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In vitro evaluation of marginal and internal adaptation after occlusal stressing of indirect class II composite restorations with different resinous bases

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Composite inlays are indicated for large cavities, which frequently extend cervically into dentin. The purpose of this study was to compare *in vitro* the marginal and internal adaptation of class II fine hybrid composite inlays (Herculite, Kerr) made with or without composite bases, having different physical properties. Freshly extracted human molars were used for this study. The base extended up to the cervical margins on both sides and was made from Revolution (Kerr), Tetric flow (Vivadent), Dyract (Detrey-Dentsply) or Prodigy (Kerr), respectively. Before, during and after mechanical loading (1 million cycles, with a force varying from 50 to 100 N), the proximal margins of the inlay were assessed by scanning electron microscopy. Experimental data were analysed using non-parametric tests. The final percentages of marginal tooth fracture varied from 30.7% (no base) to 37.6% (Dyract). In dentin, percentages of marginal opening varied from 9.2% (Tetric Flow) to 30.1% (Prodigy), however, without significant difference between base products. Mean values of opened internal interface with dentin varied from 11.06% (Tetric Flow) to 28.15% (Prodigy). The present results regarding dentin adaptation confirmed that the physical properties of a base can influence composite inlay adaptation and that the medium-rigid flowable composite Tetric Flow is a potential material to displace, in a coronal position, proximal margins underneath composite inlays.

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In direct class II adhesive restorations, incremental methods (1–5), the use of ceramic inserts (6) or the application of a base (3,7) have been proposed to reduce the stresses developed within the tooth-restoration system due to composite polymerization shrinkage. However, these techniques are not yet considered sufficiently effective to be applied in large class II restorations in consideration of the polymerization shrinkage of current materials (8–10) and spontaneous post-curing that takes place over several days after composite insertion (11, 12). In such conditions, the semi-direct or indirect techniques are the adequate alternatives (13).

Because large cavities often extend close or below the cemento-enamel junction, rubber dam placement as well as cementation is complicated. The application of a base underneath semi-direct and indirect restorations therefore represents a common, non-invasive alternative to a surgical crown lengthening in order to relocate cavity margins supra-gingivally (14). The base also fulfils additional requirements, such as reinforcing undermined cusps, filling undercuts and providing the necessary geometry for an inlay/onlay restoration.

Functional loading and thermal cycling are additional sources of stress that further increase the risk of adhesive or cohesive failures. Therefore, while awaiting further improvements in dentin bonding efficacy and reliability and a significant reduction of composite polymerization shrinkage, efforts have also to be made to favor other compensatory phenomena (8, 9, 15, 16). The elastic modulus (E) of the restorative material, among other physical properties, is of great importance to evaluate their potential stress-absorbing effect (3,7). Depending on the stiffness and deformation capability of the material, stress within the adhesive interface can be lowered (elastic modulus lower or matching the one of surrounding structures) or just passed onto the next interface without absorption (high elastic modulus). The ideal E-modulus of a base material has yet to be established.

In indirect restorations, the bond strength between the resinous base and luting composite and between the luting composite and inlay, resulting from micromechanical retentions or copolymerization, was found to be critical (17, 18), especially after restoration post curing. If this interface would be a weak component of the restoration, it might have significant consequences. To date, however, no significant rate or even occasional debonding or loss of adhesively luted restorations has been documented.

The aim of this *in vitro* study was to test the hypothesis that the elastic module of composite bases can influence the marginal and internal adaptation of class II indirect composite restorations after simulated occlusal fatigue loading. Attention was also paid to the quality of the different interfaces in order to identify the most vulnerable areas of the restoration.

Material and methods

Specimen preparation

Freshly extracted human third molars were used for this study. The inclusion criteria were absence of carious lesions and a complete root formation. The teeth were stored in a sodium azide solution (0.2%) at 4°C until the experiment onset.

For each specimen, the root length was adjusted to fit in the test chamber of the mechanical loading device (Department of Cariology, Endodontics & Pedodontics; Laboratory of Electronics of the Medicine Faculty; University of Geneva) (Fig. 1). After the specimen was properly positioned, it was fixed with light-curing composite on a metallic holder (Baltec; Balzer, Liechtenstein); then, the root base was embedded with self curing acrylic resin to complete the tooth stabilization. Class II cavities (MOD) were prepared, with proximal margins located 1.0 mm below (mesially) and above (distally) the cementum–enamel junction (Fig. 1). The dimensions of the tapered preparations were 4.0 mm wide and 2.0 mm deep at the bottom of the proximal box, and 3.0 mm wide and deep for the occlusal isthmus; all walls had 10–15° of divergence. The cavities were prepared using coarse diamond burs under profuse water spray (Cerinlay no. 3080.018 FG; Intensiv, Viganello, Switzerland) and finished with fine grained burs of the same shape (Cerinlay no. 3025.018 FG; Intensiv).

