Original Article

Marginal Adaptation of Indirect Composite, Glass-Ceramic Inlays and Direct Composite: An *In Vitro* Evaluation

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Abstract:

Objective: This experimental *in vitro* study compared marginal adaptation of indirect composite, glass-ceramic inlays and direct composite.

Materials and Methods: Seventy-five recently extracted human molars were randomly divided into three groups (n=25) and mesio-occluso-distal cavities with the same dimensions were prepared in the teeth. Indirect composite and glass-ceramic inlays were fabricated following manufacturer's instructions and the marginal gap was measured by a stereomicroscope at magnification 40× before cementation. After cementation of inlays and restoring the third group by direct composite, all the specimens were thermocycled and the marginal gaps were measured exactly as previously described. Repeated measure ANOVA and post-hoc Tukey test were used for pairwise comparison of occlusal, proximal, and gingival marginal gaps in each group. One-way ANOVA and post-hoc Tukey test were used for comparison of mean marginal gap in the three groups and for comparison of marginal gap before and after cementation in inlays, paired T-test was used.

Results: The marginal gap of direct composite (19.96 μm) was significantly lower than that of indirect composite inlay (48.47 μm), which in itself was significantly lower than that of glass-ceramic inlay (60.96 μm). In all the restorations, marginal gap in the gingival margin was significantly higher than occlusal and proximal margins. The marginal gap of inlays did not change after cementation and thermocycling.

Conclusion: This study indicated that the marginal gaps of the evaluated restorations are less than 100 μm, which is clinically acceptable.

Key Words: Dental Marginal Adaptation; Inlays; Composite Resins

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INTRODUCTION

Patients have been more interested in tooth-colored restorations even in the posterior areas of the mouth as a result of esthetic awareness [1]. Several materials and techniques have been introduced for tooth-colored intra-coronal restorations, which include direct composite, indirect composite and ceramic inlays [2].

Posterior direct composites provide esthetics and may increase the strength of the remaining tooth structure because of bonding [3]; however, obtaining adequate proximal contact and occlusal morphology is difficult [4]. The polymerization shrinkage produces contraction forces, which may compromise the bond between the tooth and composite. This leads to marginal opening, pulpal irritation, post-operative sensitivity, marginal staining and secondary caries [5,6].

To overcome the problems associated with di-

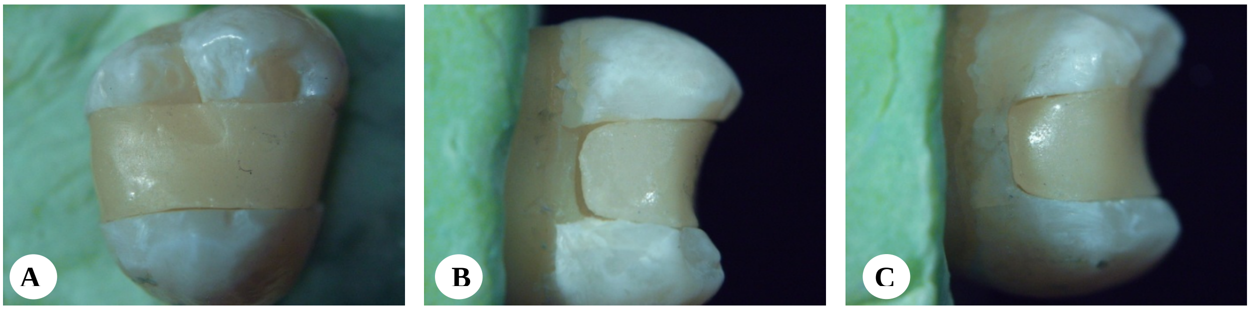

Fig 1. Glass-ceramic inlay in place before cementation (10×): Occlusal view **(A)**, Mesial view **(B)**, Distal view **(C)**.

rect composites, composite inlays were introduced in the early 1980s. In this method, the operator has better control over anatomic form and proximal contacts [3,7] and polymerization shrinkage is limited to the thin layer of resin cement [8].

Ceramic inlays have higher esthetics, color stability and stain resistance [3], but are more expensive, time-consuming and technique sensitive. Marginal adaptation of direct composites and esthetic inlays is an important characteristic with a significant role in the long-term clinical performance of the restoration [9]. Several studies have shown that if occlusal marginal gap is greater than 100 µm, excessive wear of resin cement will occur and if this gap is in the proximal surface of the tooth near the gingiva, the risk of gingival inflammation and periodontal disease will increase. In addition, because of bacterial growth and adhesion on resin cement, secondary caries and pulp damage or marginal deterioration might occur [10-12]. It is critical to establish a low marginal gap in ceramic and composite inlays because of the inherent limitations of resin cements such as relatively high polymerization shrinkage and high co-efficient of thermal expansion [9].

This study evaluated marginal adaptation of an indirect composite inlay, a glass-ceramic inlay, and a direct composite.

MATERIALS AND METHODS

The study was designed as an experimental *in vitro* study. Seventy-five caries-free, recently extracted human molars were selected for the purpose of this *in vitro* study and were stored in a 0.5% chloramines T solution for seven days [13]. Any calculus and soft tissue deposits were removed from the teeth using a hand scaler. The roots of the teeth were embedded in auto-polymerizing acrylic resin (Acropars 200, Marlic, Tehran, Iran) up to 2 mm apical to the cemento-enamel junction [14]. The shape and dimensions of all cubic acrylic blocks were the same (25×15×15 mm^3). The specimens were randomly divided into three groups (n=25) according to the restorative materials used: group A for indirect composite inlays (GC-Gradia, GC Corp, Tokyo, Japan); group B for lithium disilicate glass-ceramic inlays (IPS-Empress 2, Ivoclar Vivadent, Shaan, Liechtenstein); and group C for direct composites (Tetric Ceram, Ivoclar Vivadent, Shaan, Liechtenstein).

Class II MOD cavities without bevel were prepared observing the following dimensions: 4.0 mm (SD=0.5) bucco-lingually, 4.0 mm (SD=0.5) occluso-gingivally in the proximal walls and 2.0 mm (SD=0.5) for pulpal wall depth.

Cavities with divergent walls were prepared in groups A and B with an eight-degree tapered diamond bur (S 856-016-8 ML, Swiss Tec, Coltene AG, Alstatten, Switzerland) and parallel-walled cavities were prepared in group C with a cylindrical diamond bur held parallel to the long axis of the tooth (S 835R-014-4ML, Swiss Tec, Coltene AG, Alstatten, Switzerland) [6,15].

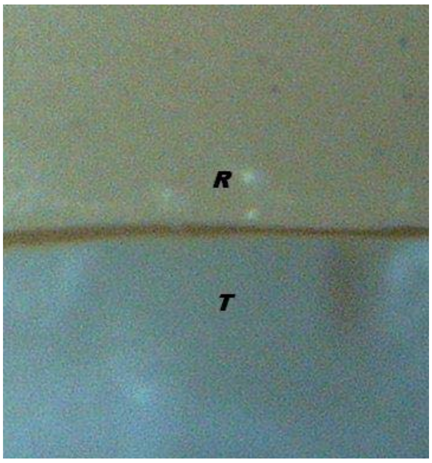

Fig 2. Occlusal view of glass-ceramic inlay in place before cementation (40×). Restoration **(R)**, Tooth **(T)**.

Fig 3. Distal view of direct composite after thermocycling (40×). Restoration **(R)**, Tooth **(T)**.

The impressions of prepared teeth in groups A and B were taken with condensation silicone (Speedex, Coltene AG, Alstatten, Switzerland) using double mixing technique [16-18].
The impressions were poured after one hour with a type IV dental stone (Elite Rock, Zhermack, Rovigo, Italy) [3].
For group A, indirect composite inlays were fabricated using incremental technique following manufacturer's recommendations.
For group B, inlay patterns were waxed up directly onto the stone dies, and then invested and pressed according to the manufacturer's instructions. All the inlays were fabricated by the same laboratory technician.
In group C, the cavities were etched with 37% phosphoric acid gel (Total Etch, Ivoclar Vivadent, Shaan, Liechtenstein) for 30 seconds for enamel and 15 seconds for dentin. Following rinsing and gentle drying to leave a moist dentin surface, bonding agent (Excite, Ivoclar Vivadent, Shaan, Liechtenstein) was applied and after 10 seconds, gently air-dried for 1-3 seconds and light-cured for 20 seconds at 500 mW/cm^2 (Coltlux II, Coltene AG, Alstatten, Switzerland). A clear plastic matrix was used to establish the proximal surface of the restoration.
The cavity was filled with oblique increments of composite (Tetric Ceram, Ivoclar Vivadent, Shaan, Liechtenstein); each increment was light-cured for 20 seconds [4,15].
The finishing procedure was completed with fine (S 8565-014-8F, Coltene AG, Alstatten, Switzerland) and extra fine (826-012-8×F, Coltene AG, Alstatten, Switzerland) finishing burs. The restorations were then polished using polishing rubbers (2103.1- 050, 2203.1-050, Coltene AG, Alstatten, Switzerland).

