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Marginal and Internal Adaptation of Bulk-filled Class I and Cuspal Coverage Direct Resin Composite Restorations

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Clinical Relevance

C-factor has an important influence on marginal and internal adaptation in large posterior cavities. A thick bonding layer does not optimize adaptation in Class I restorations.

SUMMARY

This *in vitro* study compared the marginal and internal adaptation of bulk-filled Class I and cuspal coverage direct resin composite restorations filled with different types of adhesive restorative systems and different thicknesses of bonding agent. Seventy-two intact, caries-free, freshly extracted human molars were randomly divided into 12 groups of six teeth each, according to the type of cavity (Class I [I] or Cuspal Coverage [C]), adhesive restorative system (SE Bond/Clearfil AP-X [SE] or Prime&Bond NT/Spectrum TPH [PB]) and thickness of bonding agent (normal or thick layer) in Class I restorations. Standardized Class I and Cuspal coverage cavities with enamel outer margins were prepared and restored with the corresponding type and thickness of bonding agent and respective resin composite. The resin composite was placed and polymerized in one increment (bulk filling). Dentinal fluid was simulated using 1:3 diluted horse serum and fed into the pulp chamber both during restoration and stressing. In six of the 12 groups, the restorations were subjected to 1.2 million mechanical occlusal cycles (maximum force 49 N; frequency 1.7Hz) and 3,000 simultaneous thermal cycles (5-50-5°C). Marginal adaptation before and after mechanical and thermal stressing was assessed by using the replica technique and quantitative evaluation under SEM at 200x magnification. The teeth were dissected in a mesio-distal direction with a slow rotating diamond disc under water cooling, and the internal adaptation was also assessed by using the replica technique under the conditions described. Statistical evaluation of the continuous margin at the external and internal interface was performed with one-way analysis of variance (ANOVA) and Tukey's Studentized Range (HSD)

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test (*p*=0.05). Even though Cuspal coverage restorations (SE- C: 96.89±1.83 and PB- C: 97.15±2.93) exhibited statistically significantly better external adaptation than Class I restorations (SE- I: 63.95±12.82 and PB- I 64.74±14.62) before stressing, there was no statistically significant difference after mechanical and thermal stressing (SE- C: 76.35±18.53 and PB- C: 76.02±12.49 SE- I: 54.67±10.82 and PB- I: 59.94±15.20). After stressing, SE Bond Cuspal coverage restorations (SE- C: 96,72±3,26) exhibited superior internal adaptation compared to SE Bond Class I restorations (SE- I: 57.83±12.91). No difference was observed in internal adaptation between Prime&Bond NT Cuspal coverage and Class I restorations (PB- C:36.46±21.82, PB- I: 38.71±6.76). In Class I restorations, the increased thickness in bonding did not improve the marginal and internal adaptation either before or after stressing. Bulk-filled direct resin composite Cuspal coverage restorations exhibited marginal adaptation similar to bulk-filled direct resin composite Class I restorations. The internal adaptation of Cuspal coverage SE Bond/Clearfil AP-X restorations was superior to all the other groups tested.

INTRODUCTION

Direct composites have become increasingly popular as tooth-colored restorations for extensive lesions in posterior teeth.[1] Adaptation of the restorative material to cavity margins (marginal adaptation) and internal cavity surfaces (internal adaptation) is crucial for the long-term performance of any restoration.[2-3] One of the main factors responsible for defects at the marginal and internal interfaces of restorations is the shrinkage that accompanies polymerization of resin composites.[4-5] Polymerization shrinkage is regarded as the main limitation of today's resin composites, as it generates stress at the tooth-restoration interface, which may lead to marginal gap formation,[6-9] marginal discoloration,[10] post-operative sensitivity[11-13] and secondary caries.[5]

Many methods have been proposed to overcome the negative effects of polymerization shrinkage, such as various techniques of incremental layering of the restorative composite,[14-16] different protocols of light-curing,[17-18] use of a resin-modified glass-ionomer base in a sandwich technique[19-21] and use of semi-direct[22-24] and indirect restorations.[20,23,25]

