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In Vitro Evaluation of Marginal Adaptation of Direct Class II Composite Restorations Made of Different "Low-Shrinkage" Systems

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Clinical Relevance

The use of bulk-filling restorative materials should lead to a restoration marginal quality comparable to conventional and so-called low-shrinkage restorative materials in enamel and acceptable marginal quality in dentin over a short to medium period of clinical use.

SUMMARY

The present study evaluated the influence of various low-shrinkage restorative systems in class II direct composite restorations following simulated occlusal loading. Forty MOD class II cavities were prepared on freshly extracted human lower third molars with proximal margins located mesially 1.0 mm coronal to and distally 1 mm apical to the cementoenamel junction. The samples were randomly distributed into five experimental groups corresponding to the following restorative systems: a conventional resin composite (Tetric) as active control group, a low-shrinkage composite (Extra Low Shrinkage [ELS]) alone or combined with its corresponding flowable version (ELSflow) used as a 1- to 1.5-mm liner, a bulk-filling flowable composite (Surefil SDR) covered by a 1-mm layer of restorative composite (Ceram-X), and a restorative bulk-filling composite (SonicFill). All specimens were submitted to 1,000,000 cycles with a 100N eccentric load into saline. Tooth restoration margins were analyzed semiquantitatively by scanning electron microscopy before and after loading. The percentage of perfect adaptation to enamel varied from 94.15% (SonicFill) to 100% (ELS) before loading and from 69.22% (SonicFill) to 93.61% (ELS and ELSflow) after loading. Continuous adaptation to cervical dentin varied from 22.9% (Tetric) to 79.48% (SDR/Ceram-X) before loading and from 18.66% (Tetric) to 56.84% (SDR/Ceram-X) after loading. SDR/CeramX and SonicFill showed the best cervical dentin adaptation.

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INTRODUCTION

The detrimental impact of resin composite polymerization shrinkage on restoration interface quality and stability has been recognized since the early use of this material and has led to the recommendation of various compensating procedures such as incremental methods,[1-5] the use of ceramic inserts,[6] the application of base/liners,[2,3,7-9] or indirect techniques.[10] The aforementioned, traditional restorative solutions shared the objective of limiting the development of marginal or internal defects, which can affect restoration behavior and longevity.

The use of incremental techniques was validated by several long-term clinical reports, demonstrating also the satisfactory clinical behavior of hybrid and microhybrid composite technology[11-13]; however, these methods, which are considered the "standard of care" for managing polymerization stresses in medium to large class II cavities, all have been at times considered cumbersome and stimulated the dental industry and clinicians to look for alternative and simplified operative protocols. Various technological solutions were then investigated, including improved filler technology (blend of fillers and/or increase of filler load); improved, novel matrix structure with reduced shrinkage (ie, silorane)[14,15]; use of stress-decreasing compounds within the resin matrix[16,17]; changes in light-initiation technology to increase curing depth; and use of sonic vibrations and energy to favor flow and adaptation of highly filled resin composite (SonicFill, patent US7014462 B1). Today, however, little information exists about the real clinical benefit of these new technologies used alone as a simplified filling method or in combination with some of the aforesaid stress control concepts.

The true challenge for simplified restorative systems based on a bulk-filling approach or the application of a thick flowable composite base underneath a single layer of restorative material is to demonstrate both satisfactory initial quality and medium- to long-term behavior (marginal, surface, and restoration bulk integrity) when compared with conventional composite technology and clinical protocols. So far, the available short-term clinical trials do not demonstrate fully convincing performance of either silorane technology or bulk-fill techniques on permanent teeth.[18-20] The short- and medium-term performance of bulk-filling technique proved satisfactory in only two studies dealing with the treatment of primary teeth.[21,22] The quantity and consistency of clinical evidence are clearly insufficient to unconditionally recommend these new systems.

