Title: Indirect repair of saliva-contaminated materials using veneering ceramics

Running title: INDIRECT REPAIR PROTOCOL FOR CHIPPING FRACTURES

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Abstract

Purpose: To analyze the in vitro efficacy of a surface conditioning liquid facilitating ceramic repairs of saliva-contaminated metal-ceramic and all-ceramic restorations.

Materials and Methods: Specimens constructed from non-precious alloy (NPA), precious alloy (PA), lithium-disilicate (LD), zirconia (ZI), veneering ceramics for zirconia (VZI), veneering ceramics for lithium-disilicate (VLD), and veneering ceramics for metal alloys (VM) were manufactured (total: n=168; each material n = 24). Veneering ceramic cylinders (thickness: 2mm) were hand-layered on top of the specimens. Shear bond strength (SBS) tests were performed, measuring the maximum bond strength (MBS) of the cylinders on the specimens. Following this, the specimens were artificially aged and stored in artificial saliva for 30 days at 37°C. After physical cleaning using aluminum oxide air abrasion, a new surface conditioning liquid was applied (test, n=84) or not (control, n=84). New ceramic cylinders were hand-layered followed by a second SBS test. Descriptive statistics, linear regression analyses, and a one-sample t-test (α=0.05) were used to ascertain the differences within (pre- vs. post-repair) and between the groups.

Results: All specimens in the test group could be repaired, whereas 18 repairs in the control group failed. After the repairs, an MBS decrease was observed for the NPA specimens of the control group (-15.5MPa, p = 0.004) but not among any of the test groups. Comparing the change in MBS between the test and control groups, the reduction was significantly higher in the repaired NPA specimens of the control group (mean difference 11.8 MPa, p=0.017).

Conclusions: Using the analyzed surface conditioning liquid, metal-ceramic and all-ceramic materials can be repaired, while some repairs failed without the liquid. The initial bond strengths between core

and veneering materials could be restored in all specimens when the new surface conditioning liquid was applied.

Keywords: dental prosthesis, ceramics, artificial aging, bond strength, veneer, chipping

Fixed implant restorations, including single crowns, fixed partial- or even complete dentures, have proven their clinical success for partially and fully edentulous patients over the last three decades.[1,2] Dental ceramics are widely used in these types of restorations for veneers on metal or ceramic frameworks, and even in monolithic restorations, due to their good esthetics, natural appearance, and favorable optical properties.[3-5] Although designs and manufacturing techniques have evolved remarkably, chipping of the veneering ceramic or framework fracture, still occur independent of the material.[6] Technical complications in these restorations have been reported to be associated with clinical and technical or laboratory factors, such as parafunctional habits, inadequate design, lack of ceramic polishing, etc.[7] Furthermore, these complications not only affect oral function, but also the patients' quality-of-life.[8]

In response to chipping fractures, intraoral repairs are usually performed using direct composite resins due to their easy clinical handling and low economic impact.[9,10] Intraoral repairs using ceramic materials are impossible due to the sintering process. Therefore, the restorations must be removed when attempting repair with ceramic materials.[11-13] In contrast to a tooth-supported or a cement-retained implant restoration, a screw-retained implant restoration theoretically provides the possibility of removing the restoration for extraoral repairs in a dental laboratory.[14] Shape modifications can also be beneficial upon observation of longitudinal changes in the soft tissues or adjacent tooth positions, leading to incisal step-formations or spaces between the pontic areas and soft tissues.[15] Such changes near single-implant crowns have been demonstrated to be frequent even in adult patients.[16] However, even under laboratory conditions, ceramic repairs or modifications of worn restorