Because of their excellent chemical and physical properties, biocompatibility, and resistance to plaque accumulation, zirconium dioxide (zirconia) ceramics have been used as a framework material for implant-supported single and fixed dental prostheses in the posterior and anterior regions. Evidence from clinical studies indicates that implant-supported zirconia-based prostheses have favorable clinical performance and a high survival rate.

To achieve superior esthetics for implant-supported prostheses, surgical procedures such as soft and hard tissue augmentation are required. However, these procedures are unpredictable when the volume of missing tissue is large. In addition, the costs of surgery, healing time, and pain and discomfort make surgery difficult for some patients. Alternatives to reconstructing defective soft and hard tissue include gingival prostheses—an easier and more predictable approach. Prosthetic approaches can obviate unnecessary additional surgical procedures and yield esthetically as well as functionally pleasing outcomes.

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Auto-polymerizing acrylic resin, flexible silicone material, gingiva-colored porcelain, and resin composite are used as gingiva-colored layering materials in implant-supported prostheses. Although gingiva-colored porcelain is frequently layered on framework materials for reconstruction of defective soft and hard tissue, because of its excellent esthetics and biocompatibility, it has several shortcomings. Shrinkage of gingiva-colored porcelain during firing can result in gaps between the porcelain and soft tissue, and distortion of implant-supported prostheses. In addition, chipping of porcelain and limited repairability of implant-supported zirconia-based prostheses have been reported. Recent studies reported that indirect resin composites are a promising alternative to porcelain as a gingiva-colored material. Combined application of a phosphate monomer and silane enhanced initial bond strength of light-polymerized and photo/heat-polymerized gingiva-colored layering resin composites to porcelain-coated zirconia ceramics.

**MATERIALS AND METHODS**

The details of the materials assessed in the present study are shown in Table 1. A total of 110 zirconia disks (11×2.5 mm) were fabricated with the Katana system (Kuraray Noritake Dental, Tokyo, Japan). The zirconia disks were machine-milled with a milling device (Katana).
Table 1  Materials assessed in the present study

| Material/Trade name                  | Code | Manufacturer                   | Components                                      |
|--------------------------------------|------|---------------------------------|-------------------------------------------------|
| **Zirconia ceramic material**        |      |                                 |                                                 |
| Katana Zirconia                      |      | Kuraray Noritake Dental, Tokyo, Japan | 94.4% ZrO$_2$, 5.4% Y$_2$O$_3$                  |
| **Indirect resin composite**         |      |                                 |                                                 |
| Ceramage concentrate GUM-D           | CER  | Shofu, Kyoto, Japan             | UDMA, urethane diacrylate, zirconium silicate   |
| Ceramage Pre-Opaque                  |      | Shofu                           | UDMA, HEMA, aluminum silicate                   |
| Ceramage Opaque GUM-O                |      | Shofu                           | UDMA, HEMA, aluminum silicate                   |
| Estenia C&B Gingival P2              | EST  | Kuraray Noritake Dental         | Bis-GMA, methacrylate, photoinitiator, pigment, filler (glass, macro alumina) |
| Estenia C&B Opaque modifier P        |      | Kuraray Noritake Dental         | Bis-GMA, methacrylate, photoinitiator, pigment, filler (quartz, composite, others) |
| **Feldspathic porcelain for zirconia**|      |                                 |                                                 |
| Cerabien ZR Shade base SBA2          |      | Kuraray Noritake Dental         | SiO$_2$, Al$_2$O$_3$, Na$_2$O, K$_2$O, etc.     |
| **Priming agent**                    |      |                                 |                                                 |
| Clearfil Photo Bond                   | CPB  | Kuraray Noritake Dental         | Catalyst: MDP, HEMA, Bis-GMA                    |
| Clearfil Porcelain Bond Activator     | Act  | Kuraray Noritake Dental         | Universal: accelerators, ethanol                 |
| Estenia Opaque Primer                 | EOP  | Kuraray Noritake Dental         | 3-TMSPMA, Bis-GMA                                |
| Super-Bond PZ primer Liquid B         | PZB  | Sun Medical, Moriyama, Japan    | MMA, 3-TMSPMA                                   |

MDP: 10-methacryloyloxydecelyl dihydrogen phosphate; 3-TMSPMA: 3-trimethoxysilylpropyl methacrylate; HEMA: 2-hydroxyethyl methacrylate; Bis-GMA: bisphenol A-glycidyl methacrylate; UDMA: 1,6-bis(2-methacryloyloxyethyloxycarbonylamino)-2,4,4-trimethylhexane; UTMA: urethane tetramethacrylate; MMA: methyl methacrylate

DWX-50N, Kuraray Noritake Dental) from pre-sintered zirconia blocks (Katana Zirconia, Kuraray Noritake Dental), and fully sintered in a heat furnace (Katana F-1, Kuraray Noritake Dental) at 1,375°C for 90 min. The zirconia disks served as the bonding substrate.

A light-polymerizing gingiva-colored indirect resin composite (CER; Ceramage, Shofu, Kyoto, Japan) and a photo/heat-polymerizing gingiva-colored indirect resin composite (EST; Estenia C&B, Kuraray Noritake Dental) were used as the veneering material. Four priming agents —Clearfil Photo Bond (CPB; Kuraray Noritake Dental), Clearfil Photo Bond with Clearfil Porcelain Bond Activator (CPB+Act; Kuraray Noritake Dental), Estenia Opaque Primer (EOP; Kuraray Noritake Dental), and PZ primer Liquid B (PZB; Sun Medical, Moriyama, Japan)— were applied to the substrate surface. All priming agents contained at least one adhesive functional monomer in the solvent (Table 1).

The surfaces of the zirconia specimens were wet-ground with 600-grit silicon carbide abrasive paper (Tri-M-ite Wetordry sheets, 3M, St. Paul, MN, USA). The specimens were then airborne particle-abraded with 50-μm Al$_2$O$_3$ particles (Hi-Aluminas, Shofu) at a pressure of 0.2 MPa for 20 s at a distance of 10 mm from the surface. The area for feldspathic porcelain (Cerabien ZR SBA2, Kuraray Noritake Dental) coating was determined by using a piece of plastic tape (Star Traper-GP, Sakurai, Tokyo, Japan) with a circular hole (diameter, 5.0 mm) on the surface of each zirconia disk. The porcelain powder was mixed with the corresponding liquid (Meister Liquid, Kuraray Noritake Dental) supplied by the manufacturer, and a thin layer of porcelain slurry was veneered on the coating area. Then, the plastic tape was carefully removed from the specimen. The specimens were fired at 930°C for 1 min in a vacuum furnace (SingleMat Porcelain Furnace, Shofu) to prepare the porcelain coating on the surface of the zirconia specimens. The surfaces of the porcelain-coated specimens were then airborne particle-abraded with Al$_2$O$_3$ particles (Hi-Aluminas; Shofu) for 2 s at a pressure of 0.2 MPa from a distance of 10 mm.

The surface of each specimen was treated with one of the four priming agents, namely CPB, CPB+Act, EOP, and PZB, according to the manufacturers’ instructions.
Table 2 Application protocol for priming agents and indirect resin composites

| Material/Code | Application protocol |
|---------------|----------------------|
| **Priming agent** |                         |
| CPB           | Catalyst and Universal were mixed in equal amount. The mixture was applied to specimen surface with applicator and mildly aired. |
| CPB+Act       | CPB and Act were mixed in equal amount. The mixture was applied to substrate surface with applicator and mildly aired. |
| EOP           | Priming agent was applied to specimen surface with applicator and mildly aired. |
| PZB           | Priming agent was applied to specimen surface with applicator and mildly aired. |
| **Indirect resin composite** |                         |
| CER           | Pre-Opaque was applied and light polymerized for 60 s.  
|               | Opaque GUM-O was applied and light polymerized for 60 s.  
|               | Concentrate GUM-D was filled in the ring and then light-polymerized for 5 min. |
| EST           | Opaque modified P was applied and light polymerized for 90 s.  
|               | Gingival P2 was packed into the ring and light-polymerized for 5 min.  
|               | Heat-polymerization was additionally applied at 110°C for 15 min. |

See Table 1 for descriptions of abbreviations.