In direct restorations, the amount of stress generated by polymerization shrinkage depends mainly on the volume of the resin composite and the C-factor of the cavity.[26-29] The greater the amount of resin composite, or the cavity's C-factor, the higher the polymerization stresses that are generated. It is for this reason that large Class I cavities, which have the highest C-factor from all other cavities in posterior teeth, often puzzle clinicians with post-operative sensitivity when they are bulk-filled in one layer of restorative composite. In order to avoid this problem, clinicians should use appropriate layering techniques in order to minimize the negative effects of polymerization shrinkage. This results from smaller increments of restorative composite having less volume and, subsequently, producing less stress during polymerization. At the same time, each increment has a more favorable C-factor, as it is bonded to small portions of the cavity's internal walls and has more unbonded surfaces, a factor that also contributes to minimizing the polymerization stresses.

The multi-layering technique is also used in large Cuspal coverage restorations (overlays), even though these restorations have a favorable C-factor. This is due to the fact that it is clinically demanding to achieve the proper occlusal anatomy and proximal contact points, and it is practically impossible to place the restorative composite in one increment and be able to produce a proper result.[30] The question remains, if these restorations were placed in one increment, whether the shrinkage of such a large volume of restorative composite that was polymerized in bulk would produce detrimental effects on the marginal and internal adaptation of the Cuspal coverage restoration despite of a very favorable C-factor.

The use of a low-filled flowable composite that acts as an "elastic layer" in order to absorb shrinkage stresses has also been proposed as a way to minimize the negative effects of polymerization shrinkage.[31-33] Some of the current bonding systems, if placed in multiple layers as manufacturers often recommend, will produce a thick bonding interface that may act as an intermediate "elastic layer." Nevertheless, regardless of the fact that such a technique has been shown to be beneficial,[32] it is not yet clear whether it is sufficient to counteract high polymerization stresses, such as those that develop in bulk-filled large Class I cavities.

Even though both the volume of the restorative composite and the C-factor of the cavity are recognized as critical factors of the negative effects of polymerization shrinkage, their effect on marginal and internal adaptation of direct resin composite restorations in posterior teeth has not been clearly determined. There are numerous articles in the literature that address polymerization shrinkage,[34-38] but few examine its interaction with marginal[17,39-41] and internal adaptation.[42] Additionally, it is quite common that some *in vitro* research results lead to controversial clinical assumptions.[43] For this reason, basic research conclusions need to be verified in laboratory experiments that simulate clinical conditions. Thus, this *in vitro* study compared the marginal and internal adaptation of bulk-filled Class I and Cuspal coverage direct composite restorations filled with different types of adhesive/composite systems and with different thicknesses of bonding systems.

METHODS AND MATERIALS

Seventy-two intact, caries-free, freshly extracted human molars were selected for the current study. These molars were refrigerated in 0.1% thymol solution until use. After cleaning, the molars were randomly assigned to 12 experimental groups of six teeth each, according to the type of cavity (Class I [I] or Cuspal coverage [C]), adhesive/restorative system (SE Bond/Clearfil AP-X [SE], Kuraray Medical Inc, Tokyo, Japan or Prime&Bond NT/Spectrum TPH [PB], Dentsply DeTrey GmbH, Konstanz, Germany) and thickness of the bonding agent (normal or thick layer in Class I cavities) (Table 1 and Figure 1). The molars were prepared for the simulation of dentinal fluid following a protocol previously established by Krejci and others.[44] In brief, the apices were sealed with two coats of nail varnish, and the teeth were mounted on custom-made specimen holders. A cylindrical hole was drilled into the pulpal chamber, a metal tube was adhesively luted through this hole and connected by a flexible silicone hose to an infusion bottle filled with horse serum diluted to a 1:3 ratio with 0.9% NaCl under hydrostatic pressure of about 25 mm Hg. One day before starting the cavity preparations, the pulp chambers were evacuated (only the dentinal fluid, not the pulpal tissue) and filled with the horse serum. Intrapulpal pressure was maintained at 25 mm Hg during cavity preparation, restoration placement, finishing and stressing.

Standardized large Class I cavities (6 mm bucco-lingual, 6 mm mesio-distal and 5 mm deep) were prepared on the occlusal surface of each tooth. The cavities were prepared with 80 µm diamond burs (Diatech Dental, Coltène Whaledent, Altstätten, Switzerland) under continuous water-spray. A new bur was used after every four cavity preparations. In teeth that were selected for Cuspal coverage restorations, all the external walls (buccal, lingual, mesial and distal) were removed to the depth of the existing pulpal floor, thus transforming the Class I to a Cuspal coverage cavity. This was done in order to ensure that the depth of both cavities were the same, while the pulpal floor was prepared in a similar way in all the teeth. The enamel margins were not beveled, instead, they were finished using 15 µm finishing diamond burs (Diatech Dental) under continuous water spray, in order to remove any loosely attached enamel prisms.

The adhesive systems (SE Bond or Prime&Bond NT) were applied following the manufacturers' recommendations. In the Class I thick SE Bond group, one extra layer of SE bonding resin was applied. In the Class I thick Prime&Bond NT group, two extra layers of bond

Figure 1. *Graphic representation of the different types of restorations used in this study.*

Table 1: *Description of the Groups Used in This Study*

Group	Bonding System	Restorative Composite	Cavity	Stressing
1 (SE-I)	SE Bond[1]	Clearfil AP-X[3]	Class I	Yes
2 (PB-I)	Prime&Bond NT[2]	Spectrum TPH[4]	Class I	Yes
3 (SE-C)	SE Bond[1]	Clearfil AP-X[3]	Cuspal coverage	Yes
4 (PB-C)	Prime&Bond NT[2]	Spectrum TPH[4]	Cuspal coverage	Yes
5 (SE/T-I)	SE Bond[1] – Thick	Clearfil AP-X[3]	Class I	Yes
6 (PB/T-I)	Prime&Bond NT[2] – Thick	Spectrum TPH[4]	Class I	Yes
7 (SE-I)	SE Bond[1]	Clearfil AP-X[3]	Class I	No
8 (PB-I)	Prime&Bond NT[2]	Spectrum TPH[4]	Class I	No
9 (SE-C)	SE Bond[1]	Clearfil AP-X[3]	Cuspal coverage	No
10 (PB-C)	Prime&Bond NT[2]	Spectrum TPH[4]	Cuspal coverage	No
11 (SE/T-I)	SE Bond[1] – Thick	Clearfil AP-X[3]	Class I	No
12 (PB/T-I)	Prime&Bond NT[2] – Thick	Spectrum TPH[4]	Class I	No

Batch numbers: [1]SE Bond 41226; [2]Prime&Bond NT 0103001060; [3]Clearfil AP-X 00346B; [4]Spectrum TPH 00796.

were applied, as the primer and bonding resin are mixed in the same bottle and each coating was thinner than SE Bond. The restorative composite (Clearfil AP-X or Spectrum TPH) was applied in bulk in Class I cavities. In the Cuspal coverage restorations, one 2 mm layer of restorative composite was also placed in bulk. The top surface of the Cuspal coverage restorations was flattened with the aid of a glass plate, using a celluloid strip (Hawe Striproll, Hawe Neos Dental SA, Bioggio, Switzerland) in-between, so that the glass plate would not stick to the restorative composite. Polymerization of the adhesive systems and the restorative composite was performed with a halogen light-curing unit (Optilux 500, Demetron/Kerr, Danbury, CT, USA) using a monitored power output density of 800 mW/cm^2 (Curing Radiometer Model 100, Demetron/Kerr). After light-curing the restorative composite, finishing and polishing of the restoration margins was performed with 15 µm finishing diamond burs (Diatech Dental) and flexible aluminum oxide discs with decreasing grit sizes (Sof-Lex, PopOn, 3M ESPE, Seefeld, Germany) under a stereomicroscope at 12x magnification (Leica MZ6, Leica Microsystems AG, Wetzlar, Germany).

