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Effect of Operator-specific Handling on Tooth-composite Interface and Microleakage Formation

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Clinical Relevance

After calibration of the restoration procedure, three operators experienced differences in tooth-composite interface morphology and microleakage formation. These differences reflect technique-sensitivity of the etch-and-rinse adhesive. The lowest microleakage on dentin was related to an enhanced interface integrity. After additional application of an adhesive component, sealing of the enamel and dentin was partially enhanced, but microleakage formation did not decrease. These results are helpful in the comparative evaluation of other bonding systems.

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SUMMARY

The aim of this *in vitro* study was a comparative investigation of tooth-composite interface morphology and microleakage formation after the calibrated restoration of Class II cavities with a proven multi-component, three-step, total-etch adhesive system by three experienced operators. The current study also aimed to acquire data about the well-tried adhesive system under defined laboratory conditions for further comparative assessments with other adhesives.

Forty Class II cavities were prepared on extracted, caries-free molars. In the first study (Part A), 24 cavities were restored (n=8 each) according to the manufacturers' instructions.

In the second study (Part B), 16 teeth (n=6, 4, 6) were filled in the same way; however, the last component of the same adhesive system was applied twice. The teeth were prepared for microleakage testing and morphological assessment of the composite-tooth interface by scanning electron microscopy. The three operators had differences with regard to adhesive layer formation, inter-/peritubular adhesive penetration and the formation of adhesive failures on the dentin interface and microleakage on dentin. The lowest microleakage on dentin was related to enhanced peritubular and intertubular adhesive penetration.

After double application of an adhesive component (Part B), the sealing of the enamel and dentin with adhesive increased partially, and adhesive failures on dentin were partly diminished, but no distinct effects on microleakage formation were found.

The results confirm the technique-sensitivity of the etch-and-rinse adhesive related to interface morphology and microleakage formation. These results are helpful in the comparative evaluation of other bonding systems.

INTRODUCTION

A main topic in the field of tooth-colored adhesive restoration of cavities is the experimental and clinical comparative assessment of restorative systems. Because of differences in thermal expansion of the restoration and tooth, stress resulting from polymerization shrinkage of the composite and numerous other physical and chemical loadings on the restoration during its intraoral exposure, gaps may develop along the interface tooth-restoration, resulting in microleakage formation, pulpal irritation, secondary caries and restoration failure.[1] Since it takes several years to produce evidence of clinical assessments of restoration systems,[2] experimental studies are indispensable for estimating their clinical potential. Although there is no accepted experimental mode for the early experimental assessment of restorative systems, and clinical trials still remain the ultimate test,[3-4] experimental *in vitro/in vivo* bond testing may predict the results of clinical studies to a certain degree.[1,4-5] Between bond strength measurements on enamel and dentin[6-8] and studies related to the biocompatibility of system components[9-11] and spectroscopic investigations,[12-13] numerous imaging methods can help to characterize restoration systems in great detail by investigating phenomena, such as marginal integrity, microleakage and the mechanisms of mechanical adhesion (interlocking/hybridization of enamel and dentin).[14] Such experimental screenings include investigating tooth substrates of different qualities (sound/carious dentin)[8,15-19] and C-factors,[20-22] simulation of pulpal pressure and the oral environment,[23-25] the application of thermal and occlusal stresses, fatigue simulation[26-27] or, for better simulation of the clinical situation, studies on *in vivo* restored teeth that have been in use for a certain period of time.[5,9,25,28-33]

In the past, one of the intentions of the authors of the current study was to combine the clinical assessment of enamel-dentin bonding systems with experimental *in vivo* and *in vitro* studies on the basis of the micromorphological evaluation of the tooth-composite interface and microleakage formation.[2,5,24,29,34-38] This kind of experimental proof is, however, aimed at the comparative assessment of restoration systems that are investigated using the same laboratory standard, analogous to the rating of adhesive systems on the basis of bond strength values achieved within a single standardized trial.

It is widely accepted that enamel-dentin bonding is based on micromechanical retention between resin and the demineralized and primed surfaces of enamel and dentin. Good resin penetration and sufficient resin polymerization are necessary, but many factors can impair this.[1,4,39-42] In addition to the material-specific parameters and equipment used, the variability in handling by the clinical operators plays an important role.[1,6,43-48] Etch-and-rinse adhesives are considered to be partially technique-sensitive.[1] To overcome these challenges, simplified and user-friendly self-etch adhesives have been developed.[1,4,27,33,49-51]

The aim of the current study was the experimental investigation of operator (technique) sensitivity of a three-step total-etch adhesive after calibration of the restoration procedure for all operators under the conditions of a dental school. The null hypothesis was that there is no significant difference with regard to interface morphology and microleakage formation when three longstanding clinicians with experience in experimental and clinical trials perform Class II composite restorations with a well-proven multi-component total-etch adhesive system in combination with the assigned fine-particle hybrid resin composite. The current study further aimed to determine a set of base values for the microleakage and morphological assessment of interface patterns for comparative evaluations of other bonding systems under calibrated conditions for tooth-colored adhesive restorations and the introduced laboratory standard for specimen preparation and evaluation.