(Table 2), and unprimed (UP) as a control. With the exception of the EOP and UP groups, specimens in all groups were primed with EOP before bonding the opaque material to the zirconia specimens according to the manufacturer's instructions.

The specimens in each group were further randomly divided into two groups for application of the gingiva-colored indirect resin composites (EST and CER) (n=11). After surface treatment of the specimens, the bonding area was defined by applying a piece of double-coated tape (Kincsem, Horse Care Products, Tokyo, Japan) with a circular hole (diameter, 5.0 mm). The two gingiva-colored indirect resin composites were veneered on the treated surface of specimens in each group, as described below.

**CER specimens**

A thin layer of opaque material (Ceramage Pre-Opaque, Shofu) was applied and light-polymerized for 60 s with a laboratory light-polymerization unit (Solidilight, Shofu). Another opaque material (Ceramage Opaque GUM-O, Shofu) was additionally applied on the primary layered opaque material and light-polymerized with the same light-polymerization unit for 3 min. Stainless-steel rings (SUS303, Nagata Industry, Sagamihara, Japan) with an inner diameter of 6 mm and a height of 2 mm were mounted on all specimens so that they surrounded the opaque layered surface. The rings were filled with a gingiva-colored indirect resin composite (Ceramage Concentrate GUM-D, Shofu) at a standardized force of 5 N. The specimens were then light-polymerized for 5 min (Table 2).

**EST specimens**

A thin layer of opaque material (Estenia C&B opaque modified P, Kuraray Noritake Dental) was applied as a high-flow bonding agent and light-polymerized for 90 s with a laboratory light-polymerization unit (α-Light II, J. Morita, Suita, Japan). An additional opaque material was placed on top of the primary opaque layer in the same manner. A stainless-steel ring (inside diameter, 6.0 mm; depth, 2.0 mm) was then positioned to surround the opaque material. A gingival shade of indirect resin composite (Estenia C&B Gingival P2, Kuraray Noritake Dental) was packed into the ring with a force of 5 N. The specimen was then light-polymerized with the polymerization unit (α-Light II, J. Morita) for 5 min and then heat-polymerized at 110°C for 15 min in a heat oven (KL-310, J. Morita) (Table 2).

Specimens from all groups were stored in distilled water at 37°C for 24 h. Each specimen was then positioned in a steel mold and placed in a shear bond testing jig (Tokyo Giken, Tokyo, Japan). Shear bond strength was tested in a universal testing device (Type 5567, Instron, Canton, MA, USA) at a crosshead speed of 0.5 mm/min. Load at fracture was converted to shear bond strength (MPa) by dividing failure load (N) by bonding area (mm²).

The results were first analyzed with the Levene test for equality of variance by using statistical software (IBM SPSS Statistics, version 24.0, IBM, Armonk, NY, USA). When the Levene test did not show homoscedasticity, the results were analyzed with the Kruskal-Wallis test (IBM SPSS Statistics, version 24.0, IBM) followed by the Steel-Dwass test for multiple comparisons (Kryplot 5.0, KyensLab, Tokyo, Japan). Differences between two gingiva-colored indirect resin composites within an identical surface treatment were additionally analyzed with the Mann-Whitney U-test. The significance level was set at 0.05 in all analyses.
The fractured interfaces of tested specimens were examined with a stereomicroscope (×32, StemiDV4, Carl Zeiss, Jena, Germany) to determine failure mode after shear bond testing, which was classified as A (adhesive failure at the porcelain/gingiva-colored resin composite interface), B (adhesive failure at the porcelain/gingiva-colored resin composite interface, and cohesive failure inside the porcelain), or C (cohesive failure inside the porcelain). Representative fractured specimens were osmium-coated with a sputter coater (HPC-IS, Vacuum Device, Mito, Japan) and observed with a scanning electron microscope (SEM; S-4300, Hitachi High-Technologies, Tokyo, Japan) operated at 15 kV.