Half of the restored teeth (groups 1-6) were simultaneously stressed by thermal and mechanical loading for 10 days in a computer-controlled chewing machine.[44] Thermocycling was performed with flushing water at two different temperatures (5°C and 50°C) for 3000x, with a dwelling time of two minutes for each temperature range. Mechanical loading consisted of 1.2 million cycles at a frequency of 1.7 Hz, with a maximum load of 49 N transferred to the center of the occlusal surface by using a natural lingual extracted molar cusp as the antagonist.

Marginal adaptation before and after stressing was assessed by using the replica technique and quantitative evaluation in SEM at 200x magnification following a protocol previously established by Krejci and others.[44] In brief, before and after stressing, the teeth were cleaned with rotary polishing brushes and nylon bristles (Hawe Neos Dental SA) impregnated with toothpaste, rinsed and dried, and impressions of the restorations were made with a polyvinylsiloxane material (President light body, Coltène Whaledent). Epoxy replicas (Epofix Kit, Struers, Rødovre, Denmark) were generated from these impressions; subsequently, gold-coated and qualitative and quantitative marginal analysis were carried out in a Scanning Electron Microscope (Philips XL20, Eidhoven, Netherlands) at 200x magnification. The marginal micromorphology was evaluated for the following qualities: "continuous margin" and "non-continuous margin" along the outer periphery of the restorations. The quality criterion "non-continuous margin" was further characterized with the criteria "marginal fissure," "enamel fracture" and "composite resin fracture." The different marginal qualities were assessed as a percent of the total length of margins analyzed. The values were statistically analyzed with one-way analysis of variance (ANOVA) at a confidence level of 95% (p=0.05). A post-hoc Tukey HSD-test was used for multiple pair-wise comparisons between groups.

For evaluation of the internal adaptation, the teeth (groups 1-6 after stressing; groups 7-12 before stressing) were dissected in a mesio-distal direction using a slow rotating diamond disc (Isomet Low Speed Saw 11–1180, AB Bühler Ltd, Evanston, IL, USA) under water cooling and subsequently polished to 4000 grit without applying pressure. The sectioned surfaces were replicated and evaluated according to the procedure described above. The results were expressed as the percent of continuous interface relative to the total length measured. Statistical evaluation was also performed with one-way analysis of variance (ANOVA) and Tukey's Studentized Range (HSD) test (p=0.05).

RESULTS

The qualitative evaluation of marginal adaptation revealed that continuous marginal adaptation was achieved in several areas (Figure 2a). Even though non-continuous margins characterized as "marginal fissures" were observed in all restorations (Figure 2b), "enamel fractures" were only present in Class I restorations (Figures 2c and 2d). No "composite resin fractures" were observed in the marginal adaptation evaluation.

