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In vivo interfacial adaptation of class II resin composite restorations with and without a flowable resin composite liner

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Abstract The aim of this study was to evaluate in vivo the interfacial adaptation of class II resin composite restorations with and without a flowable liner. In 24 premolars scheduled to be extracted after 1 month, 48 box-shaped, enamel-bordered class II cavities were prepared and restored with a flowable liner (FRC, Tetric Flow/Tetric Ceram/Syntac Single-Component) or without (TRC), cured with three different curing modes: soft start and 500- or 700-mW/cm^2 continuous irradiation. Interfacial adaptation was evaluated by quantitative scanning electron microscopic analysis using replica method. Gap-free adaptation in the cervical enamel (CE) was observed for FRC and TRC in 96.2 and 90.2%, for the dentin (D) in 63.6 and 64.9%, and for occlusal enamel (OE) in 99.7 and 99.5%, respectively. The difference between the two restorations was not statistically significant (ns). Significant better adaptation was observed for OE than CE and D ($p<0.01$), and for CE than D ($p<0.01$). Gap-free adaptation with the soft-start and 500- and 700-mW/cm2 continuous-curing modes was observed for CE: 88.7%, 92.7%, 97.9% (ns); OE: 99.8%, 98.7%, 100% (ns); and D: 64.0%, 63.9%, and 64.6% (ns), respectively. It can be concluded that neither the use of flowable resin composite liner nor the curing mode used influenced the interfacial adaptation.

Keywords Clinical study · Light curing · Sandwich · Scanning · Soft start

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Introduction

Light-cured resin composites (RCs) have been accepted as an alternative to amalgam in class II cavities, although polymerization shrinkage is still a problem [1, 2]. Shrinkage stresses may cause adhesive failures at the resin composite/tooth structure interface and/or cohesive failures within the tooth or restorative material [3–5]. These may result in post-operative sensitivity, recurrent caries or pulpal injury. Different light-curing techniques such as soft start and pulse curing and different modes of sandwich restorations have been suggested to reduce the shrinkage stress [6–14]. The reduced initial irradiance in the soft-start and pulse-cure technique may result in slower development of stiffness of resin composites and may prolong the compensating flow during polymerization [3, 11–13]. In general, a more rapid polymerization and a higher degree of conversion will lead to increased shrinkage stress [3]. On the other hand, a high conversion is important to obtain good mechanical properties and high biocompatibility [2, 15, 16]. Light-cured resin composite sandwich restorations laminated with chemically cured glass ionomer cement were introduced in the late 80s. Prati [17] showed that the laminate reduced early marginal microleakage in class II restorations. However, a high clinical failure rate with 75% replacements after 6 years was reported [8]. Recently, a modified open-sandwich restoration laminated with resin-modified glass ionomer cement showed an acceptable durability after 6 years in extensive class II restorations [18].

It is generally accepted that the use of materials with a low modulus of elasticity reduces the formation of cervical gaps and marginal leakage [19]. Application of a flowable resin composite liner before the placement of resin composite might function as an elastic liner and prevent gap formation at the internal margin [19, 20]. Labella et al. [21] stated that the relatively high polymerization shrinkage of flowable resin composites may be offset by the low modulus of elasticity of these materials and allows local distortion of the material rather than debonding. Several in vitro studies have investigated the effect of the use of a flowable resin composite liner on marginal seal of resin composite restorations with contradictory results [14, 22–27].

The aim of this study was to evaluate in vivo the interfacial adaptation of class II resin composite restorations with and without a flowable resin composite liner through a quantitative scanning electron microscopic marginal analysis technique. The resin composite was placed with a horizontal multilayering technique and three curing modes were used: soft start and a 500- or 700-mW/cm^2 continuous irradiation. The first hypothesis tested was that the use of flowable resin composite would improve the interfacial adaptation, and the second that the soft-start curing mode would improve interfacial adaptation.

Materials and methods

Forty-eight box-shaped class II restorations were placed by one dentist (AL) in 24 sound and caries-free premolars scheduled for extraction because of orthodontic reasons. The 11 patients, with a mean age of 12.3 years (range, 11–13), were asked to participate in the study at a time that was coincidental with the start of the study. Each patient provided informed and parental consent to participate in the study, which was approved by the Ethics Committee of the University of Umeå. The teeth were anaesthetised with 3% Citanest-Octapressin (Astra, Södertälje, Sweden). In each tooth a mesial and distal box-shaped class II cavity was prepared with a cylindrical diamond bur in a high-speed hand piece using copious water cooling. No bevels were prepared and all margins were placed in enamel. The buccolingual distance of the preparation was 4 mm (±0.5–1 mm) and the axial depth was 6 mm (±0.5–1 mm).