To achieve optimal long-term performance, the requirements will be first to manage polymerization stress buildup following restoration placement and then to demonstrate suitable behavior of restored teeth to repeated oral strains though appropriate mechanical properties. Actually, the reaction to functional loading and hydrolytic degradation will define the material resistance to fatigue and subsequent interface and restoration breakdown.[23] The fatigue behavior of restorations and the occurrence of adhesive or cohesive failures depend on some important material properties such as flexural strength, fracture toughness (K_{Ic}), and elasticity modulus (E).[24-26] It was shown, for instance, that the latest property has a crucial impact on stress development within the tooth restoration system.[2,3,7,27,28] The use of an elastic base or liner with low E modulus, acting as a stress-breaker element within the restoration, has been extensively evaluated since the first works by Davidson and coworkers[27-29] and largely validated *in vitro*.[30,31] When using new simplified restorative systems featuring distinctive physicochemical characteristics, the potential impact of the above mentioned parameters on restoration quality and behavior is unknown and justifies additional investigations. In consideration of a rather well-established consensus suggesting medium- to long-term observation periods (about three to five years) to discriminately appraise the clinical performance of various operative protocols and material choices,[32-35] the use of *in vivo*, preclinical trials such as fatigue testing[36-39] appears particularly suitable today for evaluating new, simplified restorative protocols.

The aim of this *in vitro* study was to test the hypothesis that low-shrinkage restorative systems have the potential to improve restoration adaptation after simulated *in vitro* occlusal stressing, as compared with a traditional microhybrid restorative composite applied with a classical, well-documented incremental technique. The quality of the different interfaces was also evaluated to identify the restoration's most vulnerable areas.

METHODS AND MATERIALS

Specimen Preparation

Forty freshly extracted human third molars were used for this study. Samples were collected anonymously, and their use complied with all local human subject oversight according to the Swiss Human Research Act, under article 2.

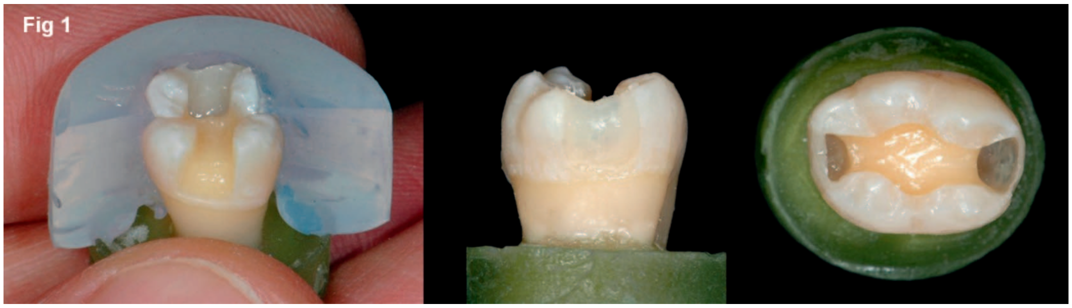

Figure 1. *Transparent silicone matrix used to improve restoration adaption, shorten finishing steps, and avoid margin overhangs and tedious, damaging finishing.*

The inclusion criteria were an absence of carious lesions, a complete root formation, and no visible tooth defect resulting from the extraction. 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). 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, leaving the last 3 mm toward the cementoenamel junction free to provide proper access to restorative procedures.

A new, original technique was used to box proximal cavities, with the aim to facilitate material placement, improve restoration adaptation, and shorten finishing steps. Then, an impression of the tooth was made prior to cavity preparation with a putty silicone (Memosil 2, Heraeus Kulzer, Hanau, Germany) placed in a 2 cm diameter cylindrical plastic tube used as tray. After setting, the tube was removed and all the silicone material overlaying the tooth occlusal surface trimmed off before slicing this impression in two parts buccolingually (Figure 1). To simulate the use of a metallic matrix such as commonly employed, aluminum foil was adapted with a burnisher to each proximal surface of the silicone impression just before tooth preparation and application of the filling material, as further described.

Class II cavities (MOD) were then prepared, with the proximal margins located mesially 1.0 mm coronal to and distally 1 mm apical to the cementoenamel junction (Figure 2). The dimensions of the slightly divergent preparations were 4.0 mm in width and 2.0 mm in depth at the bottom of the proximal box and 3.0 mm in width and depth for the occlusal isthmus, all walls being only slightly divergent. The cavities were prepared using preparation diamond conical burs with round tips under profuse water spray (80 μm grain size, ISO 856/018, Strauss & CO, Ra'Anana, Israel). All enamel margins were beveled with a fine diamond flame bur (40 μm grain size, ISO 862/010, Strauss & CO) under air spray. The 40 prepared teeth were randomly assigned to one of the five study groups (one active control group and four experimental groups), corresponding to the combination of restorative materials and procedures listed in Table 1 and 2.

