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Original Article

Microleakage in different primary tooth restorations

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Abstract

Background: Microleakage may cause tooth sensitivity, secondary caries, discoloration and even failure of the restoration. In order to overcome these potential problems, materials that are able to bind to the tooth structure have been developed, such as composite resin and glass ionomer cement. The purpose of the study was to compare microleakage arising from amalgam (Am), composite resin (CR), glass ionomer (GI), Ketac-Silver (KS), and GI filling with banding (GI+B) when these materials are used for class II restoration of a primary molar.

Methods: Fifty primary molars were collected and class II cavities were prepared on each tooth. The teeth were randomly divided into five groups (Am, CR, GI, KS, and GI+B), each of which received a different material as part of the restoration. The restored teeth then underwent 100 cycles of thermocycling that consisted of 55°C for 30 seconds, 19°C for 20 seconds, and 5°C for 30 seconds. The teeth were then immersed in 0.5% basic fuchsin solution for 24 hours. Afterwards, the teeth were embedded and sectioned mesiodistally through the center of each restoration. Dye penetration associated with the occlusal and cervical margins of each restoration was then assessed.

Results: Cervical leakage was greater than occlusal leakage in the CR, GI and KS groups ($p < 0.05$). When leakage on occlusal margin was examined, however, the Am group showed greater leakage than the CR, GI, and GI+B groups ($p < 0.05$). When leakage on the cervical margin was examined, the Am group showed greater leakage than the GI and GI+B groups, while the KS group showed greater leakage than the GI+B group ($p < 0.05$).

Conclusion: Restorations using GI and GI+B indicated that these materials performed better than the other materials in this study overall. However, none of the materials were entirely devoid of leakage.

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Keywords: banding; class II restoration; microleakage; primary molar

1. Introduction

The aim of caries restoration is to prepare the cavity, to remove carious tissue and bacteria, to fill the resulting cavity with an appropriate restorative material, to restore the esthetics of the tooth, to restore chewing functionality, and to prevent the recurrence of caries. Microleakage is the movement of bacteria, liquid, and chemical substances between restoration and tooth.[1] Such leakage will result in the discoloration/staining of the restoration, produce tooth sensitivity, aid in the recurrence of caries, and, finally may lead to failure of the restoration.[2,3] As a result of the above, the amount of microleakage that takes place is an important consideration when selecting a restorative material.

The main cause of microleakage is poor adaptation between the restorative material and the original tooth structure. Another secondary cause is volume change in the restorative material due to cohesive shrinkage during restoration and oral thermal changes after restoration; such volume changes will

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cause a gap to appear between the restorative material and tooth that allows microleakage to occur.[4] The methods available to evaluate microleakage include direct visual examination,[5,6] microscopic examination,[7,8] scanning electron microscopic examination,[9–11] air pressure,[12] dye penetration,[13–16] the use of a chemical tracer,[17,18] the use of radioactive isotope tracer,[19–21] neutron activation analysis,[22] electrochemical methodologies,[23] measuring bacteria penetration,[24] the artificial caries method,[25] and three-dimensional image analysis.[26] Among these methods, using sectioning allows the examiner to see only part of the leakage and not the whole course of leakage. By contrast, using air pressure, neutron activation analysis, an electrochemical methodology, and measuring bacteria penetration does allow the volume of leakage to be measured but does not allow the course of leakage to be determined. Both the dye penetration approach and the chemical tracer method have the merits of easy manipulation, easy analysis of the results and no need for expensive instrumentation. As a result, these approaches are widely accepted as methods when studying the microleakage of dental restorative materials.

In order to overcome the problems of microleakage, some direct bonding materials have been developed including composite resin (CR), glass ionomer (GI) cement and alloy reinforced GI cement. Information regarding microleakage by primary tooth restorations is limited.[27–30] The purpose of the present study was to compare the microleakage of various different restorative materials when they are used to treat class II cavities of primary molar teeth.

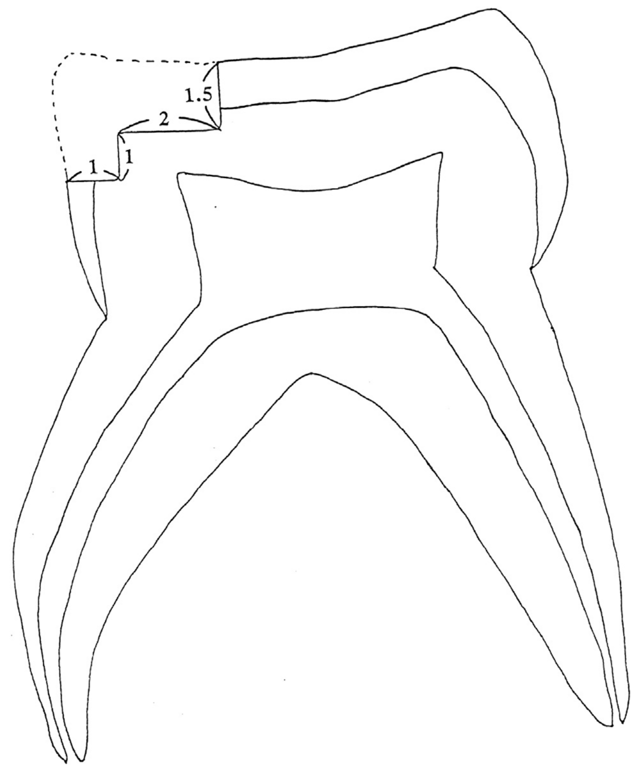

Fig. 1. The dimensions of the cavity preparation: occlusal cavity depth: 1.5 mm, occlusal cavity floor mediodistal width: 2 mm; proximal box mediodistal width: 1 mm, axial wall height: 1 mm. The cervical margin in the proximal box must be on sound enamel. All the cavosurface line angles were butt-jointed and the axiopulpal line angle was rounded.

2. Methods

2.1. Sample selection and cavity preparation

Fifty primary molar teeth were collected at Taipei Veterans General Hospital after the approval of patient's guardians. The teeth used for the study were children's exfoliated primary molars. The collected teeth were cleaned to remove any debris and surrounding soft tissue and they were then stored in normal saline at room temperature. The criteria for tooth selection for this study were that no or minimal caries was present on at least one proximal surface of each tooth. On each tooth a Class II cavity was prepared using a No. 330 carbide bur, and copious water cooling involving one proximal surface that had no or minimal caries. The size of the cavity was buccolingual width: 2 mm; occlusal cavity depth: 1.5 mm, occlusal pulpal floor mediodistal width: 2 mm; proximal box mediodistal width: 1 mm, and axial wall height: 1 mm. (Fig. 1). The cervical margin in the proximal box had to be on enamel. All the cavosurface line angles were butt-jointed while the axiopulpal line angle was rounded. The prepared teeth were randomly divided into five groups with 10 teeth in each group. These groups were amalgam (Am), CR, GI, Ketac-Silver (KS), and GI filling with banding (GI+B), each of which were used to create the filling. The list of materials used is shown in Table 1.

2.2. Restoration procedures

2.2.1. Am group

After the cavity was cleaned and dried by compressed air, two layers of Copalite were applied. Matrix band and the retainer were mounted on the tooth. Am was mixed, filled, and condensed into cavity following the manufacturer's instructions. The occlusal morphology of the restoration was burnished and the restored teeth were stored in normal saline for 24 hours. Finally, the teeth were polished and then returned to normal saline for storage.

2.2.2. CR group

After the cavity had been cleaned with water and dried with compressed air, the cavity was etched with 37% phosphoric acid gel for 60 seconds followed by rinsing with water for 30 seconds. After etching, the cavity was dried with compressed air for 15 seconds, and then a bonding agent (Scotchprep dentin primer) was applied onto the dentin for 60 seconds. The bonding agent was dried by compressed air for 15 seconds, then a bonding agent (Scotchbond 2 light-curing dental adhesive) was applied to the whole cavity. The cavity with bonding agent was light-cured for 20 seconds. A translucent matrix band and retainer were mounted on the tooth. CR was introduced and cured using the incremental method (Fig. 2). The cured restoration was finished and polished 15 minutes later. A layer of dentin bonding agent

Table 1
Restorative materials used in this study.

