The purpose of this study was to determine whether a system using a resin coating material (PRG Barrier Coat) with anticariogenic ability can effectively bond orthodontic brackets to human teeth. Resin-modified glass-ionomer cement system (Fuji Ortho LC, group 1) and resin composite cement systems (BeautyOrtho Bond) combined with a self-etching primer (group 2), with the resin coating material (group 3), and with the resin coating material after an organic acid etching agent (group 4) were used for bracket bonding. The mean shear bond strength (SBS) was significantly higher in group 1 than in groups 2, 3 and 4. Groups 2 and 4 exhibited a significantly higher mean SBS than group 3. The resin composite cement system combined with the resin coating material after the organic acid etching agent can serve as an alternative for orthodontic bracket bonding.

Keywords: PRG barrier coat, Beauty ortho bond, Orthodontic bracket, Dental bonding, Scanning electron microscopy

INTRODUCTION

White spot lesions (WSLs) are an undesirable but common side effect of fixed orthodontic appliances, eventually leading to dental caries if the process continues\(^8\). The reported prevalence of WSLs ranges widely from 2% to 96% with different epidemiological techniques\(^8\). WSLs appear around the orthodontic brackets as soon as one month after the start of treatment\(^3\).

To prevent the development of WSLs and caries beneath and around brackets, many types of orthodontic adhesives containing fluoride have been used, such as glass-ionomer cements (GICs), resin-modified glass-ionomer cements (RMGICs), and adhesive resins containing surface pre-reacted glass-ionomer (S-PRG) fillers\(^5\). Most fluorides are released within one day from GICs and the concentration of fluoride released decreases sharply to almost half in three days\(^8\). Fluoride-recharging into fluoridated adhesives is needed for continued release of fluoride ions. A resin composite cement (BOB, BeautyOrtho Bond, Shofu, Kyoto, Japan) contains S-PRG fillers that can continuously release and recharge fluoride ions\(^5\). S-PRG fillers also release Na\(^+\), BO\(_3\)\(^-\), Al\(^3+\), SiO\(_2\)\(^-\), and Sr\(^2+\), reduce WSLs and demineralization, check plaque formation, enhance remineralization, and inhibit microbial metabolism and growth\(^9\).

Recently, a resin coating material (PRG Barrier Coat, Shofu) containing S-PRG fillers has been developed for treatment of dentin hypersensitivity and exposed dentin surfaces in operative dentistry\(^10\). Some researchers have investigated the bond strength (BS) of tooth-coating materials bonded to tooth dentin, and have shown that resin-type materials exhibit a higher shear bond strength (SBS) than glass ionomer-type materials\(^11\). Their study raises the question of whether the resin coating material with anticariogenic properties can serve as a bracket bonding material.

The aim of this study was to compare the SBS of orthodontic brackets bonded with resin composite cement to enamel after different enamel surface treatments. The resin coating material, which has not been used in the bracket bonding system previously and have ability to prevent WSLs and caries, was incorporated into our protocol for cement system. The null hypothesis tested was that there were no significant differences in SBS between the bracket bonding systems using the resin coating material and the previous bracket bonding systems.

MATERIALS AND METHODS

This research protocol was approved by the Research Ethics Committee of The Nippon Dental University School of Life Dentistry at Niigata (ECNG-R-401). Priori power analysis showed that for one-way analysis of variance (ANOVA) with a power of 0.8, an effect size of 0.4, an alpha error probability of 0.05 and four groups, the total sample size required was 76 teeth, with a sample size of 19 teeth for each group.

Eighty-eight human premolars extracted for orthodontic reasons were collected and stored in 0.1% (wt/vol) thymol solution at 4°C prior to testing. The criteria for tooth selection included intact buccal enamel without cracks from extraction, caries, hypoplastic enamel, and previous application of chemical agents which were confirmed using medical and dental records. Before bracket bonding, the 88 teeth were cleaned with fluoride-free pumice paste (Ortho Teeth Cleaner, Shofu) and a rubber prophylactic cup (Merssage Cup No.15, Shofu) for 20 s, rinsed with a water spray, and dried with an oil-free air drier. Then 76 teeth were randomly selected.
selected from the 88 teeth and divided into four groups of 19.

This study used premolar metal brackets (Victory series, 3M Unitek, Monrovia, CA, USA) with a mean bracket base area of 9.94 mm². The information on the bracket base area was obtained from the manufacturer. Brackets were bonded to the teeth according to each manufacturer’s instructions. The orthodontic adhesives, resin coating material, dental etching agent and light-curing unit used in this study are listed in Table 1.

