ™ | Methacrylate | GC America, Illinois, USA | Powder: Methyl methacrylate and Ethyl methacrylate copolymer Liquid: Methyl methacrylate, butylated hydroxytoluene, hydroquinone |
| Major C&B dentine | Methacrylate | Major, Moncalieri (TO), Italy | Unfilled acrylate polymer based on polymethyl methacrylate. |
| Protemp™ 4 | Bis-acryl | 3M ESPE, Seefeld, Germany | Base paste: Dimethacrylate (BisEMA6), Silane treated amorphous silica, Reaction production products of 1,6-diisocyanatohexane with 2-{(2-methacryloyl)ethyl]6-hydroxyhexanoate and 2-hydroxyethylmethacrylate (DESMA), Silane treated silica Catalyst paste: Ethanol, 2,2'- [(1-methylethylidene) bis (4,1-phenyleneoxy)] bis-, diacetate, Benzyl-phenyl-barbituric acid, Silane treated silica, Tertbutyl peroxy-3,5, 5-trimethylhexanoate |
| Luxatemp® star | Bis-acryl | DMG, Hamburg, Germany | Glass filler in a matrix of multifunctional methacrylates; catalysts, stabilizers, and additives. Free of methyl methacrylate. Total filler volume: 44% w% =24 vol% (0.02 to 1.5μm) |

Each material's test specimens were divided into control and brushing groups. The control group comprised prepared specimens that did not receive brushing. The prepared specimens in the brushing group were brushed using mechanical brushing equipment with a holder for holding the specimen block. Six-row, 0.010-inch-diameter, firm nylon, end-rounded bristle toothbrushes (Colgate-Palmolive Co Ltd) and a suspension of toothpaste (Colgate-Palmolive Co Ltd) were used. The toothbrush and block were cleaned with an ultrasonic cleaner for 15 min before use to remove debris and cleaned in distilled water before being placed in the holder. In the holder, the specimen in the block was perpendicular to the toothbrush. The brushing machine was used with a constant load of ~2 N, and the brushing time was 120 min at 150 rpm for 9,000 cycles to simulate 6 months of use [15].

The roughness of each specimen was determined using a profilometer (Talysurf series2; Rank Taylor Hobson Ltd). A computerized system (Image-Pro Plus 3.0; Media Cybernetic) was used to construct and analyze the profilometric tracing at each 90-degree angle over the surface of each specimen. Three different traces were performed along the width of each specimen evaluated.

The obtained data were analyzed using two-way ANOVA to determine whether there was a significant difference between the five materials' in terms of the control condition and thermocycling condition and between two conditions in each group. In addition, the Bonferroni test was performed to reveal which groups had significant differences in roughness. The level of significance was defined as $p$=0.05.

## Results

The surface roughness results of each group are summarized in Table 2.

The material control groups (pre-brushing) demonstrated similar roughness values. In contrast, in the brushing groups, the coated-GC Unifast Trad™ roughness was significantly lower than that of GC Unifast Trad™. In addition, the coated-GC Unifast Trad™ roughness was not significantly different than that of Protemp™ 4 and Luxatemp® star.

The scanning electron microscope (Figures 1, 2) revealed readily apparent toothbrush streaks in the PMMA groups (Figure 1D, 1F). In contrast, few streaks were observed in the bisacryl groups and coated-GC Unifast Trad™ surfaces (Figure 1E, 2).

Table 2 Mean and standard deviation values of the roughness of the control and brushing groups for each material (n=15).

| Material | Control group Mean (SD) | Brushing group Mean (SD) |
|---|---|---|
| GC Unifast Trad™ | 0.154 (0.039)$^{a}$ | 1.484 (0.278) $^{A,b}$ |
| Major C&B dentine | 0.163 (0.034)$^{a}$ | 1.870 (0.803) $^{A,b}$ |
| Protemp™ 4 | 0.147 (0.044)$^{a}$ | 0.242 (0.085) $^{B,b}$ |
| Luxatemp® star | 0.151 (0.026)$^{a}$ | 0.384 (0.071) $^{B,b}$ |
| Coated-GC Unifast Trad™ | 0.168 (0.017)$^{a}$ | 0.316 (0.091) $^{B,b}$ |

Note: within the same group (horizontal row), means with different superscripts written in lowercase letters were significantly different ($p < 0.05$). within the same condition (vertical column), means with different superscripts written in uppercase letters were significantly different ($p < 0.05$).