The prepared cavities of each tooth were randomly assigned to one of the two experimental groups: with flowable resin composite liner (FRC; Syntac Single-Component/Tetric Flow/Tetric Ceram, Ivoclar/Vivadent, Schaan, Liechtenstein) or without (TRC; Syntac Single-Component/Tetric Ceram) (Table 1). The operative field was isolated with cotton rolls and a saliva suction device was used. Steel matrix bands (Hawe Neos Dental, Bioggio, Switzerland) were applied with a Nyström retainer (Dentatus, Stockholm, Sweden) and used in combination with careful application of wooden wedges. The resin composite restorations were preceded after etching the cavities with 35% phosphoric acid (Ultra-Etch, Ultradent Products Inc., South Jordan, UT), 15 s for enamel and 5 s for dentin followed by water rinsing for 20 s and briefly air-drying, allowing the wet bonding technique to be used. Syntac Single-Component was placed in two layers with a disposable brush. The first coat was applied during 20 s, the surfaces were slightly air-dried to remove the solvent and the resin was light cured for 20 s. A second coat was applied, air-dried and light cured for another 20 s. For the FRC cavity, a first increment of Tetric Flow was applied not exceeding 2 mm. In the TRC cavity, the first increment was Tetric Ceram, also not exceeding 2 mm. Both restorations were then simultaneously light cured for 40 s. The following resin composite increments did not exceed 2 mm and were each light cured for 40 s. Three curing units with soft-start and continuous curing modes and different irradiation were used (Table 2). In the soft-start mode the irradiance increased to full irradiance during the first 15 s, remaining at this level for the rest of the curing period. All units were checked at the start with a radiometer (Optilux 100; Kerr/Demetron, Danbury, CT). For each curing unit, eight teeth were used. The restorations were finished with fine diamond burs (Drendel+Zweilling, Berlin, Germany) and polished with rubber points and cups (Identoflex, Buchs, Switzerland).

After 1 month functioning time the premolars were extracted. Care was taken not to damage the restorations by using an initial elevation technique, followed by careful application of forceps to the root surfaces. Immediately after extraction the teeth were carefully cleaned under flowing water and thereafter stored in a chlorhexidine digluconate solution (Corsodyl 2 mg/ml, SmithKline Beecham, Brentford, England) for 1 week before preparation of the teeth for scanning electron microscopy (SEM).

Scanning electron microscopy

To observe interfacial adaptation of the restorations, the teeth were sectioned in a mesiodistal direction through the middle of the restorations with a low-speed diamond disc (Horico; Hopf, Ringleb & Co, Berlin, Germany) in a hand piece with copious water spray [28]. The sections were then planed with medium and fine polishing discs (Sof-lex discs, 3M ESPE, St. Paul, MN) under continuous water spray to minimize smear layer formation. To remove the smear layer the sections were slightly etched with 35% phosphoric acid for 3–5 s, rinsed with water for 20 s and briefly dried.

Table 1 Restorative materials investigated

Material	Type	Batch no./Shade	Manufacturer
Tetric Ceram	Bis-GMA, urethane dimethacrylate, triethylene glycoldimethacrylate, inorganic fillers, catalysts, stabilizers, pigments; 77.5 wt.% filler content	B37704/A3	Ivoclar Vivadent, Schaan, Liechtenstein
Tetric Flow	Bis-GMA, urethane dimethacrylate, triethylene glycoldimetacrylate, inorganic fillers, catalysts, stabilizers, pigments; 68 wt.% filler content	E0037/A3	Ivoclar Vivadent, Schaan, Liechtenstein
Syntac Single-Component	Maleic acid, HEMA, methacrylate modified polyacrylic acid, initiators, stabilizers, water	A 15134	Ivoclar Vivadent, Schaan, Liechtenstein