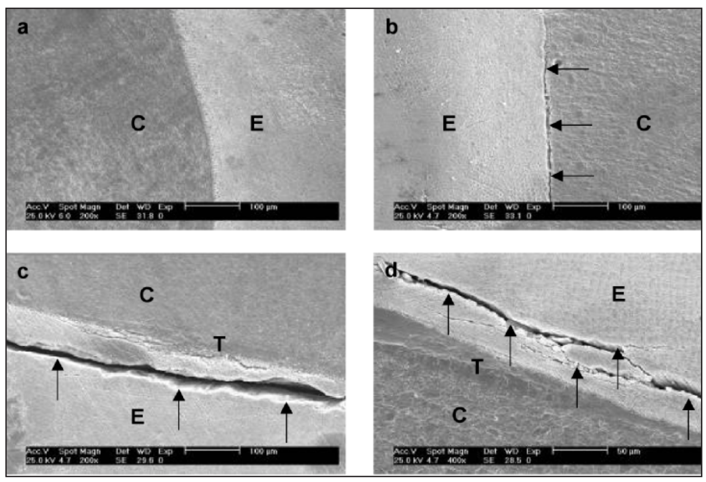

Figure 2. *Representative SEM (200x) images of marginal adaptation interfaces (C: restorative composite, E: enamel, T: thick bonding agent).*
a. Continuous marginal adaptation of Prime&Bond NT Class I restoration.
b. Non-continuous "marginal fissure" of SE Bond Class I restoration.
c. Non-continuous "enamel fracture" of Prime&Bond NT Thick Class I restoration.
d. Non-continuous multiple "enamel fractures" of SE Bond Thick Class I restoration.

The qualitative evaluation of internal adaptation also revealed that continuous interfaces were achieved in several areas (Figures 3a-c). Similar to marginal adaptation, in all restorations, non-continuous internal adaptations, characterized as "internal fissures," were observed in dentin (Figure 3d) and enamel interfaces (Figure 3e), but "enamel fractures" were only found in Class I restorations (Figure 3f). In some cases, multiple enamel cracks were observed (Figure 4), which occasionally extended to the entire width of enamel, all the way to the dentino-enamel junction (Figure 5). No "resin composite fractures" were observed in the internal adaptation evaluation.

Table 2 summarizes the values of marginal and internal adaptation before and after mechanical and thermal stressing. Even though Cuspal coverage restorations of both restorative systems (SE- C: 96.89±1.83 and PB- C: 97.15±2.93) exhibited statistically significant better marginal adaptation than Class I restorations (SE- I: 63.95±12.82 and PB- I: 64.74±14.62) before stressing, there was no statistically significant difference after stressing (SE- C: 76.35±18.53; PB- C: 76.02±12.49; SE- I: 54.67±10.82; PB- I: 59.94±15.20). No differences in marginal adaptation were detected between the restorative systems tested in Class I restorations, regardless of the thickness of the bonding agent. After stressing, SE Bond Cuspal coverage restorations (SE- C: 96.72±3.26) presented superior internal adaptation compared to SE Bond Class I restorations (SE- I: 57.83±12.91); however, no differences were detected in Prime&Bond restorations (PB- C: 36.46±21.82, PB- I: 38.71±6.76). SE Bond Cuspal coverage restorations exhibited better internal adaptation than Prime&Bond Cuspal coverage restorations both before (SE- C: 87.34±15.38 and PB- C: 43.41±27.12) and after (SE- C: 96.72±3.26 and PB- C: 36.46±21.82) stressing. A thick layer of the bonding agent in Class I restorations caused no significant differences in marginal or internal adaptation before or after stressing.

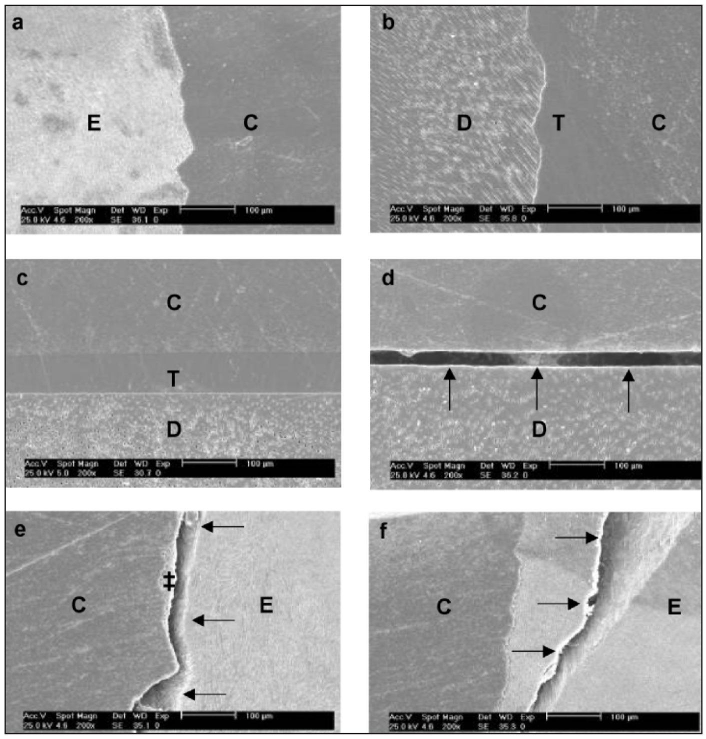

Figure 3. *Representative SEM (200x) images of internal adaptation interfaces (C: restorative composite, E: enamel, D: dentin, T: thick bonding agent).*
a. Continuous internal adaptation of Prime&Bond NT Class I restoration with enamel.
b. Continuous internal adaptation of SE Bond Thick Class I restoration with dentin of the external walls.
c. Continuous internal adaptation of SE Bond Thick Class I restoration with dentin of the pulpal floor.
d. Non-continuous "internal fissure" of Prime&Bond NT Class I restoration with dentin of the pulpal floor.
e. Non-continuous "internal fissure" of Prime&Bond NT Class I restoration with enamel of the external walls and a localized "internal enamel fracture" (marked with ‡).
f. Non-continuous "internal enamel fracture" of Prime&Bond NT Class I restoration.

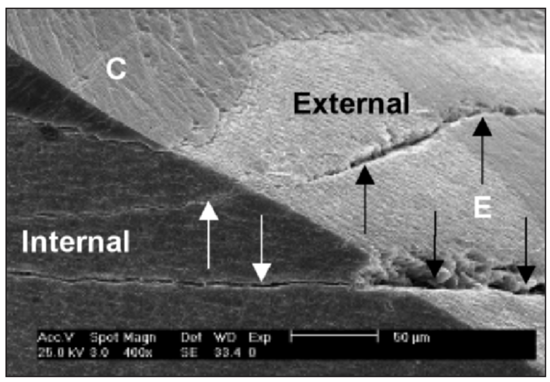

Figure 4. *Representative SEM (400x) image of multiple enamel fractures observed on both external and internal interfaces of a Class I SE Bond restoration (C: restorative composite, E: enamel).*

DISCUSSION

The results of this study demonstrated that, before mechanical and thermal stressing, Cuspal coverage restorations with a favorable C-factor (less than 1) exhibited superior marginal adaptation compared to Class I restorations that had a higher C-factor (more than 4). This was expected, and it is a point that well illustrates the importance of the C-factor. In Cuspal coverage restorations, there is only one bonded surface (pulpal floor) and, as polymerization proceeds and stresses start to build up, the material is free to shrink towards the center of the restoration and add up to the bonded surface. As a result, polymerization shrinkage, in such a case, causes only minimal problems to mar-

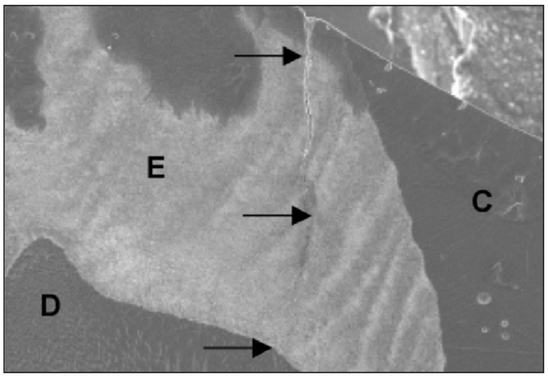

Figure 5. *Representative SEM (100x) image of an internal "enamel fracture" that extends to the entire width of enamel, all the way to the dentino-enamel junction of a Class I SE Bond restoration (C: restorative composite, E: enamel, D: dentin).*