Restorative material	Product name	Manufacturer
Amalgam	Valiant-Ph.D.	L.D. Caulk Division, Dentsply International Inc., Milford, DE, USA
Composite resin	P-50	3M Dental Product, St Paul, MN, USA
Dentine bonding system	Scotchprep dentin primer Scotchbond 2 light curing dental adhesive	3M Dental Product, St Paul, MN, USA
Glass ionomer cement	GC Fuji I & GC Fuji II	GC Corp., Tokyo, Japan
Alloy-reinforced glass Ionomer	ESPE Ketac-Silver Aplicap	ESPE. Gmbh & Co., Seefeld, Oberbay, Germany
Band[a]	Ion Ni-Chro crowns	3M Dental Product, St Paul, MN, USA

[a] The band was made by trimming off the occlusal table and the cervical constriction of an Ion Ni-Chro crown.

(Scotchbond 2 light-curing dental adhesive) was then applied onto all surfaces of the restoration and light-cured for 20 seconds. The tooth was then returned to normal saline for storage.

2.2.3. GI group

After the cavity had been cleaned with water and dried by compressed air, the cavity was conditioned with Ketac-conditioner for 10 seconds, and then the cavity was rinsed with water for 30 second followed by limited drying by compressed air. A translucent matrix band and retainer were mounted on the tooth. gi cement (Fuji II) was mixed and introduced following the manufacturer's instructions. The matrix band was removed 5 minutes later and two layers of cocoa butter were applied over restoration. This was followed by the restored tooth being stored in normal saline. After 24 hours, the restoration was finished and polished. A layer of dentin bonding agent (Scotchbond 2 light-curing dental adhesive) was applied onto all of the restoration's surface and light-cured for 20 seconds. The tooth was then returned to normal saline for storage.

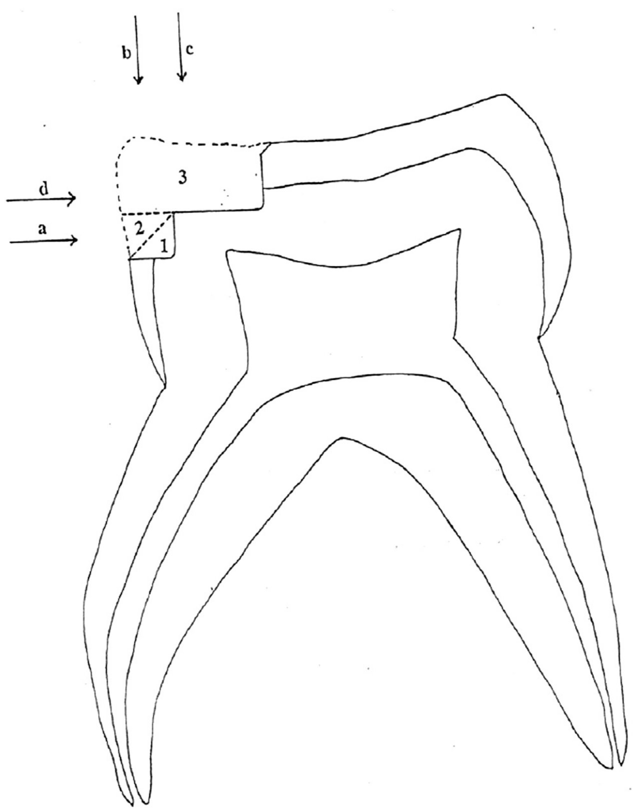

Fig. 2. The incremental technique for composite resin restoration. 1: First increment of resin from the axiopulpal line angle to the cervical margin, which was then light cured for 20 seconds; the arrow (a) shows the direction of light curing. 2: Second increment of resin to level of the occlusal pulpal floor, which was then light cured for 20 seconds; arrow (b) shows the direction of light curing. 3: Third increment of resin to complete fill of the cavity, which was then light cured for 40 seconds; arrow (c) shows the direction of light curing and arrow (d) shows the final direction of light curing for 20 seconds.