Table 2 Curing units, curing modes and curing times used

Curing unit	Type/Mode	Irradiance (mW/cm^2)	Curing time (s)	Manufacturer
Demetron 2000	QTH/continuous	500	20	Demetron, Danbury, CT
			40	
Astralis 7	QTH/continuous	700	20	Vivadent, Schaan, Liechtenstein
			40	
Elipar Trilight	QTH/soft start	650	40	ESPE, Seefeld, Germany

Replica impressions were then made of the buccal and lingual sections with a vinylsilicone impression material (President light body, Colténe, Altstätten, Switzerland) [28]. The negative impressions were replicated (Epon, TEM bedding-in-resin, Fluka AG, Switzerland) to obtain positive casts. The casts were prepared for SEM by mounting on metal stubs and coating with gold by a standard evaporation technique. All interfaces were evaluated with SEM (Cambridge Stereoscan Microscope) at ×200 and ×1000 magnification and completed when necessary with other magnifications. The quality of the interfacial adaptation and degree of interfacial irregularity were compared with standard microphotographs of marginal degradations [29]. For each restoration, the final evaluations were made double blind on the microphotographs by two evaluators. The marginal breakdown scores are shown in Table 3 [4, 28]. Scores of 1–3 represent an acceptable adaptation with an increase of irregularities at the interface and scores 4 and 5 non-acceptable adaptation with hairline crack or gap. The quality of the margins, degree of marginal opening and breakdown were described as percentages of the total length of the interfacial margins examined on the microphotographs.

Statistical analysis

The Statistical Package for Social Sciences version 11.0 (SPSS, Chicago, IL) was used to process the data. The interfacial adaptation scores are given as relative frequencies of the total lengths of the evaluated interfaces for the two restorative materials used and the three light-curing units. Differences between the FRC and TRC groups were statistically analysed by Mann–Whitney *U* test and exact test (Monte Carlo). Differences between gap-free scores for occlusal enamel, cervical enamel and dentin for both groups were tested with Wilcoxon signed rank test and exact test (Monte Carlo). The level of significance was set at $p<0.05$.

Table 3 The interfacial breakdown scores

1	Good adaptation, no interfacial opening, no deficiencies
2	Slight marginal irregularities
3	Severe marginal irregularities, no crack visible
4	Hairline crack, wider gap with bottom visible
5	Severe gap, bottom hardly or not visible

Results

Four tooth sections, three Demetron 2000 and one Astralis 7, were damaged during sectioning and could not be analyzed. The scores of the interfacial adaptation evaluations of all FRC and TRC restorations for the different tooth tissues, cervical enamel (CE), dentin (D) and occlusal enamel (OE), are shown in Table 4. Gap-free adaptation (score 1–3) for the cervical enamel part of the restorations was observed in 96.2% for the FRC and in 90.2% for the TRC, for the dentin part in 63.6 and 64.9% and for the occlusal enamel part in 99.7 and 99.5%, respectively (Figs. 1 , 2, 3, 4). The differences in scores between the FRC and TRC were not statistically significant. The gap-free scores for occlusal enamel for both groups were statistically significant, better than for cervical enamel and dentin, and the gap-free scores for cervical enamel statistically were significant, better than for dentin, OE>CE> D ($p<0.01$). Cervical enamel fractures parallel to the margins were observed in 21.7% for the FRC group and 20.8% for the TRC (Fig. 5). For the occlusal enamel the values were 2.4% for both groups. No dentin fractures were observed in the experimental groups. There was no statistical significance between the two groups.

The scores for each of the three light-curing units are shown in Table 5. Since there were no statistical differences between the two restoration techniques for each curing unit the restorations were pooled. Gap-free scores for cervical enamel were 92.7 (Demetron 2000), 88.7 (Elipar TriLight) and 97.9 (Astralis 7); for dentin 63.9, 64.0 and 64.6%; and for occlusal enamel 98.7, 99.8 and 100%, respectively. The differences were not statistically significant.