METHODS AND MATERIALS

Samples, Cavity Preparation and Restoration

Forty caries- and defect-free extracted human molars stored for up to one month in 0.1 % aqueous solution of thymol at 4°C were used.

The teeth were randomly assigned to three long-standing practicing clinicians (n=14, 12, 14). All of the operators had experience in clinical and experimental trials. Before starting the study, the restoration procedure was calibrated for all operators, once more relating to cavity preparation and every step of the restoration process, especially regarding dentin wetness and moisture removal as well as gentle drying of the adhesive components (see Table 1). Mesio-occlusal Class II cavities with cervical margins below the cement-enamel junction were prepared and smoothed with diamond burs at high speed under copious water-cooling (gingival step within dentin/cement; depth 2-2.5 mm; 80 µm diamond burs, #8223, APS, Intensiv SA, Grancia, Switzerland). All the margins were finished to a 90° angle (no bevels). After finishing (25 µm diamond burs, #3223, APS), the cavities were carefully cleaned with water and dried. The preparation of the cavity was followed immediately by the restorative procedures.

The prepared cavities were etched with phosphoric acid (37%, acid gel, Total Etch, Ivoclar Vivadent AG, Schaan, Liechtenstein), rinsed for 15 seconds with water, then briefly and gently dried with compressed air until the liquid film began to disappear (moist bonding).

In Part A (n=8 each), application of the adhesive Syntac Classic (Ivoclar Vivadent AG) was carried out according to the manufacturers' instructions (Table 1). After analyzing the results, the adhesive component Heliobond was applied twice (Part B, n=6, 4, 6; Table 1).

Subsequently, the cavities were filled with composite Tetric Ceram (Ivoclar Vivadent AG) and the restorations were contoured and finished with diamond burs (#4274, 15 µm, Composhape A & P, Intensive SA; Greenie, Shofu Inc, Ratingen, Germany).

The curing light (Astralis 10, Ivoclar Vivadent) was checked with a curing radiometer (Demetron Model 100, Demetron Research Corp, Danbury, CT, USA) before starting the study (output intensities, see Table 1). All three operators used the same curing light on all of the specimens (for curing procedures and output intensities see Table 1).

Specimen Preparation, Microleakage and SEM Investigation

The roots of the teeth were removed at least 2 mm below the cervical margin of the restoration (80 µm diamond bur, APS, Intensiv SA) and the teeth were stored in Aqua bi-destillata (37°C, 24 hours) and immersion-fixed in buffered glutaraldehyde (5%, 4°C) for 24 hours.

For assessment of the microleakage, the teeth were soaked in fresh buffer three times (one hour each; 0.1 M sodium phosphate buffer, pH 7.2), and the surfaces were covered with nail varnish except for a 1 mm window around the restorations. The samples were then immersed in basic ammoniacal silver nitrate ($AgNO_3/NH_4OH$, 3 mol/L, pH 9.5) for 24 hours at 37°C

Table 1: *Materials for Restoration, Batch Numbers and Instructions for Application of Materials*

Material	Etching Gel	Adhesive			Composite
Product	Total Etch	Syntac Primer	Syntac Adhesive	Heliobond	Tetric Ceram
Batch-#	H19817	G24888	H01340	G24037	E49732
Composition	37% phosphoric acid gel	TEGDMA, maleic acid, water, acetone	PEGDMA, glutaraldehyde, maleic acid, water	Bis-GMA, TEGDMA, initiators, stabilizers	Bis-GMA, UDMA, TEGDMA, inorganic filler, catalysts, stabilizers
Application Part A	etch enamel/ dentin for 30/15 seconds, rinse for 15 seconds, gently dry (moist bonding)	rub in gently for 15 seconds, remove the excess and gently dry with compressed air	rub in for 10 seconds, gently dry with compressed air	rub in, dry with compressed air until a shiny film surface is visible, light-cure for 10 seconds[1]	incremental filling (2 mm), first increment on the cervical step, light-cure for 10 seconds[2]
Application Part B	etch enamel/dentin for 30/15 seconds, rinse for 15 seconds, gently dry (moist bonding)	rub in gently for 15 seconds, remove excess and gently dry with compressed air	rub in for 10 seconds, gently dry with compressed air	1. rub in, dry with compressed air until a shiny film surface is visible, light cure for 10 seconds[1] 2. repeat in the same manner	incremental filling (2 mm), first increment on the cervical step, light-cure for 10 seconds[2]