2.2.4. KS group

After the cavity had been cleaned with water and dried by compressed air, the cavity was conditioned with Ketac conditioner for 10 seconds. Next, the cavity was rinsed with water for 30 seconds followed by limited drying by compressed air. A translucent matrix band and retainer were mounted on the tooth (Fig. 3). KS was mixed and introduced following the manufacturer's instructions. The matrix band was removed 5 minutes later, and two layers of cocoa butter were applied over the restoration; the restored tooth was then stored in normal saline. After 24 hours, the restoration was finished and polished. A layer of dentin bonding agent (Scotchbond 2 light-curing dental adhesive) was applied onto all the surface of the restoration and light-cured for 20 seconds. The tooth was then returned to normal saline for storage.

2.2.5. GI+B group

An Ion Ni-Chro crown (3M Company) with proper trimming was cemented to the primary molar following cavity preparation and conditioned with Ketac-conditioner. GI cement (Fuji II) was mixed and introduced following the manufacturer's instructions. Two layers of cocoa butter were applied over restoration, and then the restored tooth was stored in normal saline. After 24 hours, the restoration was finished and polished. A layer of dentin bonding agent (Scotchbond 2 light-curing dental adhesive) was applied on all the surfaces of the restoration and light-cured for 20 seconds. The tooth was then returned to normal saline for storage.

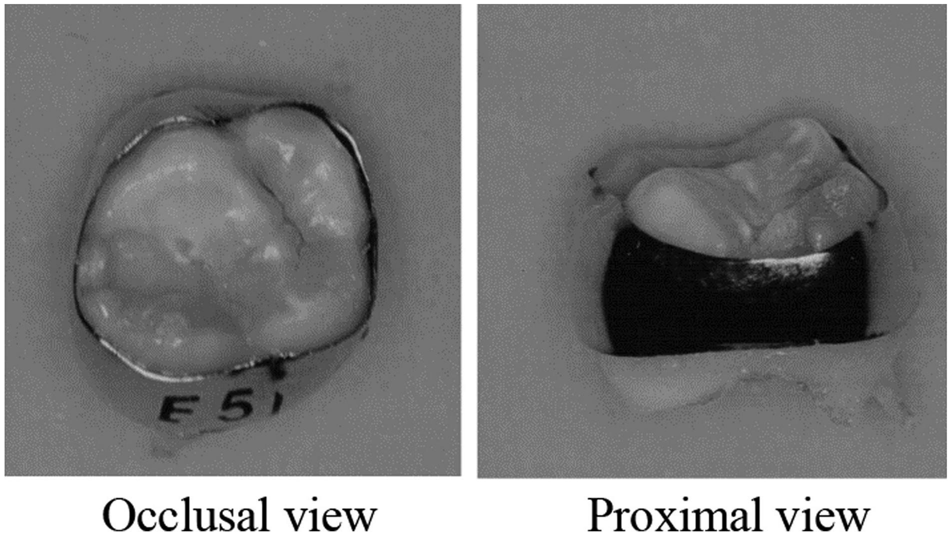

Fig. 3. The finished band on the tooth. The finished band must not cover the occlusal table of the tooth and must completely cover the cervical margin of the proximal box of the cavity.

2.3. Thermocycling, dye penetration, and grading

After all the restorations had been completed, the restored teeth were subjected to 100 cycles of thermocycling (55°C, 30 seconds; 19°C, 20 seconds; 5°C, 30 seconds). After thermocycling, all the tooth surfaces except the restoration and a 1 mm zone adjacent to the restoration's margins were covered with two coats of nail varnish. The root apices were sealed with green compound. The coated teeth were then immersed in a 0.5% basic fuchsin dye solution (Certistain Fuchsin; Merck, Darmstadt, Germany) for a period of 24 hours at 37°C. After removal from the dye, the teeth were thoroughly washed in water, dried and then mounted in resin (Orthoresin, Detrey; Dentsply, Weybridge, Surrey, UK) prior to sectioning. The teeth were sectioned mesiodistally through the center of each restoration using an Isomet saw and Isocut fluid (Buehler Ltd., Lake Bluff, IL, USA). The two sectioned surfaces were then photographed (Medical-Nikkor, 120 mm Lens, N100 body; Nikon Co., Tokyo, Japan) to create color slides at 2× enlargement. The slides were projected onto a screen (enlargement to 10×) and investigated by two examiners. The microleakage grading criteria are shown in Fig. 4. If there was any disagreement, the grading was determined by discussion between the two examiners. If the grade by the two examiners for both sectioned surface were not the same, the more severe one was used.