Restorative Procedures

After completion of the preparation, a 30 second selective enamel etching with 35% H_3PO_4 gel was performed (Ultraetch, Ultradent, South Jordan, UT, USA) prior to the treatment of all cavity surfaces with a two-step self-etch system (SEBond, Kuraray, Tokyo, Japan). Four restorative composites claiming to exhibit low shrinkage or to be used for a simplified filling approach (SureFil SDR flow and CeramX Mono+, DeTrey-Dentpsly, Constance, Germany; ELSflow and ELS, Saremco, St-Gall, Switzerland; and SonicFill, Kerr, Orange, CA, USA) were tested and compared with a well-established hybrid composite brand (Tetric, Vivadent, Liechtenstein), used here as the active control group (Table 1). The following restorative protocols were applied.

SDR Group—The cavities were filled with SureFil SDR flow until 1 to 1.5 mm (measured with a periodontal probe) below the occlusal surface, creating a base of about 3 to 4 mm thickness proximally. The remaining volume/surface was filled with the restorative material CeramX Mono+ in one increment.

ELS1 Group—A 1 to 1.5 mm thick lining of ELSflow (as measured with a periodontal probe) was applied over the entire preparation, including

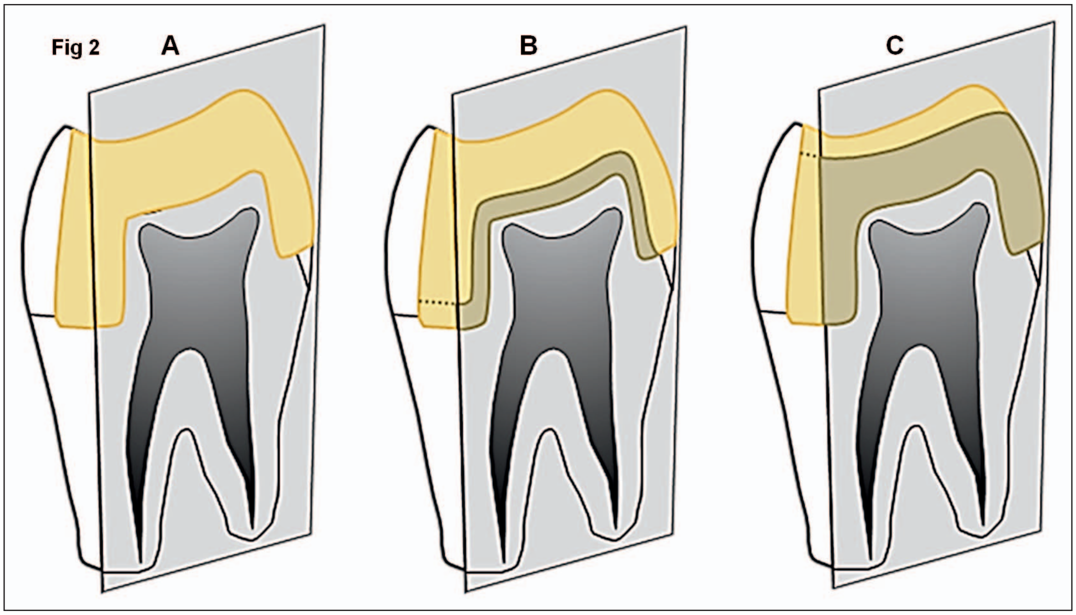

Figure 2. *Experimental restorative configurations: (A): Composite restorations made of a single material (layered or bulk; groups TET, ELS2, and SOF). (B): One-millimeter flowable composite lining underneath a restorative composite (ELS 1). (C): A ≥4-mm lining flowable material underneath a thinner layer of restorative material (SDR).*

both enamel and dentin cervical margins; the remaining cavity volume was filled with the ELS restorative composite using in proximal areas a technique similar to the three-sited light-curing technique (one layer cervically, followed by two more vertical layers)[2,3] and horizontal layers of 1.5 mm in the occlusal area.

Sonicfill Group—The entire cavities were filled in one step using the SonicFill handpiece (Kavo, Biberach, Germany) to facilitate flow of the material into the cavity.

ELS2 and Tetric—The three-sited curing technique was applied in the proximal preparations while the remaining occlusal volume was also filled in three steps, including two first oblique increments, followed by one last horizontal increment.