RMGIC system
In group 1, a 10% polyacrylic acid (Ortho Conditioner, GC, Tokyo, Japan) was applied with a sponge to buccal enamel of each tooth for 20 s, and the tooth was thoroughly rinsed with water for 10 s and accurately dried with compressed air. RMGIC (Fuji Ortho LC, GC) was applied to the bracket base. The bracket was placed on buccal enamel and pressed firmly into place to squeeze adhesive from the rim of the bracket base. Excess adhesive was removed with an explorer. The adhesive was light-cured as close as possible to the adhesive interface with a LED light curing device (Ortholux Luminous Curing Light Unit, 3M Unitek) for 20 s; 10 s mesially and 10 s distally. The LED light curing device possessed a constant intensity of 1,600 mW/cm² energy which cannot be changed in light curing process by the operator, a length of 430–480 nm and a peak of 455±10 nm.

The resin composite cement system combined with self-etching primer
In group 2, a self-etching primer (BeautyOrtho Bond self-etching primer, Shofu) was applied to buccal enamel for 10 s and gently blown off with an oil-free air drier for 5 s. The BOB was applied to the bracket base and the bracket was bonded to the self-etch enamel. Bracket placement and excess adhesive removal were performed in the same way as for group 1. The BOB was light-cured with the LED light curing device as close as possible to the adhesive interface for 20 s; 10 s mesially and 10 s distally.

The resin composite cement system combined with resin coating material
In group 3, a thin uniform layer of the resin coating material (PRG Barrier Coat, Shofu) was applied with a brush to buccal enamel. After 5 s, the buccal enamel was light-cured for 10 s with the LED light curing device. Bracket placement and excess adhesive removal, and light-curing of the BOB were performed in the same way as for groups 1 and 2, respectively.

The resin composite cement system combined with resin coating after organic acid etching agent
In group 4, the organic acid etching agent (Enamel Conditioner, Shofu) was applied to buccal enamel for 10 s, and the tooth was thoroughly rinsed and dried. The resin coating material was applied to and light-cured in the same way as for group 3, and then the bracket

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Table 1  Materials and light-curing unit used in this study

| Material                                      | Composition/Specification                                    | Lot No.  | Manufacturer          |
|-----------------------------------------------|------------------------------------------------------------|----------|-----------------------|
| Resin-modified glass-ionomer cement (Fuji ORTHO LC) | Orthodontic cleaning agent: Water, Polyacrylic acid         | 1710071  | GC, Tokyo, Japan      |
|                                               | Powder: Aluminosilicate glass                               | 1709041  |                       |
|                                               | Liqueid: Methacrylic acid ester, Polyacrylic acid, Water   | 1711101  |                       |
| Resin composite cement (BeautyOrtho Bond)     | Self-etching primer: Acetone, Water, Bis-GMA,              | 011806   |                       |
|                                               | Carboxylic acid monomer, Phosphoric acid monomer, etc.     |          |                       |
|                                               | Paste Viscos: Bis-GMA, TEGDMA, S-PRG filler, etc.           | 101908   |                       |
|                                               | Base: Glass powder, Water, Methacrylic acid monomer, etc.   | 041706   | Shofu, Kyoto, Japan   |
| Resin coating material (PRG Barrier Coat)     | Active: Phosphonic acid monomer, Methacrylic acid monomer,| 091711   |                       |
|                                               | Bis-MPEPP, Carboxylic acid monomer, TEGDMA, etc.            |          |                       |
| Organic acid etching material (Enamel Conditioner) | Etching agent: Organic acid, Thickner, etc.                | 71913    |                       |
| LED light curing unit (Ortholux Luminous Curing Light Unit) | Light-cure                                                | 658844   | 3M Unitek, Monrovia, CA, USA |
|                                               | Light source: LED                                           |          |                       |
|                                               | Light intensity: 1,600 mW/cm²                               |          |                       |
|                                               | Wavelength: 430–480 nm (a peak of 455±10 nm)                |          |                       |
|                                               | Light guide tip diameter: 8 mm                              |          |                       |

Bis-GMA, bisphenol A-glycidyl methacrylate; TEGDMA, triethylene glycol dimethacrylate; S-PRG filler, surface pre-reacted glass ionomer filler; Bis-MPEPP, 2,2’-Bis(4-methacryloxy polyethoxyphenyl) propane.
was bonded with BOB in the same way as for groups 1 through 3.

