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Behaviour of failed bonded interfaces under in vitro cariogenic challenge

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Abstract

Objectives—This *in vitro* study aimed to compare dentin wall caries development at different composite-dentin interfaces.

Methods—Dentin samples (10.4 mm²) were restored with composite resin using two adhesive systems (etch-and-rinse and self-etch techniques). Different composite-dentin interfaces with gaps were produced: a) failed bonded, which were fractured at interface after being submitted to ageing protocols (no ageing, mechanical loading or water storage); b) non-bonded interfaces, both without any adhesive material or with adhesive material applied only on the dentin. Adhesively fractured and non-bonded samples were subjected to a lactic acid gel (pH = 5) caries model with a continuous opening/closing movement of the interfacial gap for 10 days. Transverse wavelength-independent microradiographs were taken, and lesion depth and mineral loss were measured. Data were analyzed with linear mixed-effects regression models.

Results—Caries development differed among the composite-dentin interfaces ($p < 0.001$). The non-bonded interface with adhesive material on the dentin showed less lesion depth than the failed bonded groups, while the non-bonded interface without adhesive on dentin showed the deepest wall lesions. Difference between the adhesive systems was observed only in the non-bonded groups ($p = 0.003$), with the self-etch adhesive applied on the dentin showing more severe lesions. Samples broken after mechanical loading ageing showed deeper lesions than those broken after water storage ($p < 0.001$).

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Significance—Composite-dentin interfaces failed after ageing presented different demineralization from interfaces that were never bonded, indicating that the restorative treatment changes the tissue in a way relevant to secondary caries development.

Keywords

Secondary caries; Cariogenic challenge; Adhesive interface; Dentin bonding; Dental caries; Tooth demineralization; Dental bonding; Failure; Fracture

1. Introduction

In dental practice a large proportion of time is devoted to replacing restorations. The most common reasons for restoration failure are caries and fracture, with caries at the restoration margin as the main cause of composite restoration failures in high caries-risk patients [1,2]. It has been proposed that secondary caries is actually primary caries at a restoration margin [3], however, interfacial gaps have been reported to result in the unique feature of secondary wall lesions [4].

The adhesive interface is reported as an instable factor in composite restorations [5]. Water sorption has been shown to contribute to hydrolysis, plasticization of the polymer, promoting deterioration of the mechanical properties of the materials [6,7]. Moreover, cariogenic bacteria may show esterase activity at a sufficient level to induce hydrolysis-mediated degradation of the composite and adhesive, leaving the restorative materials open to biological breakdown [8].

Several studies have evaluated caries wall lesion development in restoration gaps, but most did not include the adhesive bonding step. The presence of a bonding material has already been shown to influence caries development [9,10,11]. However, in some studies bonding was only applied either on the restorative material, or on the dentin, but did not include the complete adhesive procedure, as this would not leave any gaps to investigate. Clinically, it is much more likely to encounter restoration gaps where the adhesive bond was present at baseline but has failed over time. Failure could start already during the adhesive procedure due to polymerization shrinkage, incomplete polymerization, or technical errors, or could be the result of ageing processes. A failure of the adhesive interface between a composite restoration and enamel or dentin may thus result in different types of ‘failed bonded’ interfaces, which may react differently to cariogenic challenges. For clinical relevance of *in vitro* secondary caries models, it would be interesting to observe whether distinct failed bonded interfaces react differently to a caries challenge.

The objective of this study was to compare *in vitro* dentin caries wall lesion development of ‘failed bonded’ composite-dentin interfaces with non-bonded situations where no adhesive was used or adhesive was applied only on the dentin, for two different adhesive systems. We hypothesized that lesion depth and mineral loss would be deeper for the ‘failed bonded’ interfaces than for interfaces with adhesive applied on dentin, but less deep than a situation with no adhesive.

2. Materials and Methods

Seventy-eight freshly extracted sound human molars were selected, cleaned and stored in water. Flat midcoronal dentin surfaces were exposed using #150 grit SiC paper (Siawat Abrasives, Frauenfeld, Switzerland) under running water. Complete removal of enamel was confirmed by stereomicroscopic examination. Subsequently, the dentin surfaces were polished using #600 grit SiC paper (Siawat Abrasives, Frauenfeld, Switzerland).