Table 4 Interfacial adaptation scores for all class II resin composite restorations, pooled with regard to light-curing modes with (FRC) and without flowable resin composite liner (TRC), determined as relative frequencies of the interfacial margins examined (%)

		Scores (%)						Enamel fractures
		No	1	2	3	4	5	
CE	FRC	22	83.2	5.0	8.0	3.8	0	21.7
CE	TRC	22	87.7	0.6	1.9	5.2	4.6	20.8
D	FRC	22	14.6	16.0	33.1	32.8	3.6	0
D	TRC	22	7.7	11.8	45.3	32.9	2.2	0
OE	FRC	22	97.2	1.4	1.1	0.2	0.1	2.4
OE	TRC	22	98.2	0.7	0.6	0.5	0	2.4

Score 1–3: gap-free margins, score 4–5: margins with openings
CE cervical enamel, *D* dentin, *OE* occlusal enamel

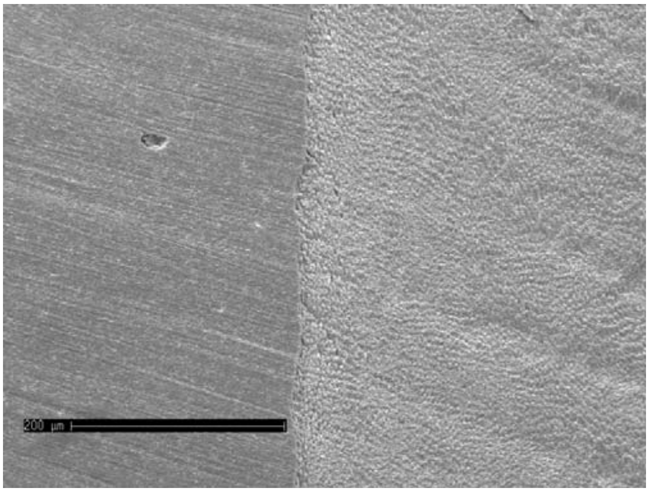

Fig. 1 Excellent interfacial adaptation (score 1) in the occlusal enamel part of a resin composite restoration without flowable resin composite liner. Original magnification ×200

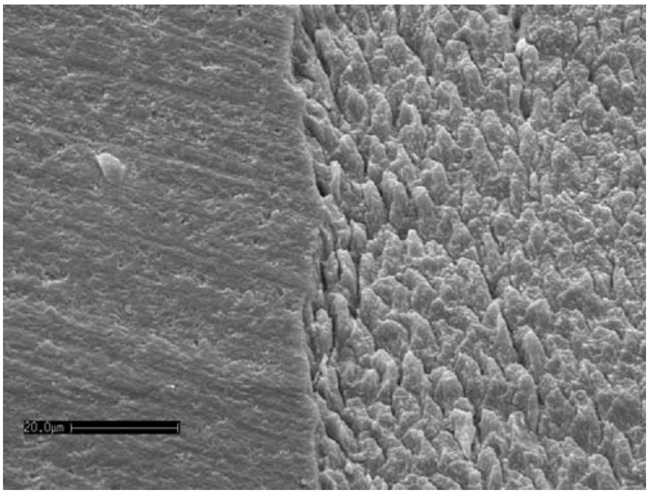

Fig. 2 Higher magnification of Fig. 1. Original magnification ×1,000

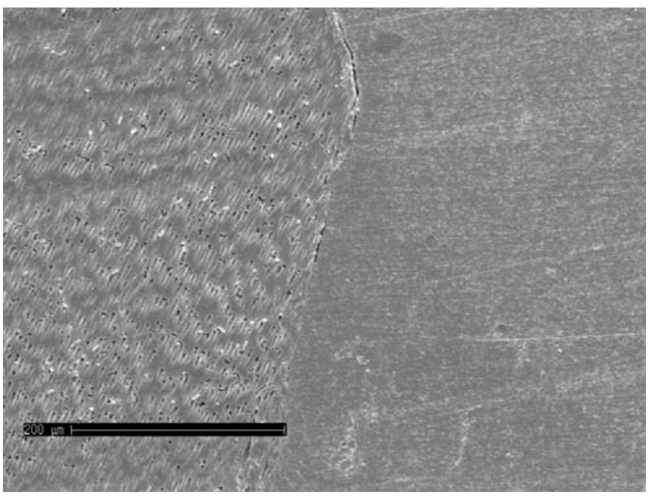

Fig. 3 Gap formation (score 5) in the dentin part of a resin composite restoration with flowable resin composite liner. Original magnification ×200