**Embedding and SBS measurement**
The crown and root of each tooth were separated using a diamond disk. The tooth crowns were embedded in a metal cylinder with self-curing resin (Provinice, Shofu). The buccal enamel surface was parallel to and projected above the brim of the specimen cylinder. A line connecting the upper and lower corners of the bonded bracket base at the right and left sides was parallel to the brim of the cylinder to apply a load in parallel to the curved buccal enamel surface. All the specimens were stored in distilled water (Japanese Industrial Standards; JIS K0557, A4) which was purified by automatic water distillation apparatus (RED260NC, ADVANTEC, Tokyo, Japan) at 37°C for 24 h. The SBS was measured using a universal testing machine (EZ-Test; Shimadzu, Kyoto, Japan), wherein the specimen was set so that the load was applied to the bracket base with a compressive shear force in the occlusogingival direction. The force needed to shear off the bracket was recorded in Newtons at a crosshead speed of 1.0 mm/min. The SBS (MPa) was then calculated by dividing the shear force by the bracket base area.

**Bond failure mode**
After bond failure, the bracket bases and buccal enamel were photographed using a stereomicroscope (Stemi 305, ZEISS, Tokyo, Japan) at 10× magnification. The photographs were stored on readable storage media on a computer. To avoid any examination bias, the photographs were coded by a person who was unrelated to this research. These coded photographs were examined by an investigator to evaluate the bond failure modes using the adhesive remnant index (ARI)\(^2\). One month later, the same examiner made a second evaluation of the ARI scores. The intraexaminer Kappa value was 0.94, thus demonstrating almost perfect intraexaminer agreement.

**Scanning electron microscope**
The remaining 12 premolars were divided into six groups of two based on the following treatments of tooth enamel: untreated enamel, and enamel treated with the 10% polyacrylic acid (Ortho Conditioner), self-etching primer (BeautyOrtho Bond self-etching primer), resin coating material (PRG Barrier Coat), organic acid etching agent (Enamel Conditioner) and the resin coating material after the organic acid etching agent. All the treatments followed the same protocols as for the SBS samples previously described. The root of each tooth was cut off and then the crown was separated into the buccal and lingual sides at the center fissure using a diamond disk. The enamel surface of the buccal side separated in each group were dehydrated, sputter-coated with gold using a sputter coat apparatus (DII-29010 SCTR Smart Coater, JEOL, Tokyo, Japan) at an acceleration voltage of 400 V for 1 min and examined under a scanning electron microscope (SEM; JSM-IT300LA, JEOL) at 350× magnification and an acceleration voltage of 10 kV or 15 kV.

**Statistical analysis**
Statistical analysis was performed using statistical analysis software (BellCurve version 2.12, SSRI, Tokyo, Japan). Means and standard deviations of SBS were calculated for each of the four groups. One-way repeated measures ANOVA and Tukey’s test were used to determine significant differences in the mean SBS between the four groups after confirming the normality of the distribution and the homogeneity of the variance. The Kruskal-Wallis and Steel-Dwass tests were used to determine significant differences in the distribution of ARI scores between the groups. All statistical tests were performed at a \(p<0.05\) level of significance.

**RESULTS**
Kolmogorov-Smirov and Leven tests confirmed the normality of the distribution and the homogeneity of the variance for the SBS, respectively.

Table 2 shows that the mean SBS was significantly higher in group 1 than in groups 2, 3 and 4 \((p=0.0011, <0.001, =0.0022,\) respectively). This table also shows that groups 2 and 4 exhibited significantly higher mean SBS than group 3 \((p<0.001, <0.001,\) respectively), and there was no significant difference between groups 2 and 4 \((p=0.9965\). The SBS of all specimens in groups 1, 2 and 4 reached 6 MPa, which is a minimum requirement for clinical use\(^3\), while the SBS for 2 (10.5%) of the 19 specimens in group 3 were less than 6 MPa.

| Group | Mean | SD  |
|-------|------|-----|
| Group 1 | 11.7 | 1.8 |
| Group 2 | 9.6* | 1.8 |
| Group 3 | 7.0 | 1.3 |
| Group 4 | 9.7* | 1.6 |

SD indicates standard deviation.
The same superscript letters indicate no significant difference among the groups.
Table 3  Adhesive remnant index (ARI) score

| Group   | 0 | 1 | 2 | 3 |
|---------|---|---|---|---|
| Group 1 | 1 | 8 | 9 | 1 |
| Group 2 | 1 | 8 | 6 | 4 |
| Group 3 | 16| 3 | 0 | 0 |
| Group 4 | 5 | 8 | 4 | 2 |

The ARI scores ranged from 0 to 3: 0, no adhesive left on the tooth; 1, less than half of the adhesive left on the tooth; 2, more than half of the adhesive left on the tooth; and 3, all the adhesive left on the tooth, with a distinct impression of the bracket base.