X-ray diffraction (XRD) was performed to analyze the debonded surface of the typical specimens for each group after shear bond testing, feldspathic porcelain-coated zirconia specimen after airborne-particle abrasion, CER, and EST disks using X-ray diffractometer (MiniFlex II, Rigaku, Tokyo, Japan) with CuKα radiation. The XRD analysis was operated at 30 kV and 15 A in a 2θ range from 3° to 40° and scanning speed of 2.0°/min.

RESULTS

Table 3 shows shear bond strengths between gingiva-colored indirect resin composites and porcelain-coated zirconia ceramics. Mean bond strength ranged from 2.7 to 14.5 MPa for CER specimens and from 5.1 to 18.2 MPa for EST specimens. For both CER and EST specimens, bond strength was significantly higher for the CPB+Act group than for the other groups. In all priming groups, bond strength was significantly higher for EST specimens than for CER specimens.

Table 4 shows failure mode after shear bond testing. For both CER and EST specimens, all specimens in the UP and CPB groups, and most specimens in the EOP group, developed adhesive failure at the porcelain/gingiva-colored resin composite interface. Cohesive failure within the porcelain was frequently observed in the PLB and CPB+Act groups, for both CER and EST specimens.

Representative SEM images of the surface of zirconia specimens and porcelain-coated zirconia specimens after airborne-particle abrasion are shown in Figs. 1 and 2, respectively. The surface of zirconia and porcelain-

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**Table 3** Shear bond strength (MPa) between gingiva-colored indirect resin composites and porcelain-coated zirconia

| Group | CER specimen | EST specimen | p-value |
|-------|--------------|--------------|---------|
|       | Mean Median SD Category* | Mean Median SD Category* |         |
| UP    | 2.7 2.7 0.8 a | 5.1 4.9 2.0 e | 0.000** |
| EOP   | 6.5 6.5 1.5 b | 8.3 7.9 1.5 f | 0.008** |
| PZB   | 10.0 10.0 2.5 c | 14.0 12.9 3.4 g | 0.001** |
| CPB   | 3.7 3.5 1.4 a | 7.4 8.7 3.7 e, f | 0.016** |
| CPB+Act | 14.5 13.6 3.3 d | 18.2 18.3 1.9 h | 0.013** |

*Identical letters indicate that the values are not statistically different (Steel-Dwass test, p>0.05).
**Statistically significant difference between the two gingiva-colored indirect resin composites for the surface treatment (Mann-Whitney U-test, p<0.05)

See Table 1 for descriptions of abbreviations.

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**Table 4** Failure mode after shear bond testing

| Group | CER specimen | EST specimen |
|-------|--------------|--------------|
|       | A B C | A B C |
| UP    | 11 0 0 | 11 0 0 |
| EOP   | 10 1 0 | 9 2 0 |
| PZB   | 0 9 2 | 0 8 3 |
| CPB   | 11 0 0 | 11 0 0 |
| CPB+Act | 0 7 4 | 0 4 7 |

See Table 1 for descriptions of abbreviations. (A) adhesive failure at the porcelain/gingiva-colored resin composite interface; (B) adhesive failure at the porcelain/gingiva-colored resin composite interface, with cohesive failure inside the porcelain; (C) cohesive failure inside the porcelain.
coated zirconia specimens was rougher and had sharper edges than that of zirconia specimens. Figures 3–5 show representative SEM images of the fracture interface after shear bond testing. For adhesive failure at the porcelain/gingiva-colored resin composite interface (Fig. 3), the debonded surface showed the same appearance as the airborne-particle abraded surface (see Fig. 2), and remnants of adhered material were not observed. An EST specimen in the PZB group exhibits adhesive failure at the porcelain-resin composite interface, and cohesive failure inside the porcelain (Fig. 4), thus illustrating the different appearance of the zirconia surface after airborne-particle abrasion. In addition, the similar appearance of the porcelain-coated zirconia surface before priming can be seen. SEM image of a debonded surface of an EST specimen from the CPB+Act group showed cohesive failure inside the porcelain, which can be covered with feldspathic porcelain (Fig. 5).
DISCUSSION