2.1. Sample preparation

One trained operator performed all adhesive and restorative procedures. The samples were prepared in different ways in order to produce different composite-dentin interfaces, all with an interfacial gap. Figure 1 illustrates schematically the steps of the study. All groups with adhesive material were made with one of two adhesive systems: a 2-step self-etch adhesive (Clearfil™ SE Bond - CSE, Kuraray Noritake, Tokyo, Japan) or a universal adhesive system applied with a 2-step etch-and-rinse technique (Scotchbond™ Universal - SU, 3M ESPE, St. Paul, MN, USA). This resulted in the following 9 experimental groups:

Failed bonded, bond broken after no ageing (CSE / SU)

Failed bonded, bond broken after mechanical ageing (CSE / SU)

Failed bonded, bond broken after water storage ageing (CSE / SU)

Non-bonded, with adhesive material on the dentin (CSE / SU)

Non-bonded, with no adhesive material.

Failed bonded samples (Figure 1a)—Sixty teeth were used to produce failed bonded samples. These samples were optimally bonded with one of the two adhesive systems (n=30 teeth). The prepared teeth were embedded in acrylic resin samples (16 mm high), leaving the prepared occlusal dentin surface free. The adhesive systems were applied following the manufacturers' instructions and light-cured for 10 s, using a LED curing device with an intensity of $\approx 900 \text{ mW/cm}^2$ (Fusion™ S7 Curing Light, DentLight Inc., Richardson, USA). Restorations of $\pm 4 \text{ mm}$ in height were built up incrementally with a composite resin (Clearfil™ AP-X, Kuraray Noritake, Tokyo, Japan). Each composite resin increment was light-cured for 20 s. After the restorative procedures, the teeth remained stored in distilled water for 24 h, at 37°C. Subsequently, the restored teeth were randomly allocated (n = 10 per group) to one of three ageing conditions: no ageing, water-storage ageing and mechanical loading.

All restored teeth were sectioned into rectangular composite-dentin samples with an approximate cross-sectional adhesive area of 10.4 mm^2 ($3.2 \times 3.2 \times 8 \text{ mm}$), using a low speed diamond saw under continuous water-cooling. Every restored tooth yielded two composite-dentin samples (n = 20 samples per group).

Mechanical loading ageing was performed before sectioning on whole restored teeth, using a Rub&Roll mechanical device, at 30 N of force, 0.4 Hz, during 3-week, resulting in 750.000 mechanical cycles. The device used for applying mechanical loading (Rub&Roll) is described in detail elsewhere [12] (Figure 2). Water storage ageing was performed after

sectioning, and consisted of storage in distilled water (37°C, changed weekly) for 5 months. The non-aged samples were stored in distilled water, at 37°C, for 24 hours after sectioning.

Creating the failed bond (Figure 1b)—For the non-aged group after 24 h, and for the aged groups after mechanical and water storage ageing conditions, the composite-dentin blocks were broken to create failed bonded interfaces. The samples were fixed onto polystyrene bars (Stripstyrene, Item 32 N°. 176, .100 x .125", Evergreen scale models, Kirkland, WA 98034) of 3.2 x 3.2 x 25 mm, with the adhesive interface placed in the middle of the bar. Subsequently, the samples were subjected to 3-point flexural loading to promote the fracture of the composite-dentin interface, using Universal Testing Machine (Materials Testing Machine LS1, Lloyd Materials Testing, Hampshire, UK) at 1 kN, and 1 mm/min cross speed. The stylus was positioned on the bar exactly above the interface, thus promoting interface fracture. The polystyrene bar remained intact during this procedure, and the dentin and composite blocks, now with an interfacial gap, remained attached to the bar. The load at fracture for each sample was recorded and the bond strength (σ) in MPa was obtained with the formula $\sigma = F/A$, where F = load for specimen rupture (in Newton) and A = bonded area (mm^2). To determine the area, the formula to calculate A (10.4 mm^2) = width (3.2 mm) x height (3.2 mm) was employed.

The broken samples were observed in stereomicroscope (40x magnification) and baseline microradiographs (see later) were assessed to categorize the type of fracture. Only samples with adhesive fractures were included in the cariogenic challenge test for further analysis. Samples showing mixed or cohesive failures were discarded, as the focus of this study was to evaluate the behaviour of the adhesively failed restoration interface with respect to the caries development. Microradiographs were also used to measure gap size.