The same superscript letters indicate no significant difference among the groups.

As shown in Table 3, there was a significant difference in the distribution of ARI scores between group 3 and groups 1, 2, and 4 (p<0.001, <0.001 and =0.0013, respectively), but no significant differences between groups 1, 2 and 4 (1 vs 2; P=0.9653, 1 vs 4; P=0.4610, 3 vs 4; p=0.3114).

Figure 1 shows typical SEM images of the buccal enamel. Perikymata can be seen on the untreated buccal enamel (A). Enamel treated with 10% polyacrylic acid (B), self-etching primer (C) and organic acid etching agent (E) exhibited mild demineralization. Self-etching primer (C) showed milder demineralization than 10% polyacrylic acid (B) and organic acid etching agent (E). A film containing S-PRG fillers in a resin matrix was found on buccal enamel treated with resin coating material (D) after the organic acid etching agent (F).

**DISCUSSION**

The null hypothesis tested that there were no significant differences in SBS between the orthodontic bracket bonding system using resin coating material and the previous orthodontic bracket bonding systems was partially rejected. Some investigators have reported that the SBS of the resin composite cement (Transbond XT, 3M Unitek) system was comparable with that of the RMGIC system, while others have reported that it was significantly higher than that of the resin composite cement (BOB) system with the self-etching primer. Based on these previous findings, our result showing that the RMGIC system (group 1, 11.7 MPa) exhibited a significantly higher mean SBS than the BOB system combined with the self-etching primer (group 2, 9.6 MPa) might be expected. In both the RMGIC system and
BOB system combined with the self-etching primer, the chemical bonding mechanism between the adhesive and buccal enamel is considered to be superior to mechanical adhesion\textsuperscript{15,16}. This is consistent with our SEM findings that buccal enamel treated with 10% polyacrylic acid (Fig. 1B) and self-etching primer (Fig. 1C) were not very demineralized, as observed in previous studies\textsuperscript{7,14}. Our findings of these significant differences in SBS also suggest the possibility that the RMGIC system is more tightly bonded to enamel by chemical means than the BOB system combined with the self-etching primer.

A method applying a resin coating material (PRG Barrier Coat, Shofu) as the bonding material (BOB system combined with the resin coating material, group 3) was developed for bracket bonding and WSL prevention in this study. No literature was found that evaluated the BS of the resin coating material for these purposes. Therefore, our results are compared with the findings of Arita et al.\textsuperscript{11}, whose study was the only one on the SBS of the resin coating material.

In our study, the BOB system combined with the resin coating material (group 3, 7.0 MPa) had a significantly lower mean SBS than the RMGIC system (group 1, 11.7 MPa) and the BOB system combined with the self-etching primer (group 2, 9.6 MPa). Moreover, the SBS of all 19 specimens in groups 1 and 2 reached 6.0 MPa, while those for 2 (10.5%) of the 19 specimens in group 3 were below 6.0 MPa, suggesting that the resin composite cement (BOB) system combined with the resin coating material may not be adequate to achieve a clinically acceptable SBS compared with the BOB system combined with the self-etching primer. These results were partly inconsistent with the findings of Arita et al.\textsuperscript{11}, who reported that the resin coating material showed a significantly higher SBS than a GIC (Fuji VII, GC). The different results between their study and ours might be caused by discrepancies in the materials used. Tooth enamel was used as the adherend in this study, while their study employed tooth dentin. Our study employed RMGIC, which has a stronger mechanical strength than the GIC used in their study\textsuperscript{7}.

In this study, bond failure occurred more frequently at the enamel–adhesive interface in the BOB system combined with the resin coating material (group 3) than in the other systems. A significantly increased occurrence of bond failure at the enamel–adhesive interface was associated with low BS. These results are consistent with some studies that found that a smaller amount of adhesive remaining on enamel resulted in a lower BS\textsuperscript{17,18}.