Both linings (Surefil SDR flow and ELSflow) were light cured for 20 seconds with continuous irradiation mode (Bluephase, Vivadent, in HIP mode: power output=1200 mW/cm^2). For all other protocols, each increment or composite bulk was light cured for 20 seconds as well, using the aforementioned irradiation conditions. All proximal cavities were restored using the silicone mold, as previously described (Figure 1). In all groups and for all aforementioned techniques, the final increment was sculpted with a hand instrument (DD1/DD2, Composculp Set, Hu-Friedy, Chicago, IL, USA) prior to final light curing, in order to ease finishing and also reduce mechanical stress on the margins.

The finishing and polishing followed immediately the restorative procedures and were performed under 10× magnification (Leica MZ6 microscope, Nidau, Switzerland). The finishing/polishing of occlusal surfaces was performed with 40 μm flame and pear-shape diamonds (ISO 368/013; Strauss & CO) followed by silicone points used under abundant water spray (Brownie; Shofu, Kyoto, Japan); for the proximal surfaces, discs of decreasing roughness

Table 1: *Combination of Products (Adhesive, Liners, and Restorative Materials) Among the Control and Four Experimental Groups*

Groups	Adhesive	Lining	Restorative
TET (ctr)	SEBond (Kuraray)	No	Tetric (Vivadent)
SDR	SEBond (Kuraray)	SDR flow (Dentsply)	CeramX mono+ (Detrey-Dentsply)
ELS1	SEBond (Kuraray)	ELSflow (Saremco)	ELS (Saremco)
ELS2	SEBond (Kuraray)	No	ELS (Saremco)
SOF	SEBond (Kuraray)	No	SonicFill (Kerr)

Table 2: *Composition and Relevant Physical Characteristics of Composites Under Evaluation (Manufacturer's Data)*

Product	Filler Content, %W	Matrix Composition	E Modulus, GPa	Shrinkage, %V	Batch No.
Tetric (Ivoclar)	81	BisGMA, TEGMA, UDMA	11.5	2.5 (24 h)	M31685
SDR (Dentsply)	68	Mod UDMA, TEGMA, EBPADMA	5.5	3.5 (24 h)	1005004013
Ceram-X mono (Dentsply)	76	Methacrylate modified polysiloxane DMA	8.5	2.3 (30 min)	1005004013
ELSflow (Saremco)	NA	BisGMA, EBPADMA	8.0	3.2 (30 min)	09.2013-74
ELS (Saremco)	75	BisGMA, BisEMA	9.0	1.3 (1 min)/2.4 (4 h)	10.2013-14
SonicFill (kerr)	83.5	BisGMA, UDMA	11.5	1.7 (12 h)	3691651

Abbreviations: %V, percentage of volumetric shrinkage; %W, weight percentage.

(rough, medium, fine, and extra fine; Sof-Lex Pop On XT, 3M, St Paul, MN, USA) were used at low speed ($\leq$1500 rpm) and with reduced pressure to limit frictional stress on the restoration margins.

Mechanical Loading

The stress test was carried out 24 hours after restoration placement and finishing, the restored teeth being kept in saline, at room temperature, during this interval as well as during the test phase inside the fatigue device chambers (University of Geneva). The teeth's pulpal cavity was penetrated buccally or palatally with a tube (sealed with Dentin Bonding Agent), which was connected to a simulated pulpal circulation of saline under a pressure of 14 cm H_2O[40]; the simulated pulpal pressure was then applied only after the restorative procedures. All specimens were submitted to 1,000,000 cycles with a 100 N eccentric occlusal load. 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 4Y of clinical service,[37,38] Restored teeth were contacted by antagonist artificial cusps, made of stainless steel with a hardness similar to natural enamel (Vickers hardness: enamel=320-325; selected steel=315); the diameter of the cusps was 4 mm and contacted the restoration's occlusal surface on the restoration's proximal fossa. By having the specimen holder mounted on a hard rubber disc, a sliding movement of the tooth was allowed between the first contact on an inclined plane and the central fossa. The function of this device was similar to that of the machine developed by Krejci and coworkers.[37,38,]

Specimen Evaluation

Before the fatigue test, as well as after completion of the loading phase, the restoration's margins were cleaned with fine pumice before etching using diluted H_3PO_4 gel to remove finishing/polishing smear and improve the readability of the replicas under scanning electron microscopy (SEM; the solution was prepared with 35% H_3PO_4 gel mixed with three times its volume of distilled water). The restoration surfaces and margins were then treated by gentle brushing of this solution for four seconds, followed by thorough water rinsing. Impression of the samples was made with polyvinylsiloxane (President Light Body, Coltene/Whaledent AG, Alstätten, Switzerland), which served for the fabrication of gold-sputtered epoxy resin replicas (Epofix, Struers, Rødrove, Denmark).