Non-bonded samples (Figure 1c)—Eighteen teeth were used to produce non-bonded samples with gap interfaces. Adhesive material was either not used at all (no adhesive), or placed on the dentin wall using one of the two adhesive systems (adhesive on dentin) ($n=6$ teeth). Dentin blocks of 3.2 x 3.2 x 4 mm dimensions (two dentin blocks per teeth, $n=12$ samples per group) were prepared using a low speed diamond saw under continuous water-cooling and were fixed onto polystyrene bars (3.2 x 3.2 x 25 mm). For the groups with the adhesive on dentin, the adhesive materials were applied on the dentin surface according the manufacturers' instructions. For the other samples no adhesive was applied.

The polystyrene bars with mounted dentin samples were secured in a vice, and matrices were placed to create composite-dentin gaps after composite application. The gap sizes as measured in the adhesively failed bonded samples ranged between 50 and 300 μm . In the non-bonded samples matrices were used to create gaps of similar size distribution. Three matrix types were used: plastic matrices of 50 and 200 μm thickness and metallic matrices of 300 μm thickness. The dentin blocks mounted on the polystyrene bars with the matrix in position were restored with resin composite material (Clearfil™ AP-X, Kuraray) parallel to the dentin wall, creating composite resin blocks (3.2 x 3.2 x 4 mm) using a mould. In this way, final sample configuration was similar for failed bonded and non-bonded samples.

2.2. Cariogenic Challenge (Figure 1d)

All samples, fixed on the polystyrene bars, were suspended in a cariogenic medium and submitted to cariogenic challenge using a hydrodynamic flow model, to enhance caries development in the gaps [9]. The polystyrene bars rested on the edges of the reservoir, and horizontal movement was limited by a putty mold. Two layers of an acid-resistant varnish had been painted onto the dentin surfaces of the samples before the cariogenic challenge, except the composite-dentin interface. Demineralization was produced with lactic acid gel (10 g of 0.1M lactic acid + 980 ml distilled water + 9.5 ml of 10M KOH) for 10 days (pH = 5). The solution was renewed every 5 days. A modified brushing machine (instead of toothbrushes, acrylic points were mounted) was used to load the samples in such a way that the gaps intermittently opened up and returned to their resting state (16x/min with 300g of load), creating a cariogenic fluid movement in and out of the gap, enhancing the demineralizing challenge at the interface [9].

2.3. Transversal Wavelength Independent Microradiography (Figure 1e)

Caries wall lesion development in dentin of the interfaces was evaluated using Transversal Wavelength Independent Microradiography (T-WIM). Microradiographs were made at baseline (T0) and after 10 days (T10) of cariogenic challenge. The microradiography settings were 60 kV, 30 mA and an exposure time of 8 sec. A step wedge with the same absorption coefficient as the tooth material (94% Al / 6% Zn alloy) was used for proper quantitative measurement of lesion depth (LD, μm) and mineral loss (ML, $\mu\text{m.vol}\%$). After exposure, the films were developed (10 min), fixed (7 min), rinsed, and dried. A digital image of each sample was recorded with a light microscope (Leica Microsystems, Wetzlar, Germany) with a magnification of 10 X and a CMOS camera (Canon EOS 50D, Tokyo, Japan).

Lesion depth and mineral loss for T-WIM were measured using thresholds of 8% (tissue edge) and 43.2% (sound) mineral. Each sample was measured with a software program (T-WIM calculation programme, version 5.25, J.de Vries, Groningen, NL) at three locations (Fig. 1e): location 1 (near to gap entrance, 200 μm distance from the sample surface); location 2 (in the middle of the sample) and location 3 (at 200 μm distance from the base). Baseline measurements (T0) were subtracted from measurements after 10 days (T10) for estimation of true lesion depth and mineral loss. The subtracted values were used in the statistical analysis.

2.4. Statistical Analysis

The bond strength values in MPa were subjected to 2-way ANOVA (ageing conditions x adhesive materials) and post-hoc Tukey test. The correlation between lesion depth and mineral loss was evaluated using Pearson's Correlation coefficient. The effect of interface conditions on both lesion severity outcomes was analyzed using linear mixed-effects regression models, with gap size and lesion location as added factors. All tests were conducted using the statistical software package R (version 3.0.1, R Foundation for Statistical Computing, Vienna, Austria), with the significance level set at 5%.