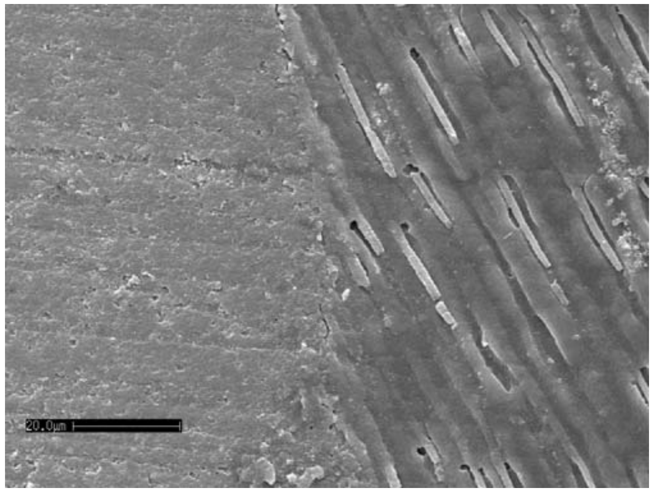

Fig. 4 Good interfacial adaptation (score 1) to dentin in a resin composite restoration without flowable resin composite liner. Long tags can be observed in dentin tubulus. Original magnification ×1,000

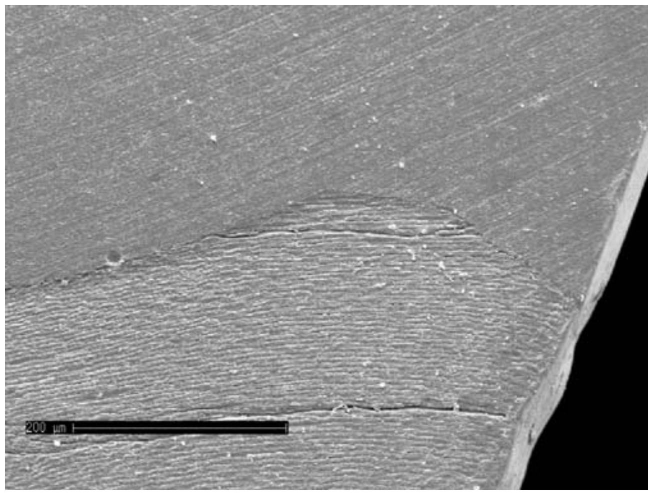

Fig. 5 Enamel fractures parallel to the cervical margins in a resin composite restoration without flowable resin composite liner. Excellent interfacial adaptation (score 1). Original magnification ×200

Discussion

The most common test to study interfacial adaptation is by dye penetration. The experimental teeth are immersed in a dye solution and after sectioning the teeth, the degree of dye penetration is evaluated with different types of microscopes [30].These tests are relatively easy and cheap to perform since they are mostly done on extracted teeth. SEM is another widely used method to evaluate interfacial adaptation. Direct observation by SEM is difficult due to the presence of the liquid phase in the tooth tissues. The vacuum procedure during SEM causes artefacts, like cracks, which can look like true gap formation if the liquid is not removed in a proper way [31]. By using a replica method, artificial gap formation can be avoided. Grundy showed a high degree of agreement comparing by SEM directly observed

Table 5 Interfacial adaptation scores for all class II resin composite restorations (FRC and TRC pooled) cured with Demetron 2000, Elipar TriLight or Astralis 7, determined as relative frequencies of the interfacial margins examined (%)

	No.	Score (%)					Enamel fractures
		1	2	3	4	5	
Cervical enamel							
Demetron 2000	13	89.2	2.8	0.7	1.9	5.4	12.7
Elipar TriLight	16	74.2	4.6	9.9	9.5	1.8	32.8
Astralis 7	15	93.6	0.9	3.4	1.8	0.3	17.2
Dentin							
Demetron 2000	13	25.0	15.5	23.4	33.0	3.1	0
Elipar TriLight	16	5.3	11.8	46.9	32.3	3.7	0
Astralis 7	15	5.4	14.6	44.6	33.4	1.9	0
Occlusal enamel							
Demetron 2000	13	97.5	0.8	0.4	1.0	0.3	1.3
Elipar TriLight	16	97.4	1.2	1.4	0	0	1.9
Astralis7	15	98.2	1.1	0.7	0	0	3.0

Score 1–3: gap-free margins, score 4–5: margins with openings

specimens with replica models [32]. The use of teeth planned to be extracted for orthodontic reasons makes it possible to study marginal and interfacial adaptation of restorations after functioning in situ [4]. The SEM analysis used in this study is both qualitative and quantitative. A similar method was described earlier by Roulet et al. [29] and was used in earlier in vivo investigations [4, 28, 33, 34].