The proximal mesial and distal aspects of the restorations were examined while the occlusal adaptation was not taken into consideration. The approximal mixed adaptation (Appr. M) refers to the entire mesial restoration adaptation (including both enamel and dentin margins). The cervical dentin adaptation (Cerv. D) refers to the specific cervical dentin adaptation on the mesial preparation side. The approximal enamel adaptation (Appr. E) refers to the distal, full enamel restoration margin adaptation. Each tooth restoration interface was analyzed quantitatively by SEM (Digital SEM XL20, Philips, Eindhoven, the Netherlands) using a standardized evaluation method.[41,42] The restoration margins were observed at a standard 200× magnification, and each margin segment, or subsegment, was delimitated by a digital marker and attributed a quality criteria, as described further (Figure 3). A dedicated software then computed the respective percentages of continuous or defective margin for the three different areas under evaluation applying those quality criteria: continuity or overfilling, underfilling, marginal opening, marginal restoration, and tooth fracture (Figure 1). When necessary for the assessment accuracy, higher magnifications were used (up to 1000×). The results for the restoration marginal adaptation before and following the loading test were expressed as percentages of continuity; the other parameters that describe

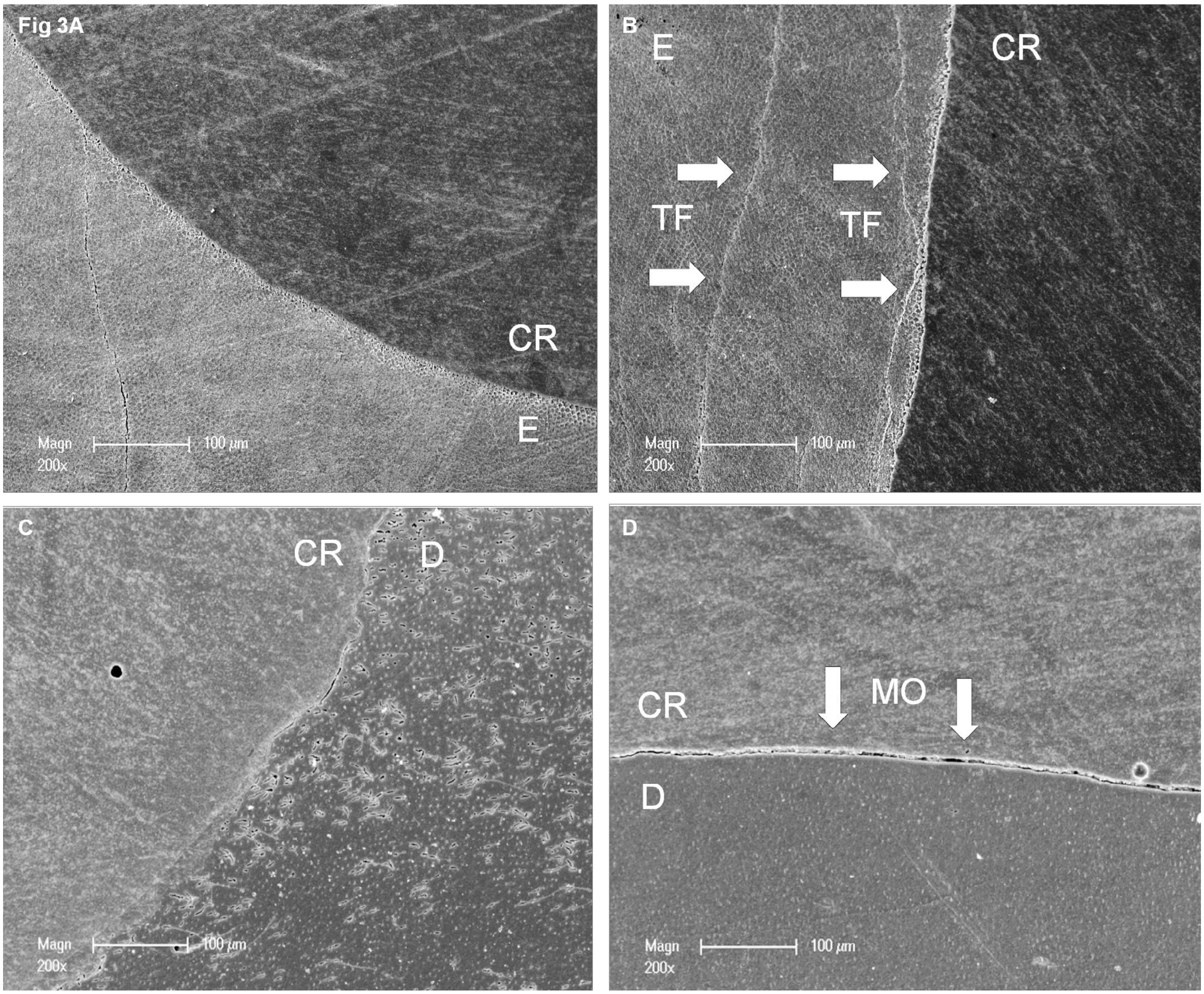

Figure 3. *Typical marginal appearance and quality under SEM, following cycling loading (one million cycles at 100N and 1.5-Hz loading frequency). NB, restoration margins were cleaned with a short etching with diluted phosphoric acid to improve replica quality and readability; CR, composite restoration; E, enamel; D, dentin. (A): Enamel margin in continuity. (B): Enamel marginal with tooth fracture. (C): Dentin margin in continuity. (D): Dentin margin with marginal opening.*

defective margin sections were pooled together and accounted for noncontinuous adaptation and were not analyzed individually. Percentages were calculated as the ratio between the cumulated distance of all segments with a continuous margin and the whole interface length. The restoration occlusal adaptation was not assessed.