[1]Astralis 10, Ivoclar Vivadent, program ADH-10 seconds/650 mW/cm², [2]Astralis 10, program PUL, 10 seconds softstart: 150-650 mW/cm², 10-second pulsate between 650-1200 mW/cm²

in darkness before rinsing again with distilled water for 60 seconds. The samples were then exposed to a photo-developing solution (Neotenal Liquid, Tetenal Photowerk GmbH & Co KG, Norderstedt, Germany) under fluorescent light (8 hours; 20°C; UV-Hand lamp N8 11102L, K Benda Laborgeräte, Wiesloch, Germany) and rinsed again with distilled water for 60 seconds. The teeth were embedded in Stycast 1266 (Emerson & Cuming, Westerlo, Belgium), mounted on plastic blocks and longitudinally sectioned (n=3 each; 200 µm thickness; Leitz 1600 Sägemikrotom, Ernst Leitz Wetzlar GmbH, Wetzlar, Germany). At the sections, the microleakage was then examined with a stereomicroscope (magnification 25x to 40x; Citoval 2, VEB Carl Zeiss, Jena, Germany; digital microscope camera DMC 2, Polaroid, Offenbach, Germany with accessory operation and control software for PC; Adobe Photoshop, Adobe Systems Inc, San José, CA, USA).

The samples were decalcified with 2% HCl for 10 seconds, deproteinized with 10% sodium hypochlorite for 60 seconds and rinsed with distilled water, after which they were dehydrated in an ascending series of ethanol baths (30% to 100%), immersed in Hexamethyldisilazan for 10 minutes (HMDS, Carl Roth GmbH + Co, Karlsruhe, Germany) and air dried.

All the samples were mounted on metal stubs (Leit-C nach Göcke, Neubauer Chemikalien, Münster, Germany; sample holder G 400, Plano GmbH, Wetzlar, Germany); they were sputter coated with gold (20 nm, Edwards Sputter Coater S 150B, BOC Edwards Ltd, Crawley, Great Britain) and examined with a scanning electron microscope (SEM, CamScan CS 24, Cambridge Scanning Comp Ltd, Cambridge, Great Britain) in the backscattered and secondary electron mode at 20 kV accelerating voltage.

Assessment Criteria

The interface morphology was characterized by:

- adhesive layer formation (percentage occurrence on enamel/dentin-composite interface),
- intertubular resin penetration (mean thickness ± standard deviation of the hybrid layer, presence of areas of incomplete intertubular resin penetration),
- peritubular resin penetration (maximum depth) and lateral resin penetration,
- tag formation on enamel and dentin (yes/no, maximum length),
- gap formation between restorative material, adhesive layer, hybrid layer and enamel/dentin, and
- occurrence of crumbly composite on the dentin interface.

The microleakage was measured in terms of the length of $AgNO_3$-penetration and was indicated as the percentage of the length of the enamel/dentin-composite interface.

Evaluation of Data

Statistics

The differences between operators/parts with regard to adhesive layer formation, hybrid layer thickness, peritubular and incomplete intertubular resin penetration, microleakage and the formation of total adhesive failures on the interface were analyzed using the Kruskal-Wallis test and the two-tailed *U*-test by Mann and Whitney (α=0.05, Bonferroni adjustment, SPSS 14.0 for Windows, SPSS Inc, Chicago, IL, USA).

Significance levels, which resulted from the Bonferroni adjustment, were 0.0071 and 0.0166, respectively. When *p*-values were above the significance levels but smaller than 0.07, it was recommended that the difference be assessed as tendential.

Ranking of Operators (interface morphology, microleakage and total adhesive failures)

The mean values of parameters measured for each operator regarding adhesive layer formation, hybrid layer thickness, incomplete intertubular resin penetration, peritubular/lateral adhesive penetration and tag formation on enamel and dentin were ranked with grades 1, 2 and 3. Grade 1 corresponded to the most favorable of the three values, grade 3 to the most unfavorable.

For each operator, a mean rank was calculated, which was related to the mean rank of the assigned microleakage (enamel and dentin).

Each of the three sections per tooth was assessed with a 1 or 0 (total adhesive failure on enamel/dentin: yes/no) and a rank for each tooth. The total number of ranks per operator was determined.

RESULTS

Tables 2 and 3 present the results of the investigation. On enamel and dentin, microleakage was generally verifiable (Figure 1). In both parts of the study, all three operators verified the typical interaction pattern on the tooth-composite interface. The adhesive layers were generally incompletely formed (Figures 2 and 3). The hybrid layers varied in thickness between 3.7 µm and 5.3 µm; however, in 17%-66% of the images, these layers were partially incomplete (Figure 4). Distinct adhesive tags arose on enamel and dentin. On dentin, these were peritubularly anchored and laterally branched (Figure 3). Adhesive failures occurred on sites with and without a detectable adhesive layer; in the former case, they occurred mostly between the adhesive and hybrid layer (Figures 5 and 2a).