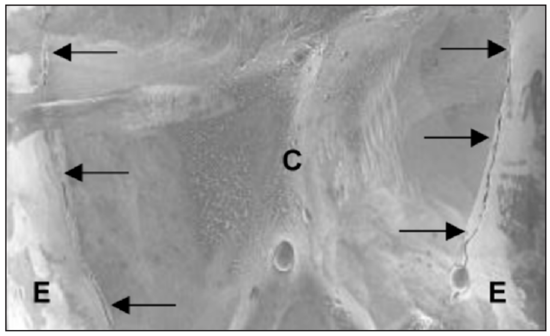

Figure 6. *Representative SEM (11x) image of non-continuous margins on opposing walls of Prime&Bond NT Thick Class I restoration (C: restorative composite, E: enamel).*

ginal adaptation. This was verified by the fact that both adhesive/restorative systems exhibited excellent marginal adaptation (above 95%). In the pilot study that preceded the actual study, this nearly perfect marginal adaptation of Cuspal coverage restorations was noted and served as the reason for not including groups with thick bonding systems in cuspal coverage restorations.

Even though before stressing marginal adaptation was excellent for both adhesive/restorative systems used in this study, there were differences in the internal adaptation of Cuspal coverage restorations between the two systems (SE- C: 87.34±15.38 vs PB- C: 43.41±27.12). This was not expected to that magnitude, as both systems, considering only the geometry and C-factor of the restoration, were expected to perform in a similar way. Nevertheless, adaptation to the tooth is a multi-factorial issue that also depends, among other factors, on the magnitude of polymerization shrinkage of the resin composite.[45-46] In a previous study, Clearfil AP-X exhibited less linear polymerization shrinkage and polymerization stress than Spectrum TPH.[35] Marginal and internal adaptation also depend on the bonding efficacy of the adhesive system.[47-49] Some adhesive systems with self-etching primers, such as SE Bond, have been shown to perform better than etch and rinse adhesive systems, including Prime&Bond NT in dentin,[50] which comprised the majority of the adhesive interface of Cuspal coverage restorations.

Unfortunately, the nearly perfect marginal adaptation of Cuspal coverage restorations was not maintained after mechanical and thermal stressing and adhesive/composite systems; the percentage of "continuous interface" after stressing was just above 75%. A qualitative evaluation of the non-continuous margins of Cuspal coverage restorations showed marginal fissures (pure open margins with gaps). Therefore, the bonding efficacy of both adhesive systems used in this study was not able to withstand the mechanical and thermal stresses of the loading procedure. On the contrary, after stressing, the internal adaptation results of the SE Bond Cuspal coverage restorations remained surprisingly high (above 95%), a point that demonstrates the

Table 2: *Percentages of "Continuous Interfaces" for Marginal and Internal Adaptation Before (initial) and After (terminal) Mechanical and Thermal Stressing*

	Marginal Adaptation						**Internal Adaptation**					
	Initial			**Terminal**			**Initial**			**Terminal**		
Group	**Mean**	**SD**	**Stat**	**Mean**	**SD**	**Stat**	**Mean**	**SD**	**Stat**	**Mean**	**SD**	**Stat**
SE-I	63.95	12.82	BC	54.67	10.82	BCD	62.13	8.95	bcd	57.83	12.91	cd
PB-I	64.74	14.62	BC	59.94	15.20	BCD	54.29	11.81	cd	38.71	6.76	d
SE-C	96.89	1.83	A	76.35	18.53	AB	87.34	15.38	ab	96.72	3.26	a
PB-C	97.15	2.93	A	76.02	12.49	AB	43.41	27.12	cd	36.46	21.82	d
SE/T-I	44.52	22.06	BCD	31.47	22.46	D	69.47	16.50	bc	63.33	9.20	bcd
PB/T-I	65.98	19.71	BC	40.78	31.03	CD	64.86	15.16	bcd	52.36	17.19	cd

Values having similar upper case letters (A,B,C,D) did not exhibit statistical significant differences of marginal adaptation ($p>0.05$).
Values having similar lower case letters (a,b,c,d) did not exhibit statistical significant differences of internal adaptation ($p>0.05$).

excellent efficacy of this self-etching adhesive system in dentin. Even though SE Bond Cuspal coverage restorations detached slightly from the margins, they remained well bonded to the interior of the restoration. From a clinical viewpoint, this might be interpreted as marginal discoloration, but not necessarily as subsequent rapid secondary caries progression.