All results of the SEM analysis were submitted to a parametric statistical analysis. An analysis of variance and Bonferroni post hoc test served for comparing the intergroup marginal continuity percentages for the different restoration areas, before and after the loading test (Instat, GraphPad Software, La Jolla, CA, USA). A paired t test served to compare the intragroup marginal adaptation percentages between pre- and postloading conditions (Instat, GraphPad Software). All tests were carried out at a 5% level of significance.

RESULTS

The study results, expressed as percentages of continuous marginal adaptation before and after loading, are presented in Table 3 together with their statistical analysis.

Table 3: *Percentages of Continuous Marginal Adaptation (±SD) for the Four Segments Under Evaluation, Pre- and Postcycling Loading*[a]

Groups	TET	ELS1	ELS2	SDR	SOF	ANOVA
Approximal enamel preloading	96.9% *(3.6)*	98.1% *(2.2)*	100% (0.00)	97.5% *(5.0)*	94.1 *(8.2)*	f=1.642 p=0.1856 NS
Approximal enamel postloading	92.8%a *(8.1)*	91.2%a *(4.9)*	93.6%a *(8.0)*	92.7%a *(13.1)*	69.2b *(27.1)*	f=4.154 p=0.0074 **S****
t-test	t=2.064 NS	t=3.634 **S****	t=2.261 NS	t=1.384 NS	t=2.792 **S***	
Approximal mixed preloading	82.7%a *(9.7)*	97.2%b *(1.4)*	97.0%b *(3.1)*	92.4%a,b *(9.5)*	90.4%a,b *(8.2)*	f=5.347 p=0.0018 **S****
Approximal mixed postloading	77.0% *(9.6)*	89.2% *(7.5)*	83.0% *(12.0)*	87.0% *(11.6)*	79.0% *(10.2)*	f=1.996 p=0.1166 NS
t-test	t=2.013 NS	t=3.400 **S***	t=3.229 **S***	t=3.185 **S***	t=2.757 **S***	
Cervical dentin preloading	22.1% *(12.0)*	60.4%a *(20.5)*	64.2%a *(23.0)*	79.5%a *(17.7)*	78.3%a *(15.0)*	f=13.255 p<0.0001 **S****
Cervical dentin postloading	18.7%a *(11.4)*	29.6%a,b *(18.2)*	29.7%a,b *(23.6)*	56.8%b *(24.0)*	51.1%b *(15.3)*	f=5.682 p=0.0012 **S****
t Test	t=2.335 NS	t=5.132 **S****	t=5.844 **S****	t=4.190 **S****	t=3.441 **S***	

Abbreviation: ANOVA, analysis of variance.
[a] *Groups with same letter are not statistically different.* *p<0.01; **p<0.001.