The present study examined the effects of various priming agents on shear bond strength of light-polymerized and photo/heat-polymerized gingiva-colored layering indirect resin composites to porcelain-coated zirconia ceramics. The results show that shear bond strength was affected by the type of priming agent. For CER and EST specimens, bond strength was highest in the CPB+Act group, among the five groups tested. Hence, the first null hypothesis, i.e., that five surface treatments would not yield differences in shear bond strengths between resin composite and zirconia framework, was rejected.

Silane activated by hydrolysis can bond hydroxyl groups on the surface of a ceramic substrate. In the hydrolysis step of silane to silanol, protonation of the alkoxyl group of silane is promoted under acidic conditions. In the CPB+Act group, a functional phosphate monomer (MDP) may have a role on the acid. Because formation of the siloxane network was facilitated by the acidic functional monomer, bond strengths between indirect resin composites and porcelain-coated zirconia ceramics were enhanced. This confirms the results of previous studies, which noted that a siloxane network was successfully formed between a resin composite and zirconia coated with feldspathic porcelain. In addition, the present failure mode assessment showed frequent cohesive failure within the porcelain in the CPB+Act group. The presence of feldspathic porcelain on the zirconia surface was supported by the XRD analysis in the present study. Thus, combined application of MDP and silane yields higher bond strength between gingiva-colored resin composite and porcelain-coated zirconia ceramics.

The second null hypothesis—that different resin composite materials would not yield differences in shear bond strengths between resin composite and zirconia framework—was also rejected. Bond strength was higher for the photo/heat-polymerized (EST) gingiva-colored indirect resin composite than for the light-polymerized (CER) gingiva-colored indirect resin composite in all groups. These results are consistent with those of previous studies of bonding between indirect resin composites and metal alloys, which found photo/heat-polymerized indirect resin composites provided higher bond strengths than did light-polymerized indirect resin composites, perhaps due to differences in the size of filler particles, the type of polymerization, and the mechanical properties of gingiva-colored indirect resin composites. reported that microtensile bond strengths between resin composites and resin-luting material were affected by improved mechanical properties caused by heat treatment. Heat treatment facilitates mobility of unused polymer groups in a rigid polymerized network and enhances radical mobility and polymerization rate. This would lead to superior cross-linking density and formation of long chains, thereby increasing the final degree of conversion. Additionally, increases in diametrical tensile strength, compressive strength, and hardness, as well as improved wear, were
observed when heat treatment was used for secondary polymerization\(^{20,21}\). Furthermore, the filler content of the present photo/heat-polymerized (EST) gingiva-colored indirect resin composite and light-polymerized (CER) gingiva-colored indirect resin composite is 92 and 73 wt\%, respectively. Therefore, the shear bond strength of Estenia C&B was higher than that of Ceramage owing to disparities in the mechanical properties of the two gingiva-colored indirect resin composites. Another likely explanation for this finding is that internal stresses were relieved by post-polymerization heat treatment. Increasing the degree of conversion with heat treatment would minimize distribution and contraction of polymerization by delaying excessive shrinkage.

Ferracane and Condon\(^{25}\) reported that adhesion between the resin matrix and fillers was improved when the stress at the filler/matrix interface was relieved by post-polymerization heat treatment. The superior bond strength between photo/heat-polymerized (EST) gingiva-colored indirect resin composites and zirconia coated with feldspathic porcelain was likely due to decreased stress at the interface between the gingiva-colored indirect resin composites and zirconia coated with feldspathic porcelain.

In the present study, CER and EST specimens in the CPB+Act and PLB groups yielded bond strengths greater than 10 MPa, the suggested threshold for clinically acceptable resin composite-ceramic and resin composite-metal bonds\(^{23,30}\).