The 40 prepared teeth were randomly assigned to one of the five experimental groups, corresponding to the four different base materials, and the control group ($n = 8$).

Restorative procedures

The same restorative and luting composite material and the same multifunctional adhesive were used for all groups (Herculite, Nexus and Optibond FL, Kerr; Romulus, CA, USA).

After completion of the preparation, enamel was selectively etched for 20 s prior to a 10-s full-cavity etching. The cavity was thoroughly rinsed for 30 s and gently air-dried (3 s air spray) so that conditioned dentin was kept slightly moist. The primer and adhesive (Optibond FL; Kerr) were then placed, according to the manufacturer's instructions. The bonding resin was light-cured for 40 s. Except for the control group specimens (CTRL), a base material was applied in order to create a layer of approximately 1 mm using a transparent matrix. The base extended to the cavity margins on both sides (Fig. 2). The material was light-cured for 60 s. The light curing unit (Visilux XL 3000; 3M, St Paul, MN, USA), equipped with a new bulb, had an illumination intensity of 525 mW cm^{-2}.

Different base materials were used for each of the four experimental groups: two flowable microhybrid composites, Revolution (Kerr) (REVO) and Tetric Flow (Vivadent, Schaan, Liechtenstein) (TFLO); a compomer, Dyract (DeTrey-Dentsply; Constance, Germany) (DYRA); and a restorative composite, Prodigy (Kerr) (PRODI).

For the control group, dentin and enamel surfaces were only covered by OptiBond FL. Material characteristics and group description are given in Tables 1–3.

After base application, cavity margins were refined again with fine diamond burs (Cerinlay no. 3025.018 FG), and impressions were made with an irreversible hydrocolloid (alginate) impression material (Blueprint Cremix; DeTrey-Dentsply). Hard stone (GC Fujirock EP; Fuji) individual dies were prepared. A very thin layer of wax was placed on each die as an isolation medium but without covering preparation margins. All inlays were made with the same microhybrid composite (Herculite enamel, shade A2; Kerr). The inlays were also submitted to a photo-thermal treatment (T = 110°C) for 7 min in a post-curing unit (D.I 500 oven; Coltène, Alstätten, Switzerland). The internal surfaces of the inlays were sandblasted with 50 μm aluminum oxide at a 2 bar pressure.

Before adhesive cementation, prepared teeth were kept for 1 wk in a water-saturated atmosphere. Then, cavities were again acid-etched for 30 s to condition enamel margins and to remove any residual contaminant from the cavity surfaces. The three components of the Nexus adhesive

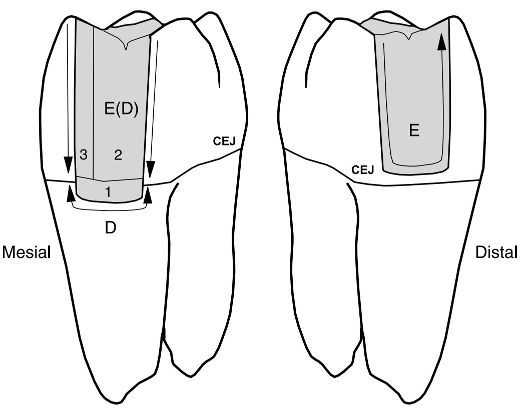

Fig. 1. Configuration of the class II preparation used in this study, showing the different areas considered for the marginal adaptation evaluation.

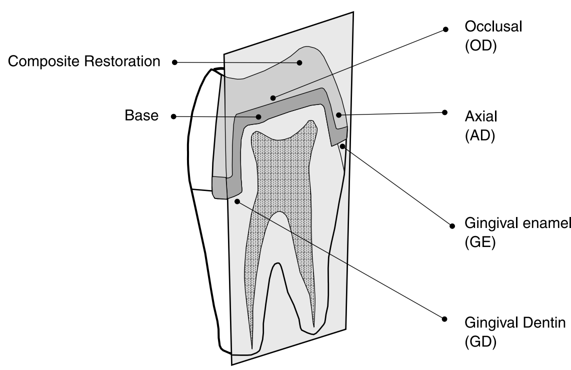

Fig. 2. Restoration configuration for test samples and areas considered for the internal adaptation evaluation.