In the main, enamel bonding was favored, as was indicated by generally lower microleakage and cleft formation (Tables 2 and 3). In areas on dentin where no adhesive layer was detectable, the composite appeared to be partially crumbling (Figure 6).

Table 2: *Characteristics of Tooth-composite Interface and Microleakage for Three Operators and Parts A and B*

Operator/ Part	Adhesive Layer Formation, %		Hybrid Layer Thickness, µm	Incomplete Intertubular Resin Penetration, %	Peritubular Penetration, µm	Tag Formation Length, µm		Microleakage % Cavity Margin	
	Enamel	Dentin				Enamel	Dentin	Enamel	Dentin
1 A	22.3 ± 16.6[a,c,j]	9.9 ± 3.8[a,b,j]	4.9 ± 0,7[b]	33[a,b,k]	<7.8[a,b]	+	>120	15.5 ± 22.5[k]/*5.1*	38.0 ± 27.4/*31.8*
1 B	65.0 ± 15.9[f,j]	50.9 ± 16.4[f,j]	5.3 ± 1.1[f]	17[d,g,k]	<6.4	+	>70	60.3 ± 44.7[k]/*69.9*	21.2 ± 13.3[f,g]/*25.4*
2 A	70.9 ± 14.3[a]	53.9 ± 14.6[a,i]	4.7 ± 2.0	66[a]	<4.3[a,k]	+	>100	31.6 ± 26.9/*26.9*	42.1 ± 13.6/*35.7*
2 B	82.7 ± 7.8[f,h]	84.2 ± 7.2[e,f,i]	3.9 ± 0.5[f]	63[d]	<5.5[k]	+	>200	35.8 ± 43.8/*20.9*	47.6 ± 18.0[f]/*46.3*
3 A	53.4 ± 23.1[c]	38.9 ± 22.4[b]	3.7 ± 0.5[b]	57[b]	<4.4[b,l]	+	>70	11.6 ± 12.1/*7.5*	56.4 ± 25.9/*52.7*
3 B	51.4 ± 15.4[h]	43.2 ± 14.4[e]	4.0 ± 1.0	63[g]	<5.3[l]	+	>90	32.3 ± 46.8/*4.5*	60.3 ± 32.7[g]/*52.4*

Mean value ± standard deviation, cursive number: median, [a,b,d,e] significantly different (p<0.0166), [i,j] significantly different (p<0.0071), [c,f,g,h,k,l] a tendency to differ (0.0166/0.0071 <p<0.07), equal letters mark values with significant differences/tendencies to differ between parts/operators for enamel or dentin and features.

Table 3: *Total Adhesive Failures on Tooth-composite Interface in Parts A and B*

Operator	Part A		Part B	
	Enamel*	Dentin*	Enamel*	Dentin*
1	1/8	18/8[a,c]	0/6	0/6[a,b,d]
2	1/8	24/8[c]	2/4	9/4[d]
3	0/8	21/8	0/6	12/6[b]

**Total number of ranks as a measure for the frequency of total adhesive failures/number of teeth, [a,b] significant differences (p<0.0166), [c,d] a tendency to differ (0.0166<p<0.07), equal letters mark values with significant differences/tendencies to differ between parts/operators.*

Part A

There were no significant differences among operators with regard to microleakage formation. This also held true for operators 2 and 3 with regard to all the other parameters.

For operator 1, compared with operators 2 and 3, adhesive layer formations on enamel and dentin were significantly diminished or showed a tendency regarding this, but the dentin was regularly more conspicuous and more distinctly hybridized (Figure 3). Therefore, in these specimens, incomplete intertubular resin penetration was reduced and the peritubular adhesive penetration was enhanced. In addition, a significantly thicker hybrid layer was obtained compared with operator 3, as well as in the tendency-diminished number of total adhesive failures on the dentin interface compared with operator 2.

The mean ranks of operators 1, 2 and 3, resulting from criteria characterizing interface morphology, were 1.40, 2.20 and 2.00, respectively. The mean ranks relating to microleakage formation on enamel and dentin were 1.50, 2.50 and 2.00, respectively, relating to medians of microleakage 1.0, 2.5 and 2.5.

Part B

After a double application of Heliobond, the sealing of enamel and dentin with adhesive was significantly enhanced in 3/6 cases (operators 1 and 2). For operator

Figure 1: *Light microscopic images of tooth cross-sections after the restoration of Class II cavities with Syntac Classic–Tetric Ceram.*