3. Results

The bond strength values of the bonded samples are presented in Table 1. The ageing conditions statistically influenced the bond strength values ($p < 0.001$), with both ageing protocols (mechanical load and water storage) presenting lower values than the control (no ageing). The adhesive systems did not significantly influence the fracture strength results ($p = 0.373$). Most fractures were mixed fractures (44.2%), while adhesive fractures occurred in 29.2% of the samples. However, both aged groups showed more adhesive fractures (88.57%) than the non-aged (control) group.

Results for the caries development (lesion depth and mineral loss) are shown in Table 2. Pearson's correlation analysis showed a high correlation between lesion depth and mineral loss ($R^2=0.886$, $p < 0.001$). Fig. 3a&b visualize the effect of the interface conditions on caries development, either bonding on dentin, no bonding, or adhesively failed bonded groups (all ageing groups together).

The results of the multiple linear regression analyses for lesion depth can be found in Table 3. As the lesion depth and mineral loss results are highly correlated, the analysis for mineral loss results showed very similar effects, and therefore this analysis is not presented in the table. The composite-dentin interface conditions had a highly significant effect on lesion depth (Table 3-1). The failed bonded samples showed a higher lesion depth than non-bonded samples with adhesive on the dentin ($p < 0.001$) and lower lesion depth than the non-bonded samples with no adhesive ($p = 0.044$). Comparing the two adhesive systems, no overall statistically significant differences between the adhesive materials for either lesion depth ($p = 0.870$) or mineral loss ($p = 0.736$) were observed (Table 3-2a for lesion depth). However, when comparing only the non-bonded groups (Table 3-2b), there was a significant difference between them ($p = 0.003$), with the self-etch (CSE) adhesive showing deeper lesions and more mineral loss than the etch-and-rinse (SU) bonding material. The ageing condition also statistically influenced the lesion depth and mineral loss ($p < 0.001$; Table 3--3). Mechanical loading ageing with Rub&Roll device resulted in deeper caries lesions than the water storage ageing.

Gap size was a statistically significant factor in all analyses (p values > 0.02), with wider gaps resulting in more caries development. The measurement location also influenced the caries development; location 1 (near to gap entrance) showed deeper lesions than both locations 2 and 3 (p values > 0.05).

4. Discussion

To the knowledge of the authors, this is the first study to evaluate the caries susceptibility behaviour of failed bonded interfaces. Moreover, only few studies have evaluated wall lesion development in the presence of adhesive materials [10,11].

The presence of the two adhesive materials on composite-dentin interfaces with an interfacial gap showed less mineral loss and lesion depth than the other interface conditions, mainly when the adhesive system used was the etch-and-rinse bonding material. This finding

suggests a protective factor of the presence of the adhesive on the interface. The presence of the adhesive, however, does not completely inhibit carious demineralization.

The differences between the adhesive materials were not significant for bond strength values. The two adhesive systems differ in their chemistry, and consequently in their properties, including resistance to degradation. Although, the simplified etch-and-rinse adhesives (2-steps) are considered critical in providing resistance to acids and fluids, which can reduce the longevity of bond [13,14], this was not observed in the present study as the fracture strength after ageing was comparable between adhesive systems.

The adhesives were statistically significantly different for caries development only in the non-bonded situations, where the universal adhesive material, applied with the etch-and-rinse technique, resulted in less lesion depth and mineral loss than the self-etch adhesive. This may have occurred because a universal adhesive even when used in an etch-and-rinse approach may not react to acids and fluids in the same way as genuine etch-and-rinse materials. Universal adhesives that contain MDP have shown a more stable interface after ageing [15]. Furthermore, adhesives applied with etch-and-rinse techniques produce a thicker hybrid layer, while the self-etch adhesive (Clearfil™ SE Bond) showed a thin hybrid layer [13,16]. A thin layer may result in a less stable interface and present more caries development, even taking into account that the quality of hybrid layer may be more important than its thickness [13]. Furthermore, the permeability of adhesive systems is very different and varies according to the composition of each material [17]. The permeability of the adhesive materials tested in this study may also have influenced dentin sealing and caries development. These aspects should be assessed in future studies. There was no difference between the adhesive materials when assessing caries development in the failed bonded interfaces, which can be considered the most clinically relevant condition. Both adhesive materials have been performing well clinically [16,18], with no evidence of differences in secondary caries susceptibility.