This study had some limitations. The effects of cyclic mechanical and thermal loading on bond strength were not investigated in the present study. This limitation will be addressed in future studies of the effects of these parameters. In addition, the long-term clinical stability of bonding between gingiva-colored indirect resin composite and porcelain-coated zirconia ceramics is unknown. Clinical trials are necessary in order to validate the present materials and procedures before general use in clinical practice.

**CONCLUSIONS**

Within the limitations of the present in vitro study, the following conclusions can be drawn:

1. Combined application of a phosphate monomer (MDP) and silane (3-TMSPMA) enhanced initial bond strength of light-polymerized and photo/heat-polymerized gingiva-colored layering indirect resin composites to porcelain-coated zirconia ceramics.

2. The initial bond strength to porcelain-coated zirconia ceramics was higher for the photo/heat-polymerized gingiva-colored indirect resin composite (EST) than for the light-polymerized gingiva-colored indirect resin composite (CER).

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**CONFLICTS OF INTEREST**

The authors certify that they have no conflicts of interest.

**REFERENCES**

1. Piconi C, Maccagno G. Zirconia as a ceramic biomaterial. Biomaterials 1999; 20: 1-23.
2. Tinschert J, Zwez D, Marx R, Anusavice KJ. Structural reliability of alumina-, feldspar-, leucite-, mica- and zirconia-based ceramics. J Dent 2000; 28: 529-555.
3. Manicone PF, Rossi Ionnetti P, Raffaelli L. An overview of zirconia ceramics: basic properties and clinical applications. J Dent 2007; 35: 819-826.
4. Larsson C, Vult von Steyern P, Sunzel B, Nilner K. All-ceramic two- to five-unit implant-supported reconstructions. A randomized, prospective clinical trial. Swed Dent J 2006; 30: 45-53.
5. Sailer I, Philipp A, Zembic A, Ajetursuss BE, Hammerle CH, Zwahlen M. A systematic review of the performance of ceramic and metal implant abutments supporting fixed implant reconstructions. Clin Oral Implants Res 2009; 20: 4-31.
6. Larsson C, Vult von Steyern P. Five-year follow-up of implant-supported Y-TZP and ZTA fixed dental prostheses. A randomized, prospective clinical trial comparing two different material systems. Int J Prosthodont 2010; 23: 545-561.
7. Gunge H, Ogino Y, Kihara M, Tsukiyama Y, Koyano K. Retrospective clinical evaluation of posterior monolithic zirconia restorations after 1 to 3.5 years of clinical service. J Oral Sci 2018; 60: 154-158.
8. Strietzel FP. Patient’s informed consent prior to implant-prosthetic treatment: a retrospective analysis of expert opinions. Int J Oral Maxillofac Implants 2003; 18: 433-439.
9. Duncan JD, Swift EJ. Use of tissue-tinted porcelain to restore soft-tissue defects. J Prosthodont 1994; 3: 59-61.
10. Barzilay I, Irene T. Gingival prostheses—a review. J Can Dent Assoc 2003; 69: 74-78.
11. Bidra AS, Tischler M, Patch C. Survival of 2039 complete arch fixed implant-supported zirconia prostheses: a retrospective study. J Prosthet Dent 2018; 119: 220-224.
12. Coachman C, Salama M, Garber D, Calamita M, Salama H, Cabral G. Prosthetic gingival reconstruction in a fixed partial restoration. Part 1: introduction to artificial gingiva as an alternative therapy. Int J Periodontics Restorative Dent 2009; 29: 471-477.
13. Gardner FM, Stankewitz CG. Using removable gingival facades with fixed partial dentures. J Prosthet Dent 1982; 47: 262-264.
14. Cura C, Saraçolu A, Çötert HS. Alternative method for connecting a removable gingival extension and fixed partial denture: A clinical report. J Prosthet Dent 2002; 88: 1-3.
15. Greene PR. The flexible gingival mask: an aesthetic solution in periodontal practice. Br Dent J 1998; 184: 536-540.
16. Coachman C, Salama M, Garber D, Calamita M, Salama H, Cabral G. Prosthetic gingival reconstruction in fixed partial restorations. Part 3: laboratory procedures and maintenance. Int J Periodontics Restorative Dent 2010; 30: 19-29.
17. Reshad M, Cascione D, Aalam AA. Fabrication of the mandibular implant-supported fixed restoration using CAD/CAM technology: a clinical report. J Prosthet Dent 2009; 102: 271-278.
18. Zafiropoulos GG, Rebbe J, Thielen U, Deli G, Beaumont C, Hoffmann O. Zirconia removable telescopic dentures retained...
on teeth or implants for maxilla rehabilitation. Three-year observation of three cases. J Oral Implantol 2010; 36: 455-465.

19) Koizuka M, Komine F, Blatz MB, Fushiki R, Taguchi K, Matsumura H. The effect of different surface treatments on the bond strength of a gingiva-colored indirect composite veneering material to three implant framework materials. Clin Oral Implantol Res 2013; 24: 977-984.

20) Kubochi K, Komine F, Fushiki R, Yagawa S, Mori S, Matsumura H. Shear bond strength of a denture base acrylic resin and gingiva-colored indirect composite material to zirconia ceramics. J Prosthodont Res 2013; 61: 149-157.

21) Kitayama S, Nikaido T, Maruoka R, Zhu L, Ikeda M, Watanabe A, et al. Effect of an internal coating technique on tensile bond strengths of resin cements to zirconia ceramics. Dent Mater J 2009; 28: 446-453.

22) Fushiki R, Komine F, Blatz MB, Koizuka M, Taguchi K, Matsumura H. Shear bond strength between an indirect composite layering material and feldspathic porcelain-coated zirconia ceramics. Clin Oral Investig 2012; 16: 1401-1411.

23) Lung CY, Matinlinna JP. Aspects of silane coupling agents and surface conditioning in dentistry: an overview. Dent Mater 2012; 28: 467-477.

24) Aida M, Hayakawa T, Mizukawa K. Adhesion of composite to porcelain with various surface conditions. J Prosthet Dent 1995; 73: 464-470.

25) Muratomi R, Kamada K, Taira Y, Higuchi S, Watanabe I, Sawase T. Comparative study between laser sintering and casting for retention of resin composite veneers to cobalt-chromium alloy. Dent Mater J 2013; 32: 939-945.

26) Taira Y, Egoshi T, Kamada K, Sawase T. Surface modification with alumina blasting and H2SO4-HCl etching for bonding two resin-composite veneers to titanium. Eur J Oral Sci 2014; 122: 84-88.

27) Magne P, Malta DA, Enciso R, Monteiro-Junior S. Heat treatment influences monomer conversion and bond strength of indirect composite resin restorations. J Adhes Dent 2015; 17: 559-566.

28) Trujillo M, Newman SM, Stansbury JW. Use of near-IR to monitor the influence of external heating on dental composite photopolymerization. Dent Mater 2004; 20: 766-777.

29) Daronch M, Rueggeberg FA, De Goes MF. Monomer conversion of pre-heated composite. J Dent Res 2005; 84: 663-667.

30) Peutzfeldt A, Asmussen E. The effect of postcuring on quantity of remaining double bonds, mechanical properties, and in vitro wear of two resin composites. J Dent 2000; 28: 447-452.

31) Öztan M, Alander P, Vallittu PK, Huysmans MC, Kalk W. Effect of three surface conditioning methods to improve bond strength of particulate filler resin composites. J Mater Sci Mater Med 2005; 16: 21-27.

32) Ferracane JL, Condon JR. Post-cure heat treatments for composites: properties and fractography. Dent Mater 1992; 8: 290-295.

33) Thurmond JW, Barkmeier WW, Wilwerding TM. Effect of porcelain surface treatments on bond strengths of composite resin bonded to porcelain. J Prosthet Dent 1994; 72: 355-359.

34) Matsumura H, Yanagida H, Tanoue N, Atsuta M, Shimoo S. Shear bond strength of resin composite veneering material to gold alloy with varying metal surface preparations. J Prosthet Dent 2001; 86: 315-319.