These contradictory results of marginal and internal adaptation illustrate the importance of examining both the external and internal interfaces of restorations before and after stressing in similar *in vitro* studies. The technique used in this research protocol measured the internal adaptation in a single section, but not in entire, three-dimensional adhesive interfaces. This limitation was well acknowledged, in addition to the fact that possibly altered results could have been obtained if a bucco-lingual, instead of a mesio-distal section, was used. During the pilot study, both bucco-lingual and mesio-distal sections were used and no differences could be observed. In order to measure the entire internal adaptation in all three dimensions, a micro CT-scanner, which is a non-destructive technique, could have been used and only half of the specimens would be needed. Nevertheless, this technique can only detect gaps higher than 8 µm, and smaller gaps, which were actually recorded with the technique used in this research, would have remained undetected.

One should not be confused with the measured increase in internal adaptation of SE Bond Cuspal coverage restorations, because, as a result of stressing, the restorations adhered better. These results are from different specimens, since, in order to examine internal adaptation, the teeth had to be sectioned in halves. For this reason, the results before stressing were from Group 9, while the results after stressing were from Group 3.

Class I bulk-filled restorations exhibited poor marginal and internal adaptation both before and after mechanical and thermal stressing. This was mainly attributed to their unfavorable C-factor. Class I restorations have many bonded surfaces (mesial, distal, buccal and lingual external walls, and a pulpal floor) and only one free, unbonded surface—the occlusal surface of the restoration. It is for this reason that, as polymerization proceeds, high stresses start to build up, causing marginal adaptation to fail (for both adhesive/restorative systems, used marginal adaptation was below 70%). A qualitative evaluation of the non-continuous margin in Class I restorations revealed many enamel fractures. This illustrates the fact that the bonding efficacy to enamel of both adhesive systems was sufficient to resist polymerization stresses, but, unfortunately, these stresses exceeded the strength of enamel and cracks were observed in the mass of enamel. These cracks were observed in both the marginal (Figures 2c,d, 4 and 6) and internal (Figures 3e,f, 4, 5) adaptation evaluation.

As the bonding surfaces of the external walls oppose one another (mesial–distal and buccal–lingual), the material cannot shrink towards both opposing walls, resulting in a crack in the middle of the occlusal surface of the restoration. During polymerization, restorative composite shrinks towards its center, away from the bonded surfaces. As a result, quite often, marginal fissures and enamel cracks could be observed in opposing walls (Figure 6). In order to avoid this, incremental layering techniques should be used in such large Class I restorations. Layering techniques that place separate increments on opposing walls, such as the vertical or oblique techniques, should be preferred over techniques that bond simultaneously on opposing walls, such as the horizontal layering technique.[51-53]

Based on the results of this study and taking into consideration the research protocol's limitations, the use of a thick bonding layer as a means to form an "elastic layer" and to absorb shrinkage stresses in bulk-filled large Class I restorations is not a viable clinical option. All Class I restorations in this study, regardless of the thickness of the bonding agent, exhibited poor marginal and internal adaptation. For this reason, other techniques that have proven to be beneficial in order to achieve excellent marginal and internal adaptation, should be chosen.[16,54]

CONCLUSIONS

- Bulk-filled direct-composite cuspal-coverage restorations before stressing exhibited better marginal adaptation than bulk-filled direct resin composite Class I restorations, probably due to their more favorable C-factor.
- A thick bonding layer did not significantly influence marginal and internal adaptation of bulk-filled Class I restorations both before and after stressing.
- The internal adaptation of SE Bond/Clearfil AP-X Cuspal coverage restorations was superior to all the other groups tested.

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