Table 1

List of products under investigation, common to all groups

Product	Product name (manufacturer)	Batch number
Conditioner	Ultraetch (Ultradent; UT, USA)	–
Dentin-bonding-agent I	Optibond FL (Kerr, Romulus, CA, USA)	Primer: 712501 Bonding resin: 712501
Dentin-bonding agent II	Nexus (Kerr)	1. Tooth primer: 707081 2. Activator: 708372 3. Catalyst: 709528
Luting cement	Nexus (Kerr)	Base paste: 712550 Catalyst paste: 806913
Restorative material	Herculite (Kerr)	910690

Table 2

List of base materials and group coding

Group	Product name (manufacturer)	Batch number
REVO	Revolution (Kerr)	710266
TFLO	Tetric Flow (Vivadent)	818753
DYRA	Dyract (DeTrey Dentsply)	9605041
PRODI	Prodigy (Kerr)	708037

(Kerr) were applied to all surfaces of the preparation, and the inlays were cemented following usual procedures, respecting a 1 : 1 ratio for the luting composite base and catalyst (Nexus). Each restoration surface was light-cured for 60 s. Restorations were immediately finished and polished with flame and pear-shape fine diamonds burs (40 μm then 25 μm grain size) (Intensiv nos. 4205L, 4255, 5205L and 5255) and discs (Pop On XT; 3M).

Mechanical loading

The stress test was carried out 24 h after cementation. The pulp chamber was penetrated buccally or palatally with a tube (sealed with DBA, Optibond, FL, USA), which was connected to a simulated pulpal circulation of saline water under a pressure of 14 cmH_2O (19,20). All specimens were submitted to 250 000 cycles with 50 N loading force, 250 000 cycles with 75 N and 500 000 cycles with 100 N, for a total of 1 000 000 loading cycles. The axial force was exerted at a 1.5-Hz frequency following a one-half sine wave curve. These conditions are taken to simulate about 4 yr of clinical service (21,22). Restored teeth were contacted by antagonist artificial cusps, made of stainless steel with a hardness similar to natural enamel (Vickers hardness: enamel = 320–325; steel = 315); the diameter of the cusps was 4 mm, and they contacted the restoration's occlusal surface about 1.5 mm out of the central fosse. By having the specimen holder mounted on a rubber disc, a sliding movement of the tooth was produced between the first contact on an inclined plane and the central fossa. The functions of this experimental device are similar to the machine developed by KREJCI *et al.* (21).

Specimen evaluation

Before the fatigue test, as well as after completion of each loading phase, the restoration's margins were cleaned with a brush and fine pumice and acid-etched with 37% H_3PO_4 gel (30 s on enamel and 10 s on dentin). Then, gold-sputtered epoxy resin replicas (Epofix; Struers, Rødrove, Denmark) were made from polyvinylsiloxane impressions (President light and heavy body; Coltène). The following proximal segments were observed: enamel margins on the distal and mesial sides (the gingival margin being in enamel only on the distal side) and dentin margins (mesial side) (Fig. 1). The proximal tooth-restoration interface was analysed quantitatively by scanning electron microscopy (SEM) (Digital SEM XL20; Philips, Eindhoven, The Netherlands) by employing a recognized evaluation method (23, 24). The following evaluation criteria were applied: continuity, overfilling, underfilling, marginal opening, marginal restoration or tooth fracture. The restoration margins were observed at a standard ×150 magnification. When necessary for the assessment accuracy, higher magnifications were used. Results for the restoration marginal adaptation, before and following the different loading phases, are expressed as percentages of 'marginal tooth fractures' for enamel margins (including both distal (E) and mesial (ED) tooth sides) or 'marginal opening' at the dentin margins (D). Percentages were calculated as the ratio between the

Table 3

Physical properties of base materials (manufacturer's data)

Product (manufacturer)	Filler content (wt%/v%)	E-modulus* (GPa)	Flexural strength (MPa)	Compressive strength (MPa)	Polymerization shrinkage (%)
Revolution (Kerr)	55.0/unknown	4.7	108	346	5.1
Tetric Flow (Vivadent)	67.8/43.8	7.6	110	230	4.4
Dyract (DeTrey Dentsply)	72.0/53.0	7.6	97	245	2.8
Prodigy (Kerr)	77.0/57.5	11.0	140	469	2.9

*Enamel E-module = 80 Gpa. Dentine E-modulus = 14–18 GPa (48–51).

cumulated distance of all segments showing each morphological evaluation parameters and the whole interface length (enamel: E plus ED, or dentin). The restoration occlusal adaptation was not assessed.