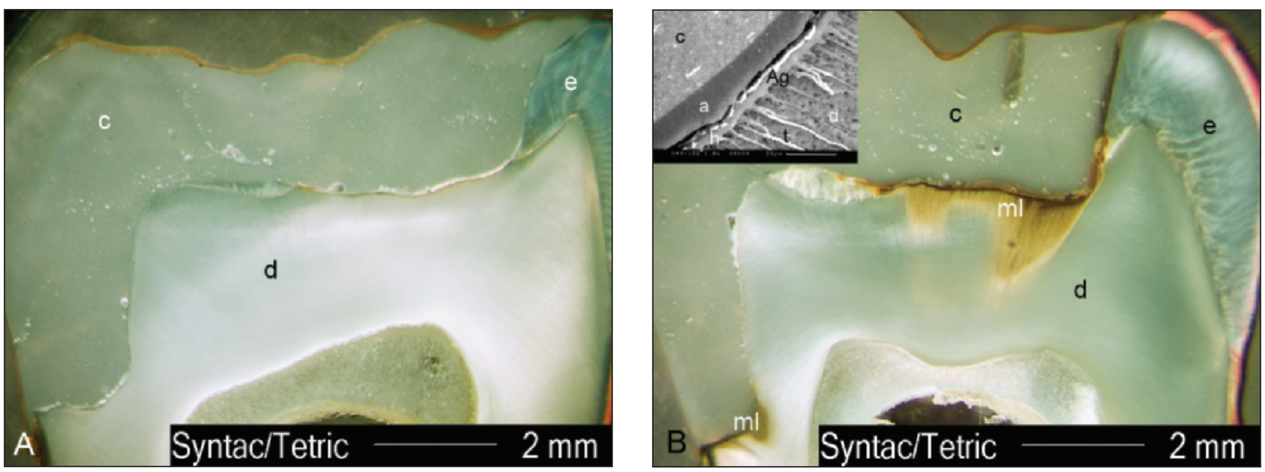

Figure 1A: No microleakage formation on enamel (e) and dentin (d); Figure 1B: Microleakage (ml) as Ag-labeling on enamel and dentin; insertion shows silver particles (Ag) within the gap on a dentin interface (SEM, c: resin composite, a: adhesive layer, h: hybrid layer, t: adhesive tag).

Figure 2: *Scanning electron microscopic images (SEM) of the composite-enamel/dentin interface.*

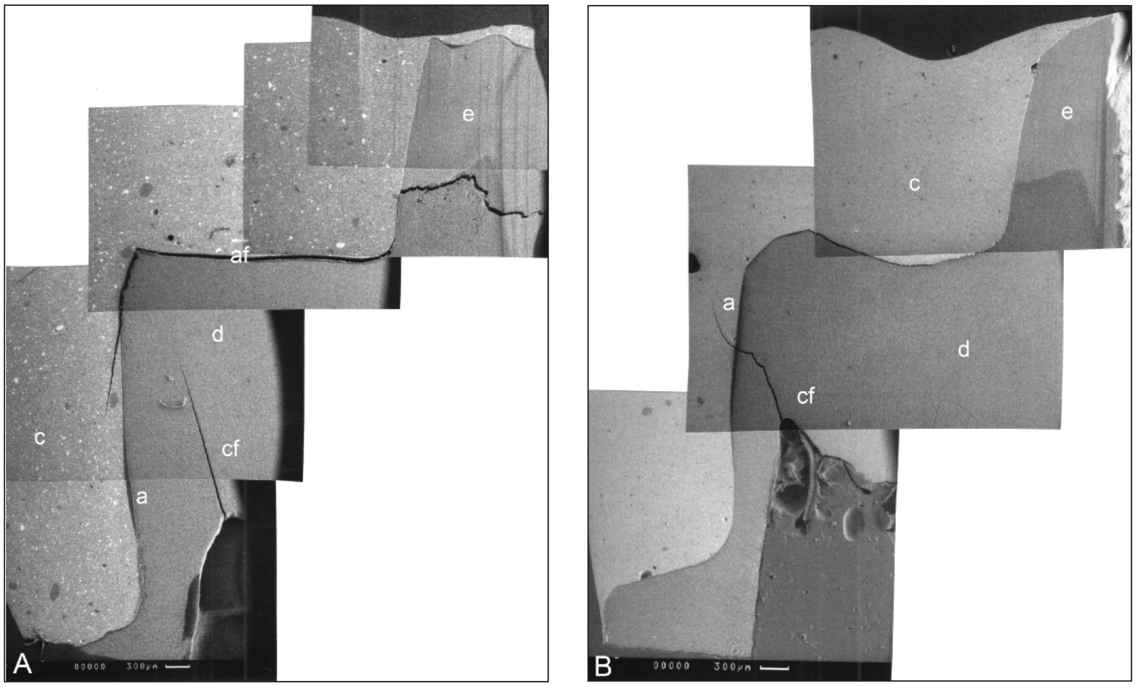

Figure 2A: Part A, incompletely formed adhesive layer (a); adhesive failure (af) on dentin interface without adhesive layer; cohesive defects (cf) in composite (c), enamel (e) and dentin (d); gap between enamel and dentin; compound on enamel. Figure 2B: Part B, incompletely formed adhesive layer; cohesive failure on dentin interface at site of an adhesive layer; compound on enamel and dentin.