The quality of the interface between the restoration and the tooth structures was analyzed according to an ordinal scale with increasing degree of marginal deficiencies. Since the scoring system is dependent on the operator's degree of reproducibility, calibration between and within the authors was regularly performed. The inter-examiner reliability gave a kappa value of 0.77. The qualitative and quantitative character of the analysis is represented by different scores measured on an SEM picture and transformed to percentages of the total length measured.

In this study, the adaptation to dentin when both resin composite materials are pooled was 64.1%, which is inferior compared with earlier studies [4, 28, 34]. This is probably caused by the bonding capacity of the dentin adhesive system used. Vargas et al. demonstrated that single-bottle adhesives produced hybrid layers of varying thicknesses, ranging from no discernible layer for Syntac Single-Component to a 50-μm-thick layer when using filler-loaded primer systems [35]. They also showed low shear bond strength for the one-bottle adhesive system, Syntac Single-Component. Manhart et al. [36], investigating marginal quality and microleakage of several restorative systems in class V cavities, showed statistically higher dentin leakage with Syntac Single-Component than for a filled single-bottle adhesive. The inferior interfacial adaptation of the adhesive was also observed recently in a similar SEM evaluation [37]. It may be that the absolute values of interfacial adaptation found are material specific, but we believe that the relationships found between the restoration techniques and curing units are universal.

Ernst et al. investigated in vitro the marginal integrity of different resin-based composites for posterior teeth and showed that the use of a flowable composite in addition to conventional restorative material seems to have a clinical benefit [38]. These results were supported by Peutzfeldt and Asmussen, who found that the use of flowable composite as first increment significantly reduced dye leakage at dentin margins in class II restorations [14]. Chuang et al. examined the effect of flowable composite liner on marginal microleakage and internal voids of class II restorations. They observed no improvement in cervical marginal seal, but a reduction of internal voids [39].

In a recently published study, Chuang et al. [40] studied the influence of thickness of the flowable liner on marginal quality and internal voids with dye-penetration test and SEM. They used flowable composite in three different thicknesses: (1) ultrathin [41], where the flowable composite is not cured before the next resin composite layer is placed in the cavity, (2) thin (0.5 and 1.0 mm) and (3) thick (approximately 2 mm), the last two cured before application of the next resin composite layer. These were compared with restorations made without flowable composite as liner. They found that restorations made with thick, precured flowable composite as first layer presented the highest percentage of marginal openings and that the ultrathin group presented the lowest. However, the precured groups showed significant reduction in interface and cervical voids. The thick precured group is comparable to the method used in this study.

For the bonding system and the resin composite materials used in this study, no statistical significant difference in interfacial adaptation was found between class II enamel-bordered resin composite restorations lined with flowable resin composite and without. The first hypothesis was therefore not accepted. No clinical benefit can be expected by the use of the flowable liner. To our knowledge, only one clinical study has been published investigating the clinical performance of a resin composite material with and without a flowable composite liner [42]. After 2 years, no statistically significant difference in the overall survival rate between the two groups was found.

In this study, the influence of three different curing modes was evaluated. Demetron 2000 represented a standard curing unit, with a power density of 500 mW/cm^2, Astralis 7 had a higher power density of 700 mW/cm^2 and Elipar TriLight, in soft-start mode, a power density of 650 mW/cm^2. The use of soft-start mode has been suggested to prolong and increase the compensating flow of the resin composite during the initial polymerization [3, 11–13]. Sahafi et al. showed that soft start did not improve the marginal adaptation of two resin composites bonded to dentin cavities compared with conventional curing [43]. Amaral et al. found no statistically significant difference regarding marginal leakage and gap formation between soft-start, pulse delay and conventional curing techniques [44]. These findings were confirmed in the present study, showing no statistically significant difference between the three curing modes. The second hypothesis was therefore not accepted.

Conclusions

For the bonding system and the resin composite materials used in this study, no improvement was shown in interfacial adaptation of class II restorations with the use of flowable liner in class II enamel-bordered resin composite restorations. The use of the soft-start or 500- or 700-mW/cm^2 continuous power density curing units did not influence the quality of the interfacial adaptation.

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