Marginal Adaptation of Inlays before Cementation

After adjusting the inlays (groups A and B) on the teeth using a control paste (Fit-Checker Black, GC, Tokyo, Japan), they were placed on the teeth and each specimen was positioned under a stereomicroscope (SZX12, Olympus, Tokyo, Japan) in a manner in which the images of occlusal, mesial and distal surfaces with magnification 10× were captured by a digital camera (DPR, Olympus, Tokyo, Japan) and transferred to a computer (Fig 1). Another magnification 4× was digitally applied to each image, so that a total of magnification 40× was obtained (Fig 2). Then the marginal gap (the distance between the dental wall and the restoration) was measured by a screen ruler (JR Screen Ruler PRO 3.0) in pixels in four locations at occlusal margins and three locations at each proximal surface (two locations at the proximal margins and one location at the gingival margin). Each location was 500 pixels far from the margin of the restoration. Screen ruler measured the marginal gap in pixels and each pixel was 4.5 µm.

Cementation of Inlays

In groups A and B, 37% phosphoric acid gel (Total Etch, Ivoclar Vivadent, Shaan, Liechtenstein) and bonding agent (Excite, Ivoclar Vivadent, Shaan, Liechtenstein) were applied on the cavities, as previously described. The internal surfaces of inlays were sandblasted with 50-µm aluminum oxide particles for 5 seconds [19].

In group A, the internal surfaces of inlays were treated with composite primer (Primer, GC, Tokyo, Japan) and light-cured for 20 seconds, and bonding agent (Excite, Ivoclar Vivadent, Shaan, Liechtenstein) was then applied. In group B, the internal surfaces of the inlays were etched with 9% buffered hydrofluoric acid (HF, Ultradent, Utah, USA) for two minutes, rinsed and dried, and then treated with a silane coupling agent (Silane, Dentsply, PA, USA) for one minute. Finally, the bonding agent (Excite, Ivoclar Vivadent, Shaan, Liechtenstein) was applied.

Dual-cure resin cement (Variolink II, Ivoclar Vivadent, Shaan, Liechtenstein) was mixed and applied to the surfaces of inlays and the teeth. The inlay was seated in place and kept under a pressure of 500 g for 10 minutes [6]. The excess cement was removed with a brush. Then the cement was light-cured from facial, lingual, and occlusal directions for 60 seconds in each direction. The cement layer was finished and polished as previously described.

All the specimens including groups A, B, and C were stored in distilled water at 37˚C for a week. The teeth were then thermocyled for 2000 cycles at 5-55˚C according to ISO-TR 11405 Standard [20].

Marginal Adaptation of Direct Composite and Inlays after Cementation and Thermocycling

Each specimen was positioned under the stereomicroscope; then the images of occlusal, mesial and distal surfaces were captured and transferred to the computer and marginal gaps were measured by the screen ruler in the manner described previously (Fig 3).

Statistical Analysis

A statistical comparison of occlusal, proximal, and gingival marginal gaps in each group was performed using repeated measure analysis of variance (ANOVA) and post hoc Tukey test. To compare the marginal gap of groups A and B together before cementation, independent T-test was used. After cementation, marginal gaps in groups A and B and marginal gaps in group C were compared with the use of one-way analysis of variance and post - hoc Tukey test. For comparison of marginal gap before and after cementation in groups A and B, paired T-test was used. All tests were carried out at 95% confidence level.

RESULTS

The mean marginal gap values of inlays before

Table 1. Marginal gap of indirect composite and glass-ceramic inlays before cementation.