1, the incomplete intertubular monomer penetration was diminished, and with operators 2 and 3, the peritubular adhesive penetration was enhanced (tendency). For operator 1, the microleakage on enamel was increased, but total adhesive failures on the dentin interface were avoided.

There were differences (significance and tendency) among all operators regarding most of the parameters assessed. The adhesive layer formation on enamel/dentin was increased with operator 2, compared with operators 1 and 3. For operator 1, compared with operators 2 and 3, the intertubular resin penetration (thickness of the hybrid layer, intertubular resin penetration) was raised, and the microleakage formation on dentin and the number of total adhesive failures on the dentin interface were reduced.

The mean ranks of operators 1, 2 and 3 regarding the criteria of interface morphology were 1.65, 1.80 and 2.15, respectively. With regard to microleakage on enamel and dentin, all the operators had the same rank of 2.00 for both means and medians.

DISCUSSION

The concept of tooth-colored adhesive restorations with etch-and-rinse, as well as self-etch adhesives, is based on the working steps of the "conditioning" of enamel/dentin, the "priming" of their surfaces and "resin application." Currently, there are a wide variety

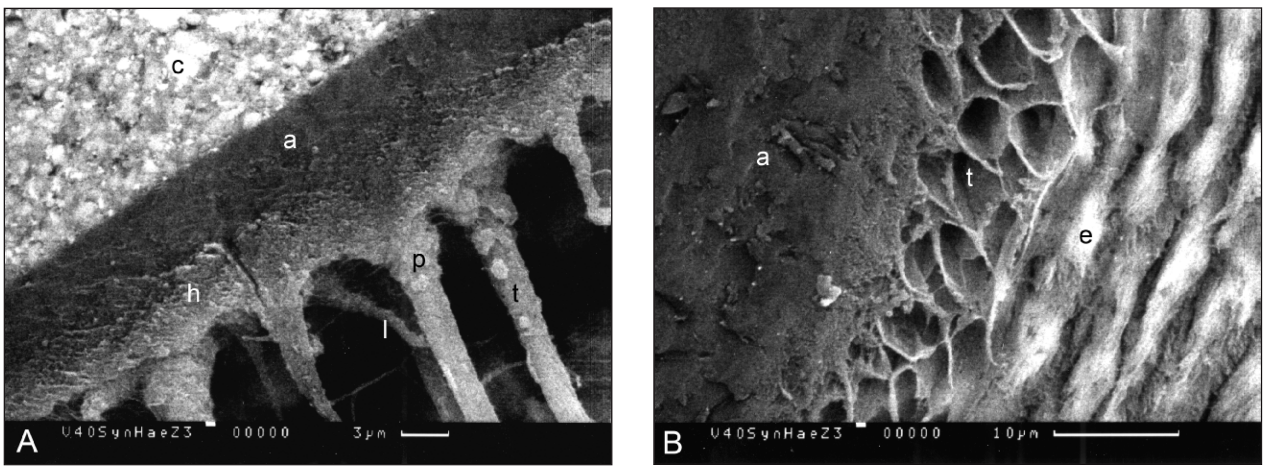

Figure 3: SEM images of interfaces (A) on dentin with resin composite (c), adhesive layer (a), hybrid layer (h), distinct adhesive tags (t), peritubular resin penetration (p) and lateral branches (l) and (B) on enamel (e) with adhesive layer and resin tags.

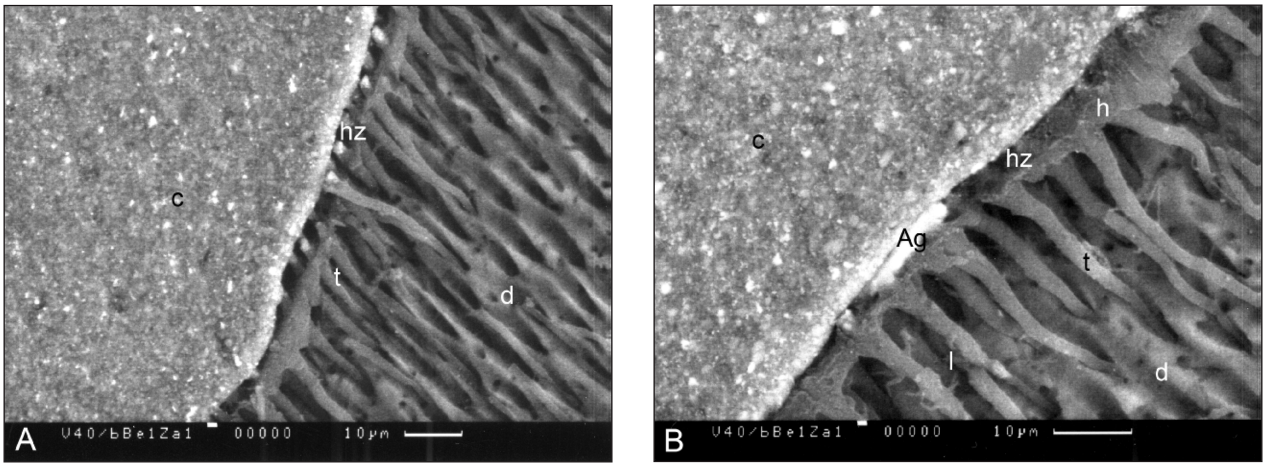

Figure 4: SEM images of dentin interfaces with incomplete intertubular resin penetration. Figure 4A: hybridoid zone (hz); Figure 4B: silver particle (Ag) within porous area (c: resin composite, h: hybrid layer, t: adhesive tag, l: lateral branches, d: dentin).