2.4. Statistical analysis

Kruskal–Wallis tests were used to compare microleakage among all the various groups. Wilcoxon signed-rank tests were used to compare microleakage between the occlusal and cervical margins for each type of restorative material. A p value < 0.05 was considered statistically significant.

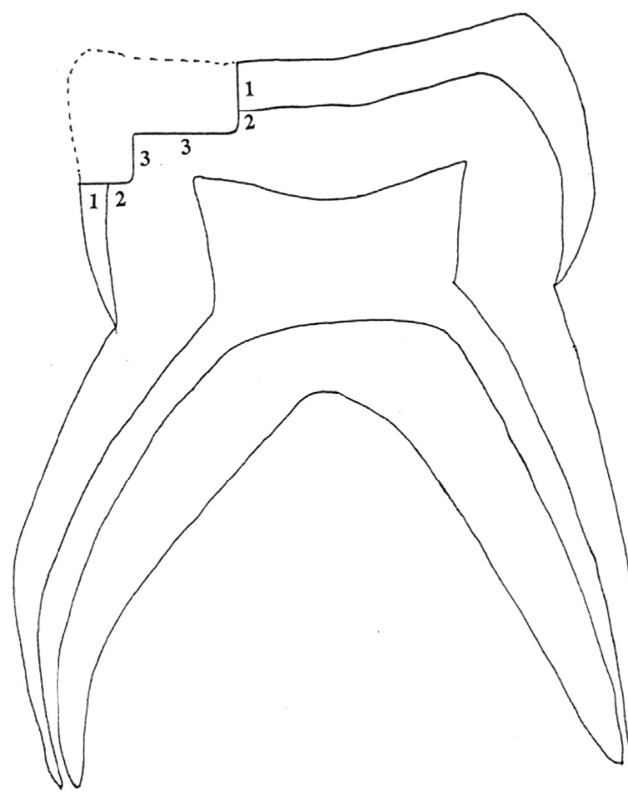

Fig. 4. Grading system used to assess dye penetration. Grade 0 = no dye penetration; Grade 1 = dye penetration to enamel only; Grade 2 = dye penetration to dentine, but not to the pulpal floor; Grade 3 = dye penetration to the pulpal floor or the axial wall or even to the pulp.

3. Results

3.1. Occlusal margin leakage

All of the teeth in the GI group showed no leakage, as noted in Table 2. Eight teeth (80%) in GI+B group showed no

Table 2
Microleakage at the occlusal margin.

Group	Grade			
	0	1	2	3
Am	0 (0%)[a]	1 (10%)	4 (40%)	5 (50%)
CR	6 (60%)	1 (10%)	3 (30%)	0 (0%)
GI	10 (100%)	0 (0%)	0 (0%)	0 (0%)
KS	4 (40%)	4 (40%)	1 (10%)	1 (10%)
GI+B	8 (80%)	2 (20%)	0 (0%)	0 (0%)

Am = amalgam; CR = composite resin; GI = glass ionomer cement; GI+B = glass ionomer filling with banding; KS = Ketac-Silver.
[a] indicates the percentage of teeth rated as that grade within each restoration group.

Table 4
Microleakage at the cervical margin.

Group	Grade			
	0	1	2	3
Am	1 (10%)[a]	0 (0%)	0 (0%)	9 (90%)
CR	3 (30%)	0 (0%)	5 (50%)	2 (20%)
GI	6 (60%)	2 (20%)	1 (10%)	1 (10%)
KS	1 (10%)	1 (10%)	4 (40%)	4 (40%)
GI+B	7 (70%)	2 (20%)	1 (10%)	0 (0%)

Am = amalgam; CR = composite resin; GI = glass ionomer cement; GI+B = glass ionomer filling with banding; KS = Ketac-Silver.
[a] indicates the percentage of teeth rated as that grade within each restoration group.