At completion of the mechanical loading, the teeth were embedded in a slow, self-curing epoxy resin (Epofix) and sectioned mesio-distally into three parts, with a central slice of 1 mm using a slow rotating saw (Isomet 11-1180; Buehlers, Lake Bluff, NY, USA). The sections were successively polished with 200, 400 and 600 grit SiC paper and etched for 1 min with a 37% H_3PO_4 gel. Impressions were then taken from the four available surfaces for fabricating gold-sputtered resin replicas. In order to avoid observation artifacts, special care was taken not to dehydrate the samples prior to taking the impression with a 'moisture tolerant' material (President light body). The restoration internal adaptation was assessed quantitatively on the gold-sputtered replicas under the SEM at a ×150 magnification and was judged according to two criteria: continuity and interfacial opening. Results are expressed as the percentage of 'interfacial opening 'relative to the whole dentin interface (Total) and in addition, to the following dentin segments: gingival enamel (GE), gingival dentin (GD), axial dentin (AD), and occlusal dentin (OD). For each specimen, results are expressed as a mean value resulting from the evaluation of the four sections (sample percentage represents an average of the data obtained for each section). Respective percentages (relative to each of the evaluation criteria or location) are calculated using the same technique as described for the marginal quality evaluation. The localization of bonding failures within the adhesive interface was tentatively identified, using higher magnifications (up to ×1000). A single trained evaluator performed all SEM observations.

Two internal sections of each group were further polished to a high gloss (wet-sanding up to a 4000 grit SiC sandpaper, LaboPol-II; Struers). After etching the surface for 30 s with 1% HCl, samples were immersed in hexamethyldisilizane (Merck, Darmstadt, Germany) for 10 min Thereafter, samples were placed on a filter paper, inside a covered glass vial and air-dried at room temperature for 24 h (25). Sections were then gold-sputtered for a direct SEM observation of adhesive interfaces at higher magnifications (×300 to ×3000). An attempt was made to identify the different adhesive interface components and to confirm the localization of failures, as observed on standard replicas.

All results were submitted to a non-parametric statistical analysis. The Kruskall–Wallis and Nemenyi tests (26) served for comparing the restorative methods. The Friedman and Wilcox–Wilcoxon tests (26) served for evaluating the influence of the number of cycles on the marginal adaptation. All tests were carried out at a 1% or 5% level of significance.

Results

Marginal adaptation

The percentages of 'over-filled 'and 'under-filled 'margins presented insignificant values; these results are therefore not reported. Mean percentages of 'marginal 'tooth fracture' and 'marginal opening' before and after the different stress phases are reported in Table 4, together with their statistical analysis.

For preloading marginal adaptation, samples with a Dyract base (DYRA) showed higher percentages of marginal tooth fracture compared with samples without base (CTRL). Otherwise, no significant difference was seen for restoration marginal adaptation to enamel or dentin after further loading phases.

In all groups, marginal tooth fractures (or fissures) were present in enamel before the fatigue test (12.7% (CTRL) to 25.9% (DYRA)) (Fig. 3). The proportion of these defects progressively increased, due to mechanical loading (2.5% (CTRL 250 000 cycles) to 37.6% (PRODI 10^6 cycles)). In dentin, the initial percentages of marginal

Table 4

Results of marginal restoration adaptation (expressed as mean percentages of 'marginal tooth fracture' and 'marginal opening' at the proximal enamel and dentin margins; standard deviation in parenthesis