Enamel Adaptation (Distal Side)

The preloading proximal enamel adaptation presented proportions of continuity varying from 94.15% (SonicFill) to 100% (ELS), with no significant difference. After loading, those proportions decreased to values varying from 69.22 (SonicFill) to 93.61 (ELS + ELSflow). The change was significant for SonicFill and ELS only while the postloading distal adaptation of SoniFill was significantly lower than the other four groups.

Mixed Margin Adaptation (Mesial Side)

The preloading mixed proximal adaptation presented proportions of continuity varying from 82.72 (Tetric) to 97.24 (ELS + ELSflow), with Tetric adaptation being significantly inferior to ELS/ELSflow or ELS groups. After loading, those proportions decreased to values varying from 77.0% (Tetric) to 89.19 (ELS + ELSflow); the reduction in percentages of continuity was significant in all groups except for Tetric. The postloading adaptation values in mixed proximal margins did not show any significant difference among groups.

Dentin Margin Adaptation (Mesial Side)

The preloading cervical dentin adaptation presented proportions of continuity varying from 22.09% (Tetric) to 79.48% (SDRflow + CeramX), with the Tetric value being significantly inferior to the other groups. After loading, the continuity values dropped to percentages varying from 18.66% (Tetric) to 56.84% (SDRflow + CeramX); the reduction in percentages of continuity was significant for all products except for Tetric. The postloading adaptation of Tetric in cervical dentin was significantly inferior to SDRflow/ceramX and SonicFill.

DISCUSSION

Phenomena such as nanoleakage, leakage, pulpal complications, and secondary caries, which are induced by interface breakdown, account for a significant part of clinical failures observed in all types of direct posterior restorations.[11-13] Then, evaluating the behavior of adhesive restorations with natural tissues under simulated function, pulpal pressure, and moist environment helps in approaching the reaction of a restoration to the most important oral cavity strains and to monitor the tooth-composite interface stability and degradation as well.[36-39] This *in vitro*, preclinical research approach is well established and has been used previously in numerous studies evaluating the *in vitro* quality of class II restorations.[30,31,39]

Overall, the materials and restorative techniques under evaluation presented satisfactory adaptation to approximal enamel (distal) and to mixed enamel-dentin margins (mesial) before and after loading (>90% continuous margins), with the exception of SonicFill and Tetric. Actually, the restorations made with SonicFill showed more postloading marginal microfractures in plain enamel margins whereas the restorations made with Tetric showed a high proportion of dentin marginal gaps, pre- and post-loading. The higher occurrence of marginal enamel microfractures reported for SonicFill might be related to the higher stiffness of this product (highest E modulus among tested products; see Table 1), which likely increases stress transmission to the restoration margins, especially when used with a bulk-filling approach. The possible clinical impact of such adverse finding, commonly observed in previous *in vitro* fatigue studies, has not been clarified.[9,43]

The most critical margin area was as usual the cervical dentin, where the multilayered restorations made of a traditional microhybrid (Tetric) and a so-called "low-shrinkage" microhybrid (ELS) used alone or in combination with a flowable resin composite liner (ELS + ELSflow) did not perform satisfactorily, as shown by significantly lower continuity proportions in pre- (Tetric only) and postloading conditions. In studies evaluating marginal adaptation in similar *in vitro* conditions, Tetric[44] and Tetric Ceram,[45] which are both microhybrids, and Tetric EvoCeram (nanohybrid)[44] placed with other adhesives presented percentages of postloading continuity varying from 83.3% to 94.6% in enamel and from 56.2% to 74.6% in dentin, which is markedly higher than in the present study for dentin adaptation (18.66%). Kwon and others[46] using the same adhesive with Tetric Ceram obtained 78.7% of continuity in mixed dentin and enamel margins, which is nearly identical to the result of the present study, with 77.0% continuous margins for the multilayered Tetric class II restorations. When considering the adaptation to dentin, the performance of Tetric then fell below the range of published data for multilayered direct composite restorations tested in similar laboratory environments. As the present study protocol involved a higher cycling load (100N instead of 49-50N or varying forces from 50 to 100N), or a higher number of cycles (one million instead of 100,000 to 600,000), it could have had a more damaging and discriminative effect on dentin adaptation, although some unidentified confounding factor could also account for such surprisingly low performance.