leakage while two teeth (20%) showed grade 1 leakage. Five teeth (50%) in the Am group showed grade 3 leakage. The CR group showed six teeth (60%), one tooth (10%), and three teeth (30%) with grade 0, grade 1, and grade 2 leakage, respectively. The KS group showed four teeth (40%), four teeth (40%), one tooth (10%), and one tooth (10%) with grade 0, grade 1, grade 2, and grade 3 leakage, respectively. There was no grade 3 leakage among the teeth in the CR, GI, and GI+B groups. After statistical analysis, the Am group showed significantly more leakage than the CR group, the GI group and the GI+B group at the occlusal margin. There was no significant difference among CR, GI, KS, and GI+B groups. There also was no significant difference between the Am and the KS groups (Table 3).

3.2. Cervical margin leakage

Nine teeth (90%) in the Am group revealed grade 3 leakage and only one tooth (10%) showed no leakage, as shown in Table 4. Within the GI group, six teeth (60%) showed no leakage, while four teeth (40%) showed some degree of leakage. In the CR group, three teeth (30%) showed no leakage, while seven teeth (70%) showed grade 2 and grade 3 leakage. Only one tooth (10%) in the KS group showed no leakage, with eight teeth (80%) showing grade 2 and grade 3 leakage. Within the GI+B group seven teeth (70%) showed no leakage, and no teeth showed grade 3 leakage. After statistical analysis, the Am group was found to show significantly more leakage than the GI group and the GI+B group at the cervical margin. The KS group showed more significant cervical leakage than the GI+B group. Furthermore, there also was no significant difference between the Am group and KS group, while the CR group showed no significant difference compared to the other four groups (Table 5).

3.3. Occlusal versus cervical leakage

The Wilcoxon signed-rank test showed significant differences in leakage between the occlusal and cervical margins for the CR, GI, and KS groups, while there were no significant difference in leakage between the occlusal and cervical margins for the Am and GI+B groups.

4. Discussion

The aim of using thermocycling was to simulate the temperature changes that occur in our oral cavity. Nelson et al showed that oral temperature is raised to 60°C within a few seconds of having a hot drink, and it will drop to as low as 4°C after having a cold drink.[4] Thermocycling will result in increased microleakage.[31,32] In a previous study there was no significant difference in microleakage between 100 cycles and 1500 cycles of thermocycling.[33] Based on this finding, in the present study we used 100 cycles with a temperature range from 5°C to 55°C for the thermocycling.

Am was the only restorative material used in the present study that was not directly bonded to the tooth structure. The Am group showed over 90% leakage affecting either the occlusal or cervical margin. The reason for this high frequency is likely to be the difference in coefficient of thermal expansion between enamel and Am (Am: $22-28 \times 10^{-6}$ cm/cm.°C; Enamel: 11.4×10^{-6} cm/cm.°C).[34] After thermocycling, gaps

Table 3
Results of the Kruskal–Wallis test for occlusal margin.

Group	Am	CR	GI	KS	GI+B
Am	X				
CR	<0.05*	X			
GI	<0.05*	NS	X		
KS	NS	NS	NS	X	
GI+B	<0.05*	NS	NS	NS	X

*significantly different.
Am = amalgam; CR = composite resin; GI = glass ionomer cement; GI+B = glass ionomer filling with banding; KS = Ketac-Silver.

Table 5
Results of the Kruskal–Wallis test for cervical margin.

Group	Am	CR	GI	KS	GI+B
Am	X	NS	<0.05*	NS	<0.05*
CR		X	NS	NS	NS
GI			X	NS	NS
KS				X	<0.05*
GI+B					X

*significantly different.
Am = amalgam; CR = composite resin; GI = glass ionomer cement; GI+B = glass ionomer filling with banding; KS = Ketac-Silver.

are formed between the amalgam and enamel. Although the leakage will lessen over time, the high copper amalgam used in this study will take about 2 years to show this effect.[35] The time span between restoration and microleakage test for amalgam group was only 2 weeks. So there was insufficient time for corrosive products to be formed to decrease the leakage. Due to the severity of the leakage affecting both the occlusal and cervical margins there was no significant difference found between occlusal and cervical leakage in the present study.

