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Evaluation of Marginal and Internal Integrity of Modified Resin-Bonded Fixed Partial Dentures: An *In Vitro* Study

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Purpose: The purpose of this study was to evaluate the microleakage of various types of resin-bonded fixed partial dentures (RBFPDs) after artificial aging.

Materials and Methods: Forty models with missing first molar were fabricated using artificial resin teeth and were divided into four groups: Group A, conventional RBFPDs design; Group B, modified RBFPDs design; Group C, assembled 3-piece RBFPDs design; and Group D, assembled 3-piece RBFPDs with different occlusal rest positions. Half of the specimens underwent chewing simulation process (240,000 cycles, 50 N load, 1.7 Hz) and thermocycling (temperatures 5°C~55°C, dwelling time 30 seconds) and the remaining 20 specimens didn't receive any treatment. All the specimens were immersed in 2% methylene blue solution for 24 hours to evaluate microleakage, and were sectioned at the middle part of abutment teeth. To evaluate the microleaskage, a dye penetration was calculated.

Result: With artificial aging, cyclic loading and thermocycling, a 3-piece RBPFD and a 2-piece RBPFD using original tooth undercuts have significantly lower microleakge ($P<0.05$) compared to the conventional design of RBPFD and modified RBPFD.

Conclusion: Within the limit of this experiment, the assembled RBFPDs exhibited a smaller microleakage than the conventional RBFPDs, implying that the assembled RBFPDs can be more effective for reducing the dislodgement of the RBFPDs.

Key Words: Artificial aging; Denture, partial, fixed, resin-bonded; Microleakage

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Introduction

Resin-bonded fixed partial dentures (RBFPDs) have been noted as an alternative to conventional restorations as a minimally invasive restorative approach[1]. Although RBFPDs is featured by a relatively small amount of tooth removal, no need for anesthesia and low manufacturing cost, it has disadvantages such as clinical failure due to debonding of the prosthesis, secondary caries, and fracture of the prosthesis[2]. In particular, debonding is the most common cause of failure in RBFPDs[2]. In order to improve the retention of the prosthesis, sandblasting, electrochemical etching, chemical etching, silica coating, and Tin plating have been introduced[3]. Despite these efforts, however, RBFPDs showed clinically unsatisfactory results and thus various designs of RBFPDs were devised[4]. Recently, the assembled RBFPDs have been developed to reduce the amount of tooth reduction by using existing tooth undercuts and to prevent the debonding of the prosthesis at function by having components with different path of insertion.

Schillingburg et al.[5] found that retention and resistance were important in addition to adhesion of cement to prevent debonding of prostheses. The retention is defined as the force that prevents the prostheses from being removed along the insertion or longitudinal axis of the tooth and the resistance is the force that prevents the prostheses from falling out when the vertical or oblique force or occlusal force were exerted on the prostheses[5]. There have been many studies comparing the retention of prostheses using a universal testing machine in order to evaluate the design of resin-bonded fixed partial dentures[1]. However, few studies so far verified the dislodgement resistance and microleakage of RBFPDs fixed using a tooth undercut and resin cement.

The purpose of this study was to evaluate the dislodgement resistance according to the design of the RBPFD by measuring and comparing the degree of microleakage between the teeth and the RBPFD after mechanical loading and thermocycling.

Materials and Methods

Second premolar and second molar (Trubyte, Dentsply, PA, USA) were placed in resin (Vertex Self-Curing, Zeist, The Netherlands) assuming loss of the first molar in the mandibular left side. Thereafter, 40 blocks were placed at the same position using a silicon index, and the specimens were divided into 4 groups according to the RBFPD design. Each group was prepared as follows. Group A had the chamfer margins above the cemento-enamel junction (CEJ) 1 mm distal to the lingual sides of the second premolar and the mesial to the lingual sides of the second molar[6]. The occlusal rest seat was formed at the distal part of the second premolar and the mesial part of the second molar[6]. Group B had the chamfer margins above the CEJ 1 mm distal to the lingual sides of the second premolar and the mesial to the lingual sides of the second molar[6]. The occlusal rest seat was formed at the mesial part of the second premolar and the distal part of the second molar. Group C had an occlusal rest seat on the distal part of the second premolar and the mesial part of the second molar. Group D had an occlusal rest seat on the mesial portion of the second premolar and the distal portion of the second molar. Following the preparation, silicone impression material (Imprint II Garant; 3M ESPE, St. Paul, MN, USA) was used to make an impression of the specimens. A gypsum model (Snow Rock; Dk Mungyo, Gimhae, Korea) was constructed using the impression material. Then nickel-chromium alloy prostheses were fabricated according to each design and cemented with Panavia 2.0 F (Kuraray, Osaka, Japan) (Fig. 1). In half of the completed prostheses, thermocycling and mechanical loading (240,000 mechanical loads of 50 N and 1,600 thermo-cycles for 30 seconds with distilled water between 5°C and 55°C) were applied (Fig. 2)[7]. After