The gap size showed an effect on the caries development. In the failed bonded samples, gap width often changed from the entrance towards the base of the gap. It has been reported that such nonuniform gaps between composite-dentin restorations, in which the dentin and composite walls are not parallel, occur frequently [19,20]. In this study, gap width was often largest at the gap entrance, and this may be part of the reason why this location (location 1) presented more caries development than the other locations inside the gap. Also, location 1 was closest to the cariogenic medium. Although voids along the adhesive interface often occur at the internal cavity walls clinically [21], the cavosurface angle of a tooth-restoration interface is also likely to present voids. Such surface voids may be more affected by the oral environment than the internal ones.

Ageing conditions (mechanical loading or water storage) also played a role on the development of wall lesions and on bond strength results. Both ageing methods resulted in a similar decrease in the bond strength values. Water-storage is a popular artificial ageing and well-validated method to assess bond durability, showing decreasing in bond strength results long time [22]. The mechanical aging protocol with the Rub&Roll device has already been shown to decrease the bond strength values [12]. In that study, however, a microtensile test

was employed, different from the flexural force employed in the present research. Water storage ageing stimulates degradation of the hybrid layer [5,13]. The durability of the hybrid layer seems to involve mechanical, thermal and chemical factors. Acidic chemical agents and also bacterial products further challenge the composite-dentin interface. It results in various patterns of degradation of unprotected collagen fibrils and is supposed to affect interface stability [6,22]. From this study, it appears likely that different types of interface breakdown may also affect caries susceptibility differently.

In the new approach (failed bond) performed in the present study, a cariogenic challenge with lactic acid gel was used. Thus, only the inorganic component of the caries process was modelled. Clinically, the caries process is driven by the cariogenic biofilm, which produces organic components, such as enzymes, which may modify the interaction with the restoration interface [23]. Therefore, further studies using biofilm models should be considered.

5. Conclusion

Adhesively failed bonded interfaces exposed to a cariogenic challenge showed lesions that were less deep than non-bonded interfaces with untreated dentin, but deeper than non-bonded interfaces with adhesive covered dentin. This indicates that there is a partial protection of the dentin by the adhesive material. Failed bonded interfaces that had been subjected to mechanical ageing before failure showed deeper caries lesion than those subjected to water storage ageing.

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Highlights

This is the first study to evaluate the caries susceptibility of failed bonded interfaces.

The failed bonded samples showed an intermediate caries development between the non-bonded groups.

Lesion development was lowest for the non-bonded samples with bonding applied on the dentin and highest for the non-bonded samples with no bonding on dentin.

These findings suggested a protective factor of the presence of the adhesive resin on the interface.

For the non-bonded groups, the self-etch adhesive showed deeper lesion and more mineral loss than the etch-and-rinse bonding material.

Mechanical loading ageing resulted in deeper caries lesions than the water storage ageing.

Fig. 1. Schematic drawing of the study design: a) bonded groups; b) creating the failed bonded interfaces; c) non-bonded groups; d) cariogenic challenge; e) lesion measurement at three locations. *Abbreviations: Comp (Composite), Dent (Dentin), CSE (Clearfil SE Bond), SU (Scotchbond Universal).*

Fig. 2.

General schematic overview of the Rub&Roll device used for mechanical load aging. The Rub&Roll consists of a container in which a cylinder is placed that is driven by a stirring motor (A). The samples are placed in the cylinder (B). Between the cylinder and the inner wall of the container there is a space where a rod (black arrow) is placed (C). When the stirring motor (cylinder) starts rotating, the rod rotates in an opposite direction, rolling over the specimens mounted in the cylinder, applying a standardized loading force.

Fig. 3. Box-plot of the caries development results: a) lesion depth (μm) and b) mineral loss ($\mu\text{m.vol } \%$), for all samples grouped by interface condition and adhesive material (CSE and SU). The failed bond groups include both non-aged and aged samples.

Table 1

Mean bond strength values (MPa) and standard deviation ($\pm$ SD) of the bonded samples, considering all types of fractures [adhesive/mixed predominantly adhesive/mixed predominantly cohesive/cohesive] (n=20)

Adhesive Material	Ageing Conditions		
	No ageing	Mechanical loading	Water storage
Clearfil SE Bond	30.0 ($\pm$ 7.5) ^a [2/7/6/5]	22.0 ($\pm$ 8.3) ^b [8/5/2/5]	20.6 ($\pm$ 4.0) ^b [7/3/4/6]
Scotchbond Universal	29.3 ($\pm$ 6.9) ^a [3/6/4/7]	18.2 ($\pm$ 6.1) ^b [8/5/3/4]	18.3 ($\pm$ 3.8) ^b [7/3/5/5]

For each row, values with different small letters indicate significant difference among ageing protocols ($p < 0.05$). No statistically significant differences were observed between adhesive materials in each column ($p > 0.05$).