CR is able to bond to tooth structure via the bonding agent. In the present study, the CR group showed 40% mild to moderate leakage over the occlusal margin, and 70% moderate to severe leakage over the cervical margin. Thus, the cervical margin showed significantly more leakage than the occlusal margin. This result is consistent with the findings of the study conducted by Fuks et al.[36] In the present study, the width of enamel at the cervical margin was about 0.2–0.6 mm, while that at the occlusal margin was about 0.5–1.0 mm. Furthermore, there can be about 0.4–1.2% linear contraction after polymerization of CR.[37] The coefficient of thermal expansion of CR is greater than that of enamel (CR: $14-40 \times 10^{-6}$ cm/cm.°C; Enamel: 11.4×10^{-6} cm/cm.°C).[34] These factors have two effects. First, the reduction in available enamel in the cervical area is likely to lead to a reduced area of bonding and a lower bonding strength compared to that of the occlusal margin. Second, the detaching forces generated during polymerization shrinkage and volume change during thermocycling are likely to cause greater leakage in the cervical area than in the occlusal area.

GI cement has a number of specific merits; these include direct bonding to the tooth structure, good biocompatibility, and the release of fluoride into the adjacent tooth structure. Thus it is suitable for restorations that involve primary teeth and early dental treatment material for patients with special needs.[38,39] The use of Ketac-conditioner before restoration facilitates an increase in the bonding strength between the GI and the cavity wall.[40] The GI group showed no leakage affecting the occlusal margin and only 40% mild to severe leakage affecting the cervical margin. Thus, the cervical margin showed significantly more leakage than the occlusal margin. The reason for this phenomenon is likely to be the thinner enamel or the presence of cracks at the cervical margin as indicated by Brown et al's study.[41] The GI filling with the banding group showed a 20% mild leakage affecting the occlusal margin, and 30% mild to moderate leakage affecting the cervical margin. The purposes for adding a band over the GI restoration is to protect the GI from abrasion, to increase retention, and to cover the cervical margin to prevent leakage. The results showed that, even when banding is added to a GI restoration, there remains a measure of mild to moderate leakage over the cervical margin. This may be due to the presence of tooth cracks or to breakdown of the GI cement during thermocycling.

KS was developed by adding silver particles to traditional GI cement to increase abrasive resistance.[42] Thornton et al showed that the tensile bond strength of GI cement (Ketac-fil) to enamel and dentin was 2.3 ± 1.6 MPa and 2.0 ± 2.3 MPa, respectively,[43] while the tensile bond strength of KS to enamel and dentin was 1.2 ± 1.7 MPa and 0.5 ± 1.3 MPa, respectively.[43] Thus it would seem that the addition of silver particles to GI cement decreases the bonding strength to tooth. In the present study, the KS group showed 60% leakage over the occlusal margin, and 90% leakage over the cervical margin. Furthermore, there was 40% severe leakage over the cervical margin. The decrease in bonding strength outlined above is likely to be the reason for this increase in leakage.

At the occlusal margin, using postcomparison, the Am group showed more severe leakage than the CR, GI, or GI+B groups ($p < 0.05$). At the cervical margin, the Am group showed more severe leakage than either the GI or GI+B groups ($p < 0.05$). In addition, the KS group showed more severe leakage than the GI+B group ($p < 0.05$). Thus it would seem that the degree of bonding of the filling to the tooth structure is the key factor that is able to prevent leakage. At the occlusal margin, the Am group, which shows no ability to bond to the tooth, produced significantly more leakage than the CR, GI, and GI+B groups, all of which are able to bond. Furthermore, the KS group with decreased bonding ability showed no significant difference in leakage compared to the Am group. At the cervical margin, due to the thinner enamel and/or the presence of tooth cracks caused by the acid etch procedure, the CR group showed the same leakage as the Am group.

In conclusion, GI cement and GI+B are highly suitable for class II restoration of primary molar teeth if microleakage is a chief concern. GI+B restoration was not superior to a simple GI cement restoration in this *in vitro* study. In the future, it will be necessary to design *in vivo* studies in order to evaluate microleakage under the real conditions found in the oral environment.

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