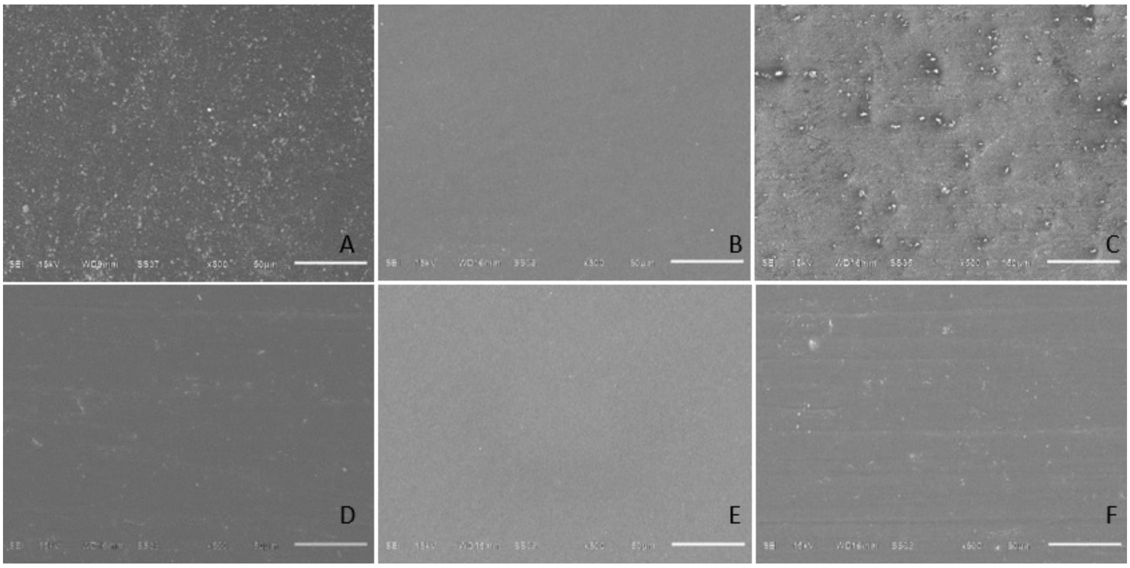


Figure 1 Representative scanning electron microscope images of the specimens (X500 magnification). A, Top-view image of GC Unifast Trad™. B, Top-view image of coated-GC Unifast Trad™. C, Top-view image of Major C&B dentine. Scanning electron microscope images of specimens (X500 magnification). D, Top-view image of GC Unifast Trad ™ after brushing. E, Top-view image of coated-GC Unifast Trad™ after brushing. F, Top-view image of Major C&B dentine after brushing.

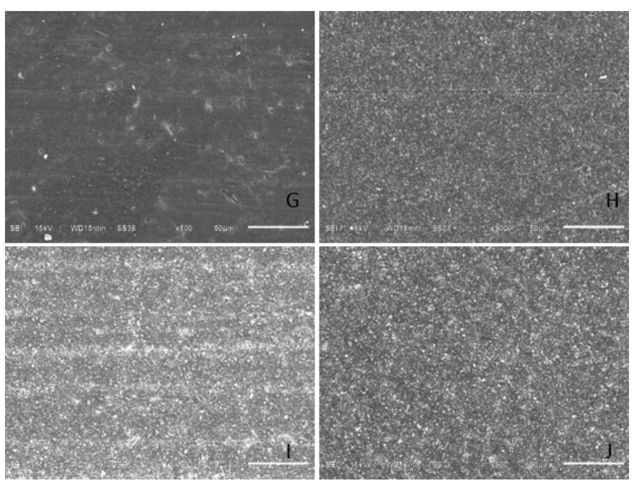


Figure 2 Representative scanning electron microscope images of the specimens (X500 magnification). G, Top-view image of Protemp™ 4. H, Top-view image of Luxatemp® star. Scanning electron microscope images of specimens (X500 magnification). I, Top-view image of Protemp™ 4 after brushing. J, Top-view image of Luxatemp® star after brushing.