A probable reason why the SBS of the BOB system combined with the resin coating material was significantly lower than the BOB system with the self-etching primer is that the components of the fillers and adhesive monomers were different. The resin coating material contains 25 wt% S-PRG filler, while the self-etching primer does not contain any fillers. The SEM images confirm that the resin coating material produces a film containing S-PRG fillers in a resin matrix (Figs. 1D and 1F), and the self-etching primer creates a mild demineralization layer without fillers (Fig. 1C), thus demonstrating that the amount of adhesive monomer could be relatively decreased in the resin coating material, as reported by Arita et al.\textsuperscript{11}. Some studies reported that the SBSs of the resin-type coating materials bonded to enamel and dentin were affected by the amount of adhesive monomer, but not by the amount of S-PRG fillers\textsuperscript{11,19}, while others showed that the SBS of orthodontic adhesives increased with increasing adhesive filler content\textsuperscript{20,21}. Therefore, in this study, more S-PRG filler and less adhesive monomer induced a lower chemical BS in the BOB system combined with the resin coating material than in the BOB system with the self-etching primer. Another probable reason is the difference in the pH values between the resin coating material and the self-etching primer\textsuperscript{17}. The pH values of the resin coating material and the self-etching primer were 3.8 and 2.8, respectively. The higher pH of the resin coating material suggests that its etching ability would be weaker than that of the self-etching primer resulting in a shallow etching pattern and insufficient penetration of the adhesive resin into the enamel. This weak mechanical interlocking may cause a low SBS in the BOB system combined with the resin coating material.

Another adhesive system was developed by combining the resin coating material after an organic acid etching agent (Enamel Conditioner, Shofu) as the bonding material (group 4). BOB system combined with the resin coating after the organic acid etching agent (group 4, 9.7 MPa) significantly increased the low mean SBS of the BOB system combined with the resin coating material (group 3, 7.0 MPa) to the level of the BOB system combined with the self-etching primer (group 2, 9.6 MPa). The organic acid etching agent was developed to improve BS by leaching calcium and phosphorus from the hydroxyapatite with a polyacrylic acid\textsuperscript{22}. This leaching probably enhanced the mild etching pattern caused by the acidic monomer contained in the resin coating material, promoted penetration of the adhesive monomer into the enamel, and increased the SBS of the BOB system combined with the resin coating material to a clinically acceptable level.

Wong et al.\textsuperscript{23} showed that although the organic acid etching agent had the weak enamel etching effects, this agent can modify enamel surface with less demineralization than the phosphoric acid etching agent, thus minimizing the unfavorable effects for bonding to tooth substrates. Yao et al.\textsuperscript{24} reported that there were no significant differences in a micro-tensile bond strength between the organic acid etching and the phosphoric acid etching agents. Therefore, the organic acid etching agent was used instead of the phosphoric acid etching agent in this study.

SEM images verified this supposition, showing that the adhesion promoter produced the same degree of enamel demineralization as 10% polyacrylic acid. The polyacrylic acid contained in the adhesion promoter appeared to form a polymeric layer on enamel, thus inducing an increase in the SBS of the resin coating
material. This speculation is supported by Es-Souni et al., who reported that the polymeric layer on enamel after polyacrylic acid conditioning could enhance the BS of GICs.

CONCLUSION

The resin composite cement system combined with the resin coating material after the organic acid etching agent was comparable to that combined with the self-etching primer in SBS, and therefore could be used as an adhesive for orthodontic bracket bonding.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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REFERENCES

1) Manfred L, Covell DA, Crowe JJ, Tufekci E, Mitchell JC. A novel biomimetic orthodontic bonding agent helps prevent white spot lesions adjacent to brackets. Angle Orthod 2013; 83: 97-103.

2) Heymann GC, Grauer D. A contemporary review of white spot lesions in orthodontics. J Esthet Restor Dent 2013; 25: 85-95.

3) Hochli D, Hersberger-Zurfluh M, Papageorgiou SN, Eliades T. Intervention for orthodontically induced white spot lesions adjacent to brackets. Angle Orthod 2013; 83: 122-133.

4) Millett DT, Cattanach D, McFadzean R, Pattison J, McColl J. Laboratory evaluation of a compomer and a resin-modified glass ionomer cement for orthodontic bonding. Angle Orthod 1999; 69: 58-64.

5) Han L, CV E, Li M, Niwano K, Ab N, Okamoto A, et al. Effect of fluoride mouth rinse on fluoride releasing and recharging from aesthetic dental materials. Dent Mater J 2002; 21: 285-295.