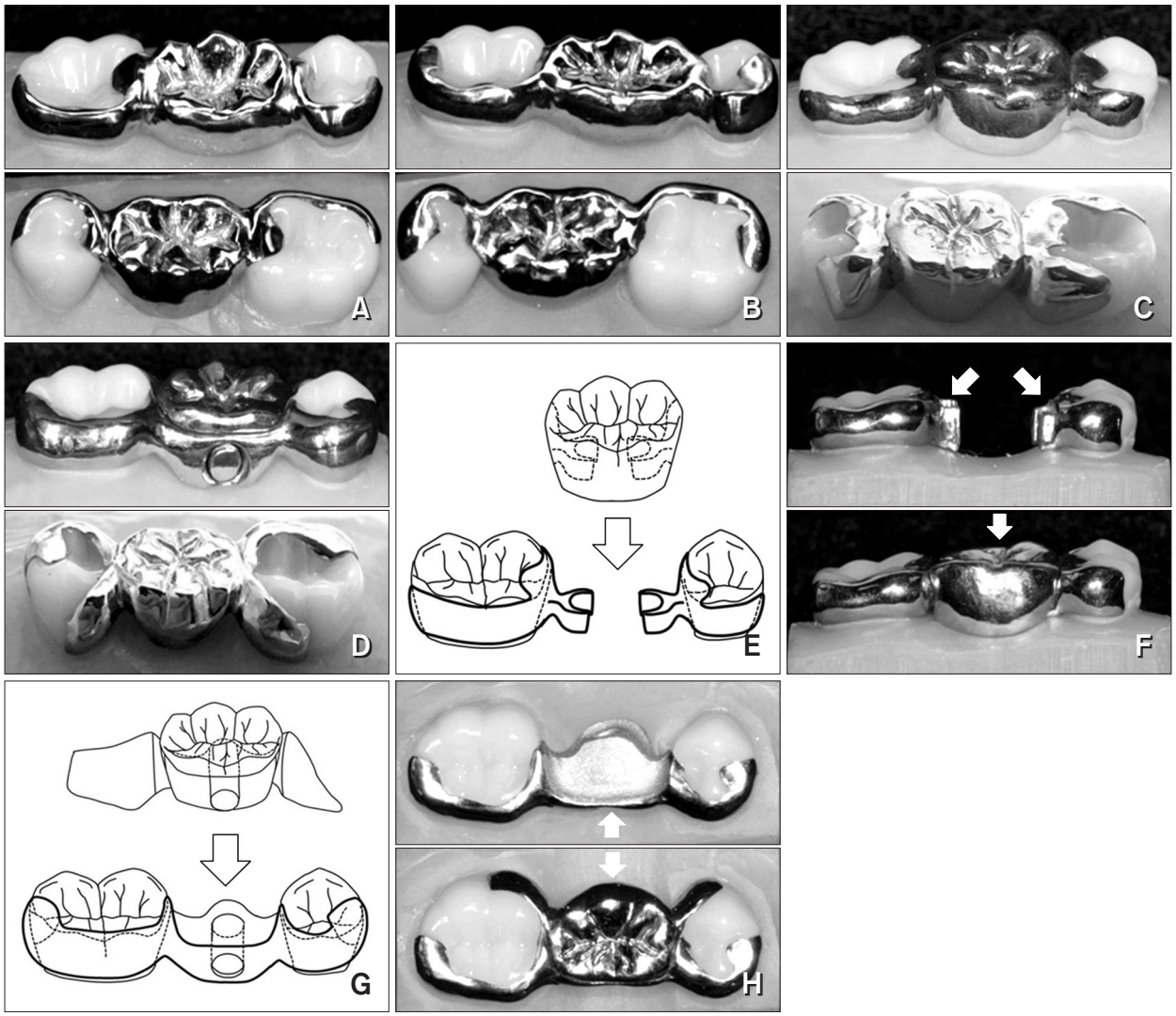

Fig. 1. Lingual and buccal aspects of resin-bonded fixed partial dentures (RBFPDs) design in this experiment. (A) Conventional RBFPD; (B) modified RBFPD; (C) 3-piece RBFPD; (D) 2-piece RBFPD; (E) schematic representation in 3-piece RBFPD; (F) two retention parts and middle pontic part in 3-piece RBFPD; (G) schematic representation in 2-piece RBFPD; (H) lingual retention part and buccal pontic part in 2-piece RBFPD. Arrows indicate the paths of insertion for each part.

artificial aging, all specimens were immersed in 2% methylene blue solution for 24 hours to evaluate microleakage, and then embedded in resin (Vertex Trayplast NF, Zeist, The Netherlands). The middle parts of the second premolar and second molar were cut in buccal-lingual direction with a cutting machine (Diamond saw; HY Inc., Incheon, Korea) and the degree of penetration was observed with a measuring microscope (Olympus BX 51; Olympus, Tokyo, Japan) at the 12.5× and 40× magnifications (Fig. 3). The length of the stained area was divided by the overall length of the prosthesis and then multiplied by 100 to calculate the percentage of dye penetration[8]. Kruskal-Wallis test and Mann-Whitney test with Bonferroni correction were used to determine any statistically significant difference (α=0.05).