## Discussion

The present study evaluated the roughness of a silane-$SiO_2$ nanocomposite-coated PMMA provisional restorative material compared with 4 commercially available provisional restorative materials before and after brushing. We found that post-brushing, the coated-GC Unifast Trad™ roughness was significantly lower than that of GC Unifast Trad™. Based on these results, the null hypothesis that coating the PMMA provisional restorative material with silane-$SiO_2$ nanocomposite would not affect surface roughness before and after brushing was rejected.

In the present study, GC Unifast Trad™ was chosen as a representative of the provisional restorative material (PMMA) commonly used in dental clinics and dental schools. PMMA is typically available as a powder and liquid. PMMA is used due to its low cost and versatility. However, after a long period of use, the surface of a PMMA provisional restoration becomes rougher, resulting in increased plaque accumulation. Therefore, fixed provisional partial prostheses with rough surfaces are more likely to be encircled by an inflamed periodontium, as demonstrated by a greater bleeding index, increased crevicular fluid secretion, and histologically inflamed tissue [16, 17]. Therefore, GC Unifast Trad™ was chosen to be coated with a silane-$SiO_2$ nanocomposite to improve its surface roughness.

Several studies revealed that methacrylate resins (PMMA) had smoother surfaces compared with bis-acryl composites. This could be due to the acrylic material's homogeneous composition and the composite material's heterogeneous composition [11, 18]. However, the present study found the roughness of the materials was not significantly different in the control condition. This is likely because during their preparation, the specimens were polished using the same procedure. Surface roughness depends on the type of prosthetic provisional restoration materials and the polishing method [19]. This study controlled the polishing procedure when preparing the specimens of each material; therefore the roughness varied based on the material type.

Quirynen *et al.* and Bollen *et al.* considered dental materials with a surface roughness less than 0.2 mm to be clinically optimum [6]. Using products with a rougher surface, plaque adhesion and staining may be increased over time due to daily oral exposure. Moreover, gingival inflammation and esthetic degradation can occur when interim restorations are required for a prolonged period of time [20].

Kanter et al. found that 10,000 strokes of simulated toothbrushing represents 1 year of brushing [8]. The present study used 5,000 strokes in a toothbrushing machine to simulate 6 months of provisional restoration service. This amount of time was selected because interim restorations remain in place for a longer time in oral rehabilitation cases [1].

Goldstein [9] demonstrated that brushing with deionized water did not affect the surface of the composite resin. They exhibited good wear resistance. Moreover, when the composite resin was brushed with toothpaste, the surface was significantly smoother compared with acrylic resin. Similarly, in the present study, after brushing, the roughness in the bisacryl groups (Protemp™ 4, Luxatemp® star) was not significantly different, however, they were significantly smoother compared with the PMMA groups (GC Unifast Trad™ and Major C&B dentine). Correspondingly, the scanning electron microscopy images demonstrated numerous toothbrush streaks in the PMMA groups. In contrast, few streaks were seen on the bisacryl groups and coated-GC Unifast Trad™ surfaces.

After brushing, all specimens demonstrated increased surface roughness. Coated-GC Unifast Trad™ had a lower surface roughness compared with GC Unifast Trad™ after the specimens were brushed for the equivalent of 6 months in the mouth. A similar study found that the roughness of acrylic resin denture base after brushing was significantly higher than that of the $SiO_2$ nanocomposite film-coated specimens [16]. Because the wear resistance of the silane-$SiO_2$ nanocomposite film was comparable to that of the composite resins, the coated-GC Unifast Trad™ roughness was not significantly different than that of Protemp™ 4 and Luxatemp® star [15]. These results indicate the effect of methacrylate-based resins on surface roughness.

## Conclusion

The surface roughness of acrylic resin coated with silane-$SiO_2$ nanocomposite film is similar to that of conventional acrylic resin and bis-acryl composite resin. After brushing, the roughness of conventional acrylic resin is higher compared with coated acrylic resin, and acrylic resin coated with a silane-$SiO_2$ nanocomposite film has a similar roughness to that of bis-acryl composite resin.