6) Bishara SE, Ostby AW, Laffoon JF, Warren J. Shear bond strength comparison of two adhesive systems following thermocycling. A new self-etch primer and a resin-modified glass ionomer. Angle Orthod 2007; 77: 337-341.

7) Zhang L, Tang T, Zhang ZL, Liang B, Wang XM, Fu BP. Improvement of enamel bond strengths for conventional and resin-modified glass ionomers: acid-etching vs. conditioning. J Zhejiang Univ Sci B 2013; 14: 1013-1024.

8) Chatzistavrou E, Elidea T, Zinelis S, Athanasiou AE, Eliades G. Fluoride release from an orthodontic glass ionomer adhesive in vitro and enamel fluoride uptake in vivo. Am J Orthod Dentofacial Orthop 2010; 137: 458.e1-e8.

9) Wiegand A, Buchalla W, Attin T. Review on fluoride-releasing restorative materials—fluoride release and uptake characteristics, antibacterial activity and influence on caries formation. Dent Mater 2007; 23: 343-362.

10) Ikemura K, Tay FR, Endo T, Pashley DH. A review of chemical-approach and ultramorphological studies on the development of fluoride-releasing dental adhesives comprising new pre-reacted glass ionomer (PRG) fillers. Dent Mater J 2008; 27: 315-339.

11) Arita S, Suzuki M, Kazama-Koide M, Shinikai K. Shear bond strengths of tooth coating materials including the experimental materials contained various amounts of multi-ion releasing fillers and their effects for preventing dentin demineralization. Odontology 2017; 105: 426-436.

12) Goto S, Hasegawa Y, Miyagawa Y, Endo T. Effects of contact compressive force on bracket bond strength and adhesive thickness. J Orofac Orthop 2020; 81: 79-88.

13) Reynolds IR. A review of direct orthodontic bonding. Br J Orthod 1975; 2: 71-78.

14) Endo T, Ozoe R, Shinkai K, Aoyagi M, Kurokawa H, Katoh Y, et al. Shear bond strength of brackets rebonded with a fluoride-releasing and re-charging adhesive system. Angle Orthod 2009; 79: 564-570.

15) Yassaei S, Davari A, Goldani Moghadam M, Kamaei A. Comparison of shear bond strength of RMGI and composite resin for orthodontic bracket bonding. J Dent (Tehran) 2014; 11: 282-289.

16) Endo T, Ishida R, Komatsuzaki A, Sanpei S, Tanaka S, Sekimoto T. Effects of long-term repeated topical fluoride applications and adhesion promoter on shear bond strengths of orthodontic brackets. Eur J Dent 2014; 8: 431-438.

17) Münchow EA, da Silva AF, da Silveira Lima G, Wolff T, Barbosa M, Ogliari FA, et al. Polypropylene glycol phosphate methacrylate as an alternative acid-functional monomer on self-etching adhesives. J Dent 2015; 43: 94-102.

18) Shukla C, Maurya R, Jain U, Gupta A, Garg J. Moisture insensitive primer: a myth or truth. J Orthod Sci 2014; 3: 132-136.

19) Ikemura K, Tay FR, Kouro Y, Endo T, Yoshiyama M, Miyai K, et al. Optimizing filler content in an adhesive system containing pre-reacted glass-ionomer fillers. Dent Mater 2003; 19: 137-146.

20) Faltermeier A, Rosentritt M, Faltermeier R, Reicheneder C, Müssig D. Influence of filler level on the bond strength of orthodontic adhesives. Angle Orthod 2007; 77: 494-498.

21) Inatomi K, Saito H, Endo T. Bond strength of indirect bonded brackets in orthodontic adhesives with different viscosities. Dent Mater J 2021; 40: 439-445.

22) Es-Souni M, Fischer-Brandies H, Zaporojshenko V, Es-Souni M. On the interaction of polyacrylic acid as a conditioning agent with bovine enamel. Biomaterials 2002; 23: 2871-2878.

23) Wong J, Taumoto A, Fischer NG, Baruth AG, Barkmeier WW, Johnson EA, et al. Enamel etching for universal adhesives: Examination of enamel etching protocols for optimization of bonding effectiveness. Oper Dent. 2020; 45: 80-91.

24) Yao C, Ahmed MH, Yoshihara K, Merceles B, Parisse Gré C, Van Landuyt K, et al. Bonding to enamel using alternative Enamel Conditioner/etchants. Dent Mater 2019; 35: 1415-1429.