Table 2

Lesion depth (LD, μm) and mineral loss (ML, $\mu\text{m}^3/\text{mm}^2$) values (mean, $\pm$ SD) for each group and the number of samples per group [n].

Interface Condition	Failed Bonded Groups				Non-bonded Groups			
	No ageing		Mechanical load ageing		Water storage ageing		Adhesive on dentin	
Material	LD	ML	LD	ML	LD	ML	LD	ML
Clearfil SE Bond	42.7 ($\pm$ 12.8) [2]	832 ($\pm$ 37.5) [2]	339.1 ($\pm$ 141.7) [8]	11256 ($\pm$ 5838) [8]	144 ($\pm$ 99.7) [7]	6677 ($\pm$ 3646.3) [7]	127.1 ($\pm$ 56.8) [12]	3047.1 ($\pm$ 1573.9) [12]
Scotchbond Universal	371.2 ($\pm$ 107.1) [3]	20467 ($\pm$ 4871.7) [3]	213.9 ($\pm$ 94) [8]	6228 ($\pm$ 4853.8) [8]	222.5 ($\pm$ 66.5) [7]	4004 ($\pm$ 3050.9) [7]	71.9 ($\pm$ 40.9) [12]	1869.4 ($\pm$ 1133.3) [12]
							304.7 ($\pm$ 151.7) [12]	12326.1 ($\pm$ 7686.7) [12]

Table 3

Multiple linear regression analyses of the lesion depth results. The estimated effect of factors (interface condition, adhesive material and ageing protocol) on lesion depth increment is presented in separate analyses, taking into account gap size and measurement locations.

1) Analysis of interface condition effect, comparing failed bond vs. adhesive on dentin vs. no adhesive:				
Interface Condition	Effect	p value	95% CI of effect	
			Lower	Upper
Intercept (failed bond)	136	<0.001	96	175
Adhesive on dentin	-150	<0.001	-197	-103
No adhesive	60	0.044	3	118
Gap size (µm)	0.6	<0.001	0.4	0.8
Measurement location 2	-30	0.004	-50	-9
Measurement location 3	-40	<0.001	-60	-20
2a) Analysis of adhesive material effect considering all interface condition, comparing CSE vs. SU:				
Adhesive Material	Effect	p value	95% CI of effect	
			Lower	Upper
Intercept (CSE)	140	<0.001	83	196
SU	-4	0.870	-59	50
Gap size (µm)	0.3	0.025	0.1	0.5
Measurement location 2	-34	0.004	-57	-11
Measurement location 3	-55	<0.001	-78	-32
2b) Analysis of adhesive material effect, adhesive on dentin samples only, comparing CSE vs. SU:				
Material - Adhesive on dentin	Effect	p value	95% CI of effect	
			Lower	Upper
Intercept (CSE)	72	<0.001	36	109
SU	-54	0.003	-86	-21
Gap size (µm)	0.2	0.008	0.1	0.3
Measurement location 2	11	0.052	0.2	21
Measurement location 3	30	<0.001	20	40
2c) Analysis of adhesive material effect, failed bond samples only, comparing CSE vs. SU:				
Material - Failed Bond	Effect	p value	95% CI of effect	
			Lower	Upper
Intercept (CSE)	97	0.001	41	153
SU	-18	0.512	-70	35
Gap size (µm)	1.2	<0.001	0.9	1.6
Measurement location 2	-65	<0.001	-97	-34
Measurement location 3	-115	<0.001	-147	-48
3) Analysis of ageing protocol effect, considering mechanical load vs. water storage ageing:				

1) Analysis of interface condition effect, comparing failed bond vs. adhesive on dentin vs. no adhesive:				
Interface Condition	Effect	<i>p</i> value	95% CI of effect	
			Lower	Upper
Ageing	Effect	<i>p</i> value	95% CI of effect	
			Lower	Upper
Intercept (mechanical load)	142	<0.001	94	191
Water storage	-53	0.012	-93	-13
Gap size (µm)	0.9	<0.001	0.7	1.3
Measurement location 2	-80	<0.001	-104	-55
Measurement location 3	-178	<0.001	-161	-113