In two recent studies, SDR flow combined with Ceram-X in class II restorations submitted to a similar fatigue test (but with a reduced number of cycles) presented postloading percentages of continuity in dentin of 50.3% and 64.9%, depending on the adhesive tested,[43] and 42.9%,[47] with those values being rather close to those reported in the present study. SonicFill presented percentages of continuity in dentin, postloading, of 51.1% in the present study and 61.7% in the other study.[47] While these percentages can be considered apparently satisfactory, such a proportion of continuous margin remains largely inferior to the best combination of adhesive, flowable resin liner, and restorative composite, peaking at 90.8% in a similar test environment for indirect composite restorations[9] or to classical multilayered full-composite restorations with continuous adaptation in dentin reaching 74.6% to 78%.[48]

The E modulus and volumetric shrinkage are of particular interest[49,50] as both properties are known to significantly affect polymerization stresses. Actually, for a given volumetric shrinkage, a lower elasticity modulus will help to reduce stresses. On the other hand, the material's stiffness (as defined by its E modulus) also influences restoration adaptation following loading because of distinct deformation and stress absorption capacity.[9,44,48] In this study, the SDR group (SDR flow E modulus=5.5 GPa) presented a better dentin and overall adaptation than the group with the ELSflow liner (E modulus=8 Gpa); considering a volumetric shrinkage within the same range, the material's stiffness is potentially the influential property. Considering again the interaction between shrinkage stress and E modulus, the similar results obtained with the ELS restorative material alone or combined with the ELSflow become more logical and suggest that using a lining with an almost similar E modulus (ELSflow and ELS E modulus are, respectively, 8 and 9 GPa) is unlikely to give any biomechanical advantage to the restoration's adaptation, although it facilitates and quickens clinical procedures.

Another influential parameter is the respective cavity and increment/layer C-factor (configuration factor),[36] which justified many evidenced-based restorative protocols.[30,31] The rationale for placing a flowable liner underneath direct class II composite restorations is then based on a low C-factor of this first layer, promoting reduced stress buildup at the cavity-restoration interface, combined also with the superior stress absorption capability of a flowable resin composite.[46,51-54] In consideration of the C-factor, simplified layering techniques (bulk-filling or extended flow base) do, however, not show any particular advantage.

In an attempt to summarize the main parameters that explain the present study's findings, the better performance of the SonicFill and SDR/Ceram-X groups in cervical dentin is potentially linked to, respectively, the low volumetric shrinkage of SonicFill and the low E modulus of SDR flow base/Ceram-X systems. As well, the rather unsatisfactory results of the TET and ELS and combined ELS/ELSflow groups are to be attributed to the higher volumetric shrinkage and E modulus of Tetric and the intermediate E modulus and medium/high volumetric shrinkage of ELS/ELSflow materials, which overcame the theoretical advantage of using a multilayering approach.

The present study tested materials and filling methods in medium-size cavities, which could have been more favorable to a low E modulus material (ie, SDR flow) because of the less critical reinforcement role played by the restoration. In larger cavities or in biomechanically compromised teeth, such nonvital teeth, long-term functional loading, and higher occlusal forces (ie, bruxism) could have a more detrimental effect on restoration adaptation because of increased tooth structure deformation. More research is then needed to confirm the relationship between cavity size, material stiffness, and long-term restoration biomechanical behavior.

CONCLUSIONS

An *in vitro* evaluation of marginal adaptation following medium-term functional loading simulation (one million cycles) was used for evaluating new filling methods and materials proposed for class II restorations.

In this preclinical test, medium-size class II restorations made with a traditional layering approach and flowable composite resin liner or simplified filling methods presented satisfactory adaptation to proximal enamel, whereas in cervical dentin, the bulk-filling technique (SonicFill) and extended flow base (SDR flow + Ceram-X) showed the best adaptation. Reported values of continuity were, however, inferior to many direct or indirect composite restorations using traditional microhybrid composites, as reported in previous, similar *in vitro* trials. As some of the new, simplified restorative systems exhibit singular composition and physical characteristics, extended fatigue tests and clinical trials will be needed to assess their performance, in particular in larger cavities and with higher functional stresses. The use of new materials for bulk filling or a simplified restorative protocol cannot yet be unconditionally recommended, based on their *in vitro* performance.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the Swiss Human Research Act, under Article 2.

Conflict of Interest

The authors declare that they have no financial, professional, or other personal interests that could influence the results or position presented in this article.

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