Locations	Indirect Composite Inlays			Glass-Ceramic Inlays			P-value
	Mean (Pixel)	Mean (µm)	SD (Pixel)	Mean (Pixel)	Mean (µm)	SD (Pixel)	
Gingival	15.12	68.04	4.95	21.28	95.76	8.65	0.004
Proximal	8.64	38.88	2.08	10.02	45.09	2.45	0.037
Occlusal	9.52	42.84	2.39	12.74	57.33	2.95	<0.001
Total	10.29	46.29	2.01	13.36	60.12	2.46	<0.001
P-value		<0.001			<0.001		

SD=Standard Deviation

cementation at occlusal, proximal, and gingival margins are shown in Table 1. The mean marginal gap values of indirect composite inlays (46.29 µm) were significantly lower than those of glass-ceramic inlays (60.12 µm, P<0.001). In both groups, marginal gaps of the gingival margin were significantly greater than both occlusal and proximal margins, according to repeated measure ANOVA and Tukey test.

The mean marginal gap values of inlays after cementation and direct composites, after thermocycling of all the specimens, at occlusal, proximal, and gingival margins are shown in Table 2. Mean marginal gap value of direct composites (19.96 µm) was significantly lower than that of indirect composite inlays (48.47 µm, P<0.001), which in itself was significantly lower than that of glass-ceramic inlays (60.96 µm, P<0.001).

In all groups, the marginal gap of the gingival margin was significantly greater than that of both occlusal and proximal margins, according to repeated measure ANOVA and Tukey test. Comparison of marginal gap of inlays before and after cementation and thermocycling revealed that there were no significant differences between marginal gap values before and after cementation (P=0.075 for group A and P=0.766 for group B).

DISCUSSION

Close marginal adaptation is crucial to the quality of composite restorations and esthetic inlays luted to teeth with composite resin cement [9,10]. Several studies have reported that the marginal gap of such restorations should be less than 100 µm [10-12,21].

In this study, marginal gaps of indirect composite, glass-ceramic inlays and direct composites in all the margins were less than 100 µm. In the present study, the marginal gap in the gingival margin was higher than that in the occlusal and proximal margins in both indirect composite and glass-ceramic inlays. In addition, the marginal gap of indirect composite inlays was significantly lower than that of glass-ceramic inlays. These findings are consistent with the results of a study on one ceramic and three composite inlays, carried out by Soares et al [14].

The marginal gap of indirect composite and glass-ceramic inlays did not increase significantly after cementation and thermocycling. This finding coincides with the results of studies by Gemalmaz et al [9], who evaluated sintered ceramic inlays and by Stappert et al [22], who assessed heat pressing glass-ceramic inlays.

The marginal gap of direct composite was significantly lower than that of indirect composite and glass-ceramic inlays. In the present study, the marginal gap was defined as the distance between the dental wall and the restoration in the marginal area, which was filled with resin cement in inlays. In direct composite restorations, because of a direct technique on the cavity, the distance between the restoration and the dental wall would be minimum, which is filled with bonding agent. Thus, the crucial factor in direct composites is marginal opening

Table 2. Marginal gap of direct, indirect composites, and glass-ceramic inlays after cementation and thermocycling.

Locations	Indirect Composite Inlays			Glass-Ceramic Inlays			Direct Composites			P-value
	Mean		SD	Mean		SD	Mean		SD	
	(Pixel)	(µm)	(Pixel)	(Pixel)	(µm)	(Pixel)	(Pixel)	(µm)	(Pixel)	
Gingival	15.60	70.20	5.08	21.36	96.12	8.42	5.82	26.19	1.68	0.004
Proximal	9.01	40.54	1.95	10.25	46.12	2.28	4.56	20.52	0.92	0.037
Occlusal	10.12	45.54	2.27	12.94	58.23	2.72	3.62	16.29	1.32	<0.001
Total	10.77	48.47	1.98	13.55	60.96	2.32	4.44	19.96	0.87	<0.001
P-value	<0.001			<0.001			<0.001			

SD=Standard Deviation

as a result of polymerization shrinkage. In this study no marginal opening was detected, which might be attributed to evaluation method (stereomicroscope with magnification 40× without sectioning the specimens). Therefore, microleakage evaluation is recommended [4,15,23] for precise comparative evaluation of margin quality in direct composites and inlays.

CONCLUSION

Under limitations of this *in vitro* study the following conclusions may be drawn:

1- Marginal gap of indirect composite, glass-ceramic inlays and direct composites was less than 100 μm, which is clinically acceptable.

2- Marginal adaptation of direct composite was better than indirect composite inlay, which in itself was better than glass-ceramic inlay.

3- In comparison of occlusal, proximal, and gingival margins in all the restorations, the marginal adaptation of gingival margin was the worst.

4- Marginal adaptation of inlays did not deteriorate after cementation and thermocycling.

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