## References


1. Turner KA, Missirlian DM. Restoration of the extremely worn dentition. *J Prosthet Dent* 1984; 52: 467-74.
2. Rosenstiel SF, Land MF, Fujimoto J, Lang SC. Contemporary fixed prosthodontics. 2001.
3. Patras M, Naka O, Doukoudakis S, Pissiotis A. Management of provisional restorations' deficiencies: a literature review. *J Esthet Restor Dent* 2012; 24: 26-38.
4. Astudillo-Rubio D, Delgado-Gaete A, Bellot-Arcís C, Montiel-Company JM, Pascual-Moscardó A, Almerich-Silla JM. Mechanical properties of provisional dental materials: A systematic review and meta-analysis. *PloS one* 2018; 13: e0193162.
5. Young HM, Smith CT, Morton D. Comparative in vitro evaluation of two provisional restorative materials. *J Prosthet Dent* 2001; 85: 129-32.
6. Quirynen M, Bollen C. The influence of surface roughness and surface-free energy on supra-and subgingival plaque formation in man: A review of the literature. *J Clin Periodontol* 1995; 22: 1-14.
7. Buergers R, Rosentritt M, Handel G. Bacterial adhesion of Streptococcus mutans to provisional fixed prosthodontic material. *J Prosthet Dent* 2007; 98: 461-9.
8. Kanter J, Koski RE, Martin D. The relationship of weight loss to surface roughness of composite resins from simulated toothbrushing. *J Prosthet Dent* 1982; 47: 505-13.
9. Goldstein GR, Lerner T. The effect of toothbrushing on a hybrid composite resin. *J Prosthet Dent* 1991; 66: 498-500.
10. Oliveira JCd, Aiello G, Mendes B, Urban VM, Campanha NH, Jorge JH. Effect of storage in water and thermocycling on hardness and roughness of resin materials for temporary restorations. *Mater Res* 2010; 13: 355-9.
11. Şen D, Göller G, İşsever H. The effect of two polishing pastes on the surface roughness of bis-acryl composite and methacrylate-based resins. *J Prosthet Dent* 2002; 88: 527-32.
12. Borchers L, Tavassol F, Tschernitschek H. Surface quality achieved by polishing and by varnishing of temporary crown and fixed partial denture resins. *J Prosthet Dent* 1999; 82: 550-6.
13. Chantarachindawong R, Luangtip W, Chindaudom P, Osotchan T, Srikhirin T. Development of the scratch resistance on acrylic sheet with basic colloidal silica (SiO2)—methyltrimethoxysilane (MTMS) nanocomposite films by sol–gel technique. *Can J Chem Eng* 2012; 90: 888-96.
14. Kamonwanon P, Hirose N, Yamaguchi S, Sasaki J-i, Kitagawa H, Kitagawa R, et al. SiO2-nanocomposite film coating of CAD/CAM composite resin blocks improves surface hardness and reduces susceptibility to bacterial adhesion. *Dent Mater J* 2017; 36: 88-94.

15. Kamonwanon P, Yodmongkol S, Chantarachindawong R, Thaweeboon S, Thaweeboon B, Srikhirin T. Wear resistance of a modified polymethyl methacrylate artificial tooth compared to five commercially available artificial tooth materials. *J Prosthet Dent* 2015; 114: 286-92.
16. Yodmongkol S, Chantarachindawong R, Thaweboon S, Thaweboon B, Amornsakchai T, Srikhirin T. The effects of silane-$SiO_2$ nanocomposite films on Candida albicans adhesion and the surface and physical properties of acrylic resin denture base material. *J Prosthet Dent* 2014; 112: 1530-8.
17. Kumar GV, Devi R, Anto N. Evaluation and Comparison of the Surface Roughness and Porosity of Different Provisional Restorative Materials: An in vitro Study. *CODS J Dent* 2016; 8: 39-45.
18. Wang RL, Moore BK, Goodacre CJ, Swartz ML, Andres CJ. A comparison of resins for fabricating provisional fixed restorations. *Int J Prosthodont* 1989; 2: 173-84.
19. Lara-Jara NU, Romo-Ramírez GF, del Pilar Goldaracena-Azuara M, Aragón-Piñ A, Girón CB-T, Méndez-González MV, *et al.* Effect of Polishing Procedure on the Roughness and Bacterial Adhesion of Provisional Restorative Materials. *Microsc Res* 2018; 6: 9-18.
20. Haselton DR, Diaz-Arnold AM, Dawson DV. Effect of storage solution on surface roughness of provisional crown and fixed partial denture materials. *J Prosthodont* 2004; 13: 227-32.