Result

Without artificial aging, there was no significant difference between all groups (P>0.05) in comparison

of microleakages in both abutments (Table 1). With artificial aging, in the molar abutments, the conventional RBFPDs (61.49%±7.24%) showed the greatest value and the 2-piece RBFPDs (33.66%±9.08%) showed the smallest value (P=0.002). In the premolar abutments, the modified RBFPDs (66.55%±6.79%) showed the largest value and 3-piece RBFPDs (31.81%±5.25%) showed the smallest value (P=0.001). However, there were no significant differences between the two groups in terms of the conventional and modified RBFPDs, 3-piece and 2-piece RBFPDs (P>0.05) (Table 1).

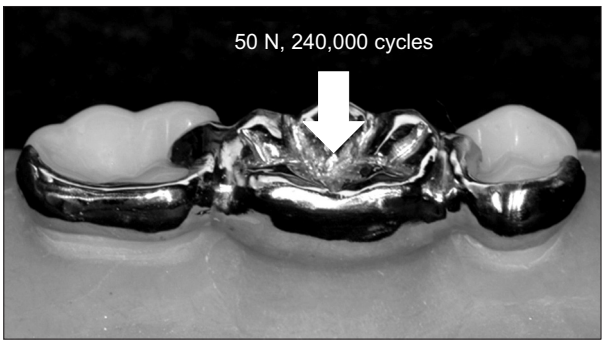

Fig. 2. Mechanical load of 50 N during 240,000 cycles in a dental chewing simulator.

Discussion

RBFPDs have been noted as an alternative to conventional restorative methods with minimal restoration of tooth damage[1]. However, it is not clinically satisfactory compared to conventional restoration methods. Hussey et al.[9] reported in a prospective study of 400 RBFPDs that there were one or more debonding of 25% of total restorations