Groups (No. of cycles)	Location	CTRL	REVO	TFLO	DYRA	PRODI
0	Enamel	12.74 A, a (6.45)	20.96 A, a, b (15.70)	14.75 A, a, b (6.73)	25.94 A, b (6.78)	17.74 A, a, b (8.33)
250 000		22.51 A, C (9.15)	27.71 A, B (1.10)	27.69 A, B (10.38)	26.04 A, B (6.36)	31.75 A, C (11.14)
500 000		27.19 B, C (9.27)	34.33 B (12.45)	32.56 A,B (13.93)	31.5 A, B (13.1)	38.98 B, C (10.78)
1 000 000		30.71 B, C (10.89)	35.31 A, B (15.25)	35.09 B (15.86)	34.59 B (11,37)	37.56 B, C (7.77)
0	Dentin	1.35 A (3.03)	4.85 A (6.90)	2.15 A (3.34)	3.25 A (4.17)	13.45 A (29.44)
250 000		4.40 A, C (7.34)	13.07 A, C (13.57)	4.57 A, C (6.38)	9.55 A, C (9.57)	20.61 A, C (30.06)
500 000		7.25 B, C (11.00)	17.85 B, C (16.71)	7.54 B, C (4.92)	21.33 B, C (18.23)	26.88 B, C (30.6)
1000 000		15.88 B (21.60)	27.44 B (15.03)	9.21 B, C (4.53)	29.24 B, C (22.68)	30.09 B, C (34.45)

For comparison between the number of cycles (columns), means with same capital letter are not statistically different at $P = 0.05$ using the Friedman and Wilcox–Wilcoxon tests F-test. For comparison between groups (rows), means with same lower case letter are not statistically different at $P = 0.05$ using the Kruskall–Wallis and Nemenyi tests. No significant difference was found for columns or rows without letter; $n = 8$ per group.

opening were low (1.35% (CTRL) to 13.45% (PRODI)) and then also increased significantly following mechanical stresses (4.4% (CTRL 250,000 cycles) to 30.1% (PRODI 10^6 cycles)). Although not significantly different from other groups, TFLO and CTRL exhibited the lowest percentages of marginal opening in dentin, throughout the test.

Internal adaptation

Mean percentages of 'interfacial opening' between the restoration (inlay or base) and cavity walls after the stress test are reported in Table 5, together with the statistical analysis exploring differences between groups and areas.

Nearly no debonding occurred between the base and luting composite or between the luting composite and the restoration; therefore, no result is provided for these interfaces.

The evaluation of internal adhesive interfaces showed scores of total 'interfacial opening' comparable to those obtained for marginal adaptation (11.1% (TFLO) to 28.15% (PRODI)). In some dentin areas (gingival and occlusal) as well as for the total dentin area, PRODI samples showed statistically more interfacial gaps than the CTRL, TFLO and DYRA groups. The internal adaptation to dentin showed only one statistical difference between areas, in the CTRL group, where adaptation to dentin axial walls proved worse than in gingival areas with enamel.

Micromorphological observations of internal interfaces

The most common observation was that debonding predominantly took place at the top of the acid resistant layer, considered as the hybrid layer (Figs 4 and 5). Other failure mechanisms, such as cohesive fractures in

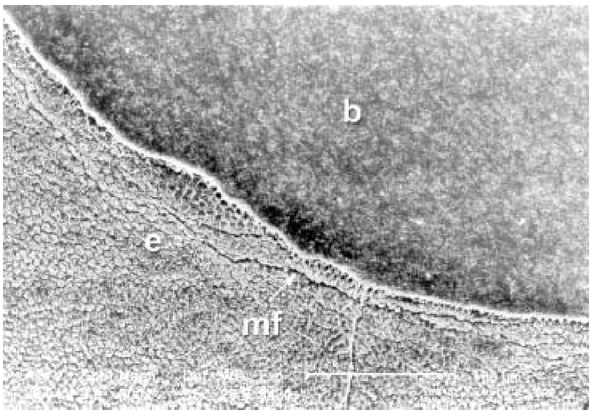

Fig. 3. Scanning electron microphotograph of composite restoration with compomer base. Marginal tooth microfracture was the only defect observed at enamel margins; b, base; e, enamel; mf, marginal fracture.

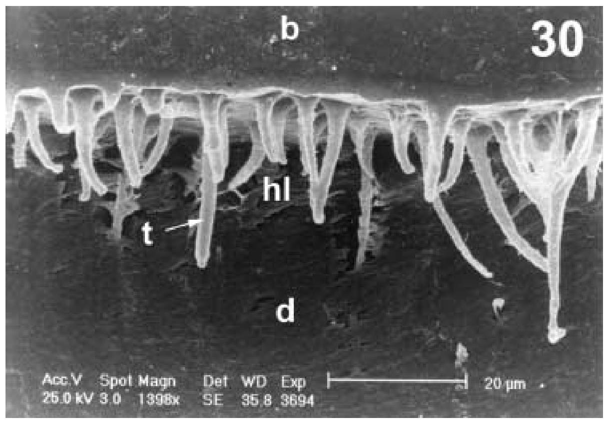

Fig. 4. Scanning electron microphotograph showing the typical appearance of the adhesive interface, with a well-organized hybrid layer and numerous resin tags (section of a sample with a Prodigy base; original magnification ×1398); b, base; d, dentin; hl, hybrid layer; t, resin tags.