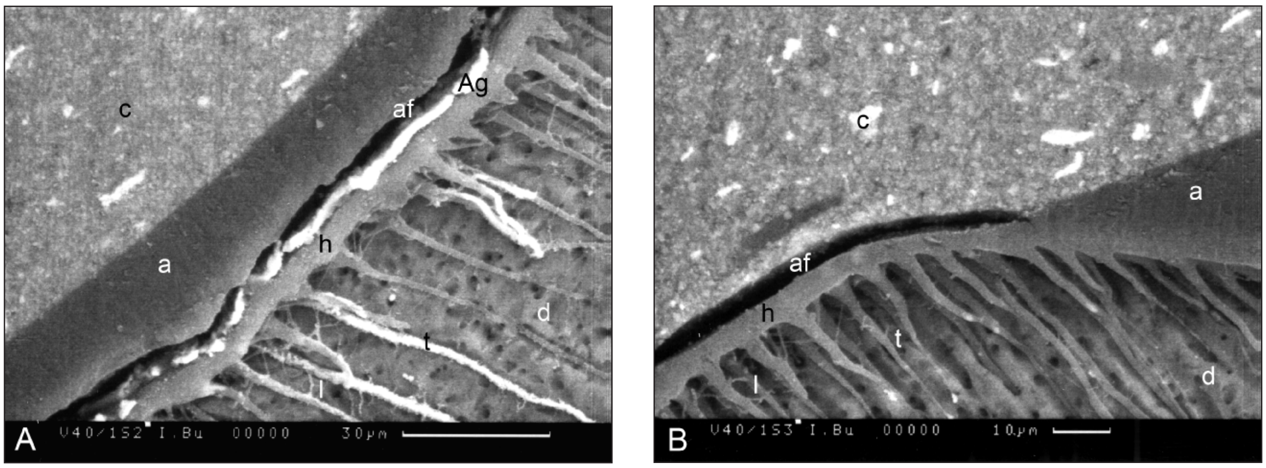

Figure 5: SEM images of dentin interfaces with adhesive failures (af) on sites with (Figure 5A) and without (Figure 5B) a detectable adhesive layer (a), (A) silver particles (Ag) within the gap, (B) adhesive failure occurs with disappearing adhesive layer (c: resin composite, h: hybrid layer, t: adhesive tag, l: lateral branches, d: dentin).

of adhesive systems available on the market. As older, multiple-step total-etch systems are considered technique-sensitive, adhesives have been developed as far as one-step, self-etch systems, simplifying handling by integrating several steps together. As a result, these systems are more user-friendly. However, in clinical and experimental studies on the application of simplified one-step self-etch systems, no advance can be seen compared with earlier multi-step total-etch adhesives.[4,7,26-27,50,52-55] On the contrary, diminished bonding effectiveness was noted in these systems, along with shortcomings in interface integrity.[17,50] However, a simple, user-friendly system is only acceptable if it functions and, thus, clinical effectiveness is of essential importance, along with technique sensitivity. On the basis of data from published clinical trials, Peumans and others[4] observed inefficient clinical performance in one-step self-etch systems when compared with three-step etch-and-rinse, two-step etch-and-rinse and two-step self-etch adhesives; whereby, three-step systems were shown to perform best. Akimoto and others[51] and Peumans and others[56] presented "excellent" clinical data for a two-step self-etch adhesive after 5- or 10-year placement. Also, in laboratory tests, "older" materials performed better than simplified adhesives.[27,50,57] The clinical data and results from experimental investigations of the interface morphology and microleakage formation for systems of different functionalities from other self-studies also confirm this.[2,5,34-38] Peumans and others[4] emphasized the simultaneously observed superior laboratory and clinical performance of three-step etch-and-rinse adhesives. These authors concluded that this probably resulted from good enamel/dentin interlocking/hybridization on the tooth-composite interface. Therefore, it is worth considering the interface morphology of these products as a basis for the comparative assessment of recently developed systems.[50]

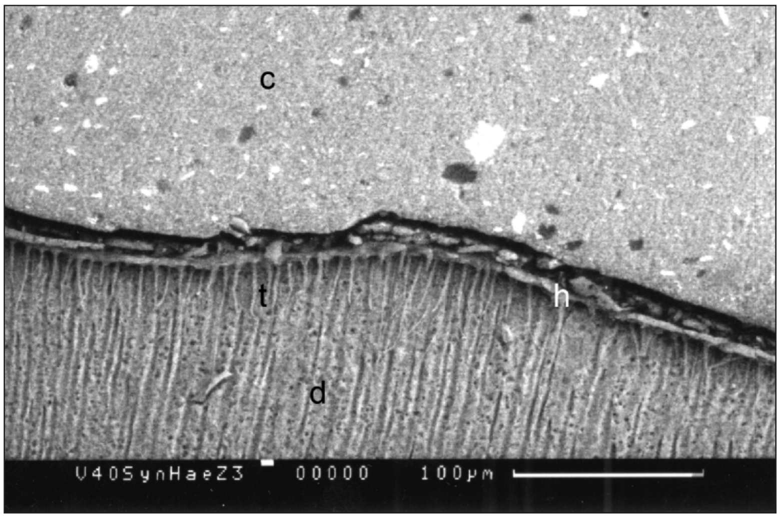

Figure 6. *SEM image of a dentin interface, no detectable adhesive layer, composite (c) is crumbling (h: hybrid layer, t: adhesive tag, d: dentin).*

In the current study, Syntac Classic was used in the functionality "multi-component" as a three-step etch-and-rinse adhesive (Part A). It was also used with a double application of the adhesive Heliobond (Part B) as the layer forming part (light-curing) of the Syntac System to produce thicker resin layers and reduce the number of adhesive failures within the interface.[41,53] It is a widespread system and is used in the clinic of the authors of the current study in combination with the composite Tetric Ceram.[58-60] Thus, it was selected as a basic material for the comparative experimental proof of other adhesive systems.[59]

It is notable that, on dentin, the (significant/insignificant) lowest amount of microleakage and total adhesive failures (operator 1; Parts A, B) corresponded with the most intensive adhesive interlocking by tag formation, lateral branches and a high-grade inter- and peritubular monomer penetration, although there was no corresponding tendency toward the sealing of dentin with adhesive. This result corresponded to the broader differences among the operators with regard to interface morphology vs microleakage in Part A and the occurrence of generally enhanced cleft formation on the dentin interface in cases of operators 2 and 3. However, the reduced number of total adhesive failures on dentin in Part B also agreed with the increased adhesive layer formation in this part. Adhesive failures along the interface on enamel and dentin generally reflect sites of insufficient bonding, independent of causal forces, such as polymerization shrinkage or forces that act during specimen preparation, sputtering and imaging with a high-energy electron beam within the vacuum in the column of an electron microscope. Such a cleft generally demonstrates the site of the weakest compound on a distinct spot within the specimen.[5,61] If the interface withstands all loadings, either a fully preserved specimen or cohesive defects within the section can be observed.

The distinct differences found among the operators regarding the criteria of interface morphology support results from other laboratory investigations[1] and demonstrate a certain technique sensitivity of Syntac Classic. Many studies have dealt with the question of which factors make multi-step adhesives more technique-sensitive and, thus, can influence the enamel/dentin bond.[1,4,6] Working-steps, such as the etching of enamel and dentin, the drying of cavities, the application of single adhesive system components and composites clearly permit even experienced clinicians enough free reign in handling. Although after the double application of Heliobond (Part B) the operators were ranked equal in microleakage, the variations between them regarding interface morphology continued. Thus, a certain "standardization" between the operators was not achieved.

When comparing Part B with Part A, the sealing of enamel and dentin and the hybridization of dentin regarding peri- and intertubular monomer penetration was increased in three of six or two of six comparisons (Table 2).

Microleakage was not reduced. However, with regard to the significantly/insignificantly decreased number of total adhesive failures on the dentin interface, the more frequently appearing adhesive layer could possibly have acted as an elastic buffer zone between composite and enamel/dentin, especially in the case of operator 1, by whom the adhesive failures on dentin were completely avoided. In this context, the reasons for the regularly found composite crumbling on the dentin interface are a matter of speculation. At these sites, an adhesive layer was never detected and, thus, the postulated elastic buffer zone was also not present. Therefore, whenever the composite-dentin compound was strong enough, acting forces could also have led to cohesive defects within the composite.

The data in this *in vitro* study provide a basis for further comparative experimental assessments of other systems under standardized clinical and laboratory conditions considering the observed technique sensitivity of Syntac Classic.

CONCLUSIONS

1. The null hypothesis must be rejected, as there were differences between longstanding "calibrated" clinicians with regard to interface morphology and microleakage formation.
2. The double application of the component Heliobond from the Syntac System resulted in partially increased sealing of enamel and dentin and in the partial reduction in adhesive

failures along the dentin interface; however, it did not lead to a diminished microleakage formation under the conditions of the current study.

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