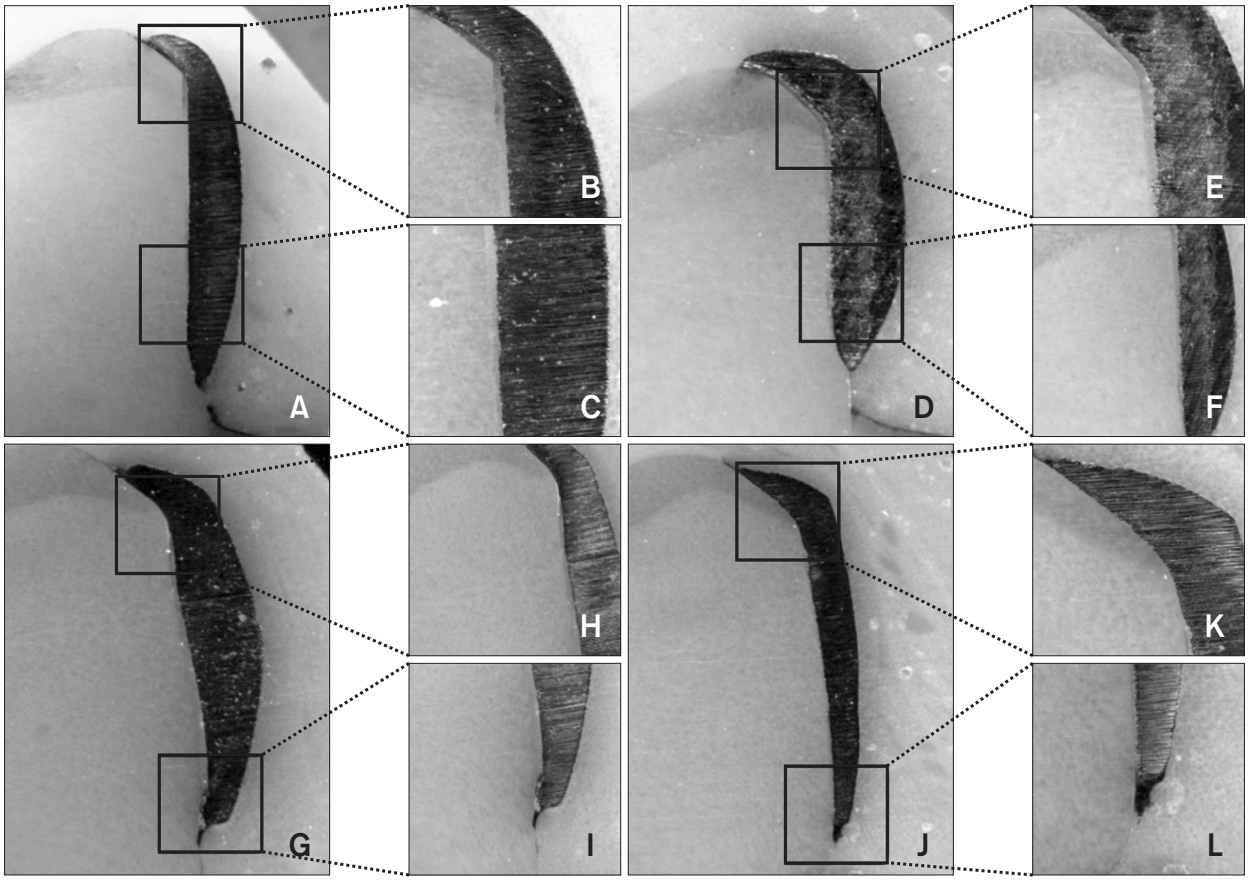

Fig. 3. Dye penetration of methylene blue to a prosthesis-tooth gap the abutment. (A~C) Conventional resin-bonded fixed partial denture (RBFPD); (D~F) modified RBFPD; (G~I) 3-piece RBFPD; (J~L) 2-piece RBFPD. A, D, G, and J: methylene blue staining ×12.5; B, C, E, F, H, I, K, and L: methylene blue staining ×40.

Table 1. Mean and standard deviation of penetration of methylene blue with/without artificial aging as percentage of each group

Abutment	Group				P-value
	Conventional RBFPD	Modified RBFPD	3-Piece RBFPD	2-Piece RBFPD	
Non aging					
Molar	17.20±2.21[a]	18.00±3.98[a]	20.91±4.28[a]	18.14±3.81[a]	0.569
Premolar	19.00±4.78[a]	17.55±5.53[a]	16.00±2.33[a]	13.81±2.50[a]	0.121
Aging					
Molar	61.49±7.24[a]	58.78±6.58[a]	35.90±7.77[b]	33.66±9.08[b]	0.002
Premolar	57.89±9.48[a]	66.55±6.79[a]	31.81±5.25[b]	37.37±2.26[b]	0.001

Values with the same superscript in each row are not significantly different (P>0.05).

RBFPD: resin-boned fixed partial denture.

after an average of 10.7 months after cementation of prostheses. Boening[10] reported that debonding of RBFPDs was more frequent in the posterior region than in the anterior region. This is attributed to the fact that the conventional RBFPDs did not resist the occlusal forces of the posterior teeth[10].

In this study, we tried to evaluate the failure of RBFPDs in the posterior region where the failure is more frequent. For this purpose, we measured the microleakage between tooth and prosthesis after applying a load of 50 N, which is equivalent to the average masticating power of adult, to 240,000 times[7]. According to the results of this study, there was not significant different between specimens without artificial aging treatment. Therefore, the difference in degree of dye penetration in artificial aging treated specimens can be considered to depend on the design of the prosthesis.

After cyclic loading and thermocycling, the conventional and modified RBFPDs showed more dye penetration than the 3- or 2-piece RBFPDs. These results in conventional and modified RBFPDs may be because the prosthesis is in contact only at the lingual side and the support is only at the occlusal rest during the vertical cyclic load of chewing simulator. On the other hand, 3-piece and 2-piece RBFPDs were fixed together at the buccal and lingual sides. In this study, it was found that the utilization of tooth undercuts in case of 3- or 2-piece RBFPDs had the advantage of reducing the amount of tooth reduction, but a disadvantage like periodontal problems due to over contoured restoration can be occured[6].

This study has the limitation that artificial teeth were used instead of natural teeth, which makes it impossible to directly compare with the actual environment in the oral cavity. In addition, the cause of the dislodgement of the oral prosthesis is physiological exercise of the natural teeth in addition to the action of the occlusal force, but this experiment does not reflect this. Additional research involving these factors will be needed.

Within the limits of this study, 3- or 2-piece RBFPDs designs showed lower microleakage than conventional RBFPDs after artificial aging. Therefore, it is considered that the assembled RBFPDs can be more effective for reducing the microleakage of the RBFPDs.

Conclusion

Within the limits of this study, 3- or 2-piece RBFPDs designs showed lower microleakage than conventional RBFPDs after artificial aging. Therefore, it is considered that the assembled RBFPDs can be more effective for reducing the microleakage and dislodgement of the RBFPDs.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgement

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