Table 5

Internal integrity of the restorations expressed as mean percentages of gap formation; standard deviation in parenthesis

Groups location	CTRL	REVO	TFLO	DYRA	PRODI
DGD	2.40 a, A (3.52)	23.31 a, b (24.64)	7.70 a, b (13.45)	6.58 a, b (11.01)	18.74 b (17.77)
MGD	12.49 A, B (16.62)	16.09 (23.52)	11.06 (15.37)	18.69 (20.45)	27.86 (26.27)
AD	17.39 B (10.96)	26.30 (18.21)	14.98 (9.62)	12.91 (8.83)	28.88 (13.34)
OD	6.80 a, A, B (5.00)	9.95 a, b, c (8.07)	7.09 a, b (6.78)	7.84 a, b, c (6.29)	28.34 c (18.78)
Total	12.54 a, b (7.10)	18.91 a, b, c (13.18)	11.06 b (7.33)	11.29 b (5.12)	28.15 a, c (13.40)

DGD, distal gingival dentin; MGD, mesial gingival dentin; AD, axial dentin; OD, occlusal dentin; Total, whole dentin interface. For comparison between products (rows), means with same lower case letter are not statistically different at $P = 0.05$ using the Kruskall–Wallis and Nemenyi tests. For comparison between locations (columns), means with same capital letter are not statistically different at $P = 0.05$ using the Kruskall–Wallis and Nemenyi tests. No significant difference was found for rows and columns without letter. $n = 8$.

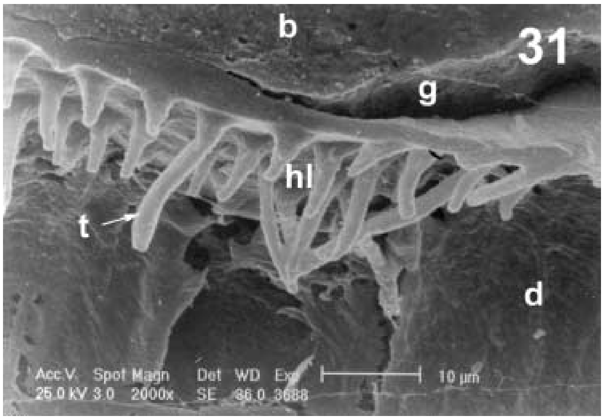

Fig. 5. Scanning electron microphotograph of an adhesive failure. The separation over the hybrid layer is clearly visible; it represents the main failure mode observed underneath adhesive class II restorations. (section of a sample with a Prodigy base; original magnification 2×000); b, base; d, dentin; hl, hybrid layer; t, resin tags.

dentin, within the hybrid layer, a detachment of the hybrid layer at its base, or an absence of hybrid layer, were virtually not observed.

Discussion

Notwithstanding that the samples were fatigued or not, this study revealed clearly that enamel at butt margins with enamel prisms cut parallel to their long axis are prone to fracturing. This is in accordance with the literature (27,28). It must be emphasized that such enamel fracturing seems typical of *in vitro* tests conducted with mechanical loading when cavity margins have a butt design (29–31) but are rarely observed in the absence of a fatigue test (32). However, no study has yet demonstrated the clinical importance of this problem in adhesively luted restorations.

The incidence of gap formation at dentin margins was minimal for the control and Tetric flow base groups but not significantly different from the other groups. Internal adaptation also proved satisfactory with proportions of gaps within the same range as for marginal adaptation. When considering the whole dentin interface, the gingival and occlusal interfaces, the internal adaptation proved less satisfactory for samples with a base of Prodigy. The samples with no base or having a base made of a material with an intermediate rigidity, such as a flowable composite (Tetric flow) or compomer (Dyract), showed less defects initially (CTRL) or after mechanical loading (CTRL, DYRA and TFLO). From the overall results for marginal and internal quality of class II composite inlays, the use of a medium rigidity material such the flowable Tetric Flow seems ideal for use as a base underneath such restorations, when a coronal displacement of dentin or enamel proximal margins is required. Further investigations are, however, needed to determine if the less than optimal results obtained with the restorative material are merely attributed to its higher elasticity modulus or to its different viscosity, potentially affecting its ability to wet the prepared surfaces.

In this study configuration, initial marginal adaptation likely reflects the ability of the restorative technique to limit stress development due to composite polymerization during base application and inlay cementation. Marginal adaptation, during and after mechanical loading, as well as internal adaptation, should reveal the efficiency of adhesive procedures and the restoration-base potential to absorb functional stresses The base configuration and the material physical properties also play a significant role here.

Previous reports indicated that low elastic modulus materials have the potential to better absorb polymerization shrinkage and functional stresses, and therefore enhance direct restoration adaptation when used as a base or liner (7, 33). This finding can be explained by the specific physical properties of flowable composites and compomers; *in vitro* measurements actually showed that these materials exhibit extremely low initial E-moduli (34), and that it exists a linear and inverse correlation between shrinkage stress and composite E-modulus (35, 36). However, a recent study reported higher initial linear shrinkage and contraction stresses for flowable composites than for filling materials (37). Material composition plays a very important role; stress development is directly related to the degree of polymerization shrinkage and material's E-modulus. However, despite these conflicting conclusions, it can be assumed that the base-liner provides a favorable configuration factor (38) (small thickness, ratio bonded to unbonded surfaces close to or inferior to 1). If this is true, the adhesive interface with the cavity floor should not sustain excessive stresses and probably remains cohesive after polymerization of this first layer. Therefore, no or minimal differences should be observed in the initial base adaptation, as verified by the present results.

If a very low E-module of the base initially favors stress absorption (during application of further increments or during cementation), it will also lead to greater deformation under load, which might ultimately provoke adhesive failures. In contrast, a rigid material (especially if more rigid than dentin) might be responsible for higher stress development within the tooth–restoration interface because of its reduced deformation capability. What remains to be determined is the ideal base-lining elasticity module, knowing that potential materials (compomers and flowable composites) exhibit highly dissimilar physical properties. In the present experimental conditions, the flowable composite Tetric flow showed the better potential to be used underneath composite inlays. Although not significantly different, the difference in final marginal adaptation to dentin between Dyract and Tetric flow bases probably reflects a superficial degradation phenomenon around the compomer base, rather than a global change in adaptation quality and biomechanical behavior, as shown by a similar internal adaptation.

Although the efficiency of bonding to post-cured composite is considered difficult or potentially deficient (17, 18, 39), the restoration–cement interface successfully sustained the in vitro loading. The usual procedure of sandblasting the internal inlay surface and covering it with uncured bonding resin proved valuable here, at least for an inlay configuration and the products selected for this study. The present finding did not confirm the need for an additional etching procedure that is considered necessary by some authors (40, 41). Also, no debonding was observed between the base and composite cement.

The internal adhesive interface showed, in most areas, a well-organized hybrid layer and numerous tags. Tag length varied within the normal range described in the literature (5–50 μm) (42). The hybrid layer thickness also lies within reported values for phosphoric acid conditioning (3–10 μm) (43). When present, debonding mostly took place between the hybrid layer and the cement. It was also predominantly observed at the transition lines between the pulpal floor and axial wall (between A and O areas), where the bonding resin layer is the thinnest. This indicates again the fragility of the hybrid layer surface and its critical influence on adhesion performance (42–46). Below a critical thickness (about 100 μm) (47) it is likely that the bonding resin will not fully polymerize, owing to oxygen inhibition, thus precluding an optimal hybrid layer stabilization. This interface can therefore be disturbed during each of the subsequent steps, potentially reducing bond strength in these areas.

Under the experimental conditions of this study, it can be concluded that the hypothesis that elasticity module and physical characteristics, in general, can be used as significant predictors of restoration quality was not fully confirmed. Furthermore, the number of cycles (mechanical fatigue) had a detrimental influence on marginal adaptation of class II composite inlays with no base or with a base made of a flowable composite, restorative composite or compomer. Base materials with an intermediate rigidity (about 7.6 GPa) (Tetric flow and Dyract) produced the best internal adaptation, while the more rigid one (Prodigy, 11 GPa) was responsible for more interfacial defects. As regards the interface morphology, debonding took place predominantly on top of the hybrid layer; this interface was again identified as the weak link in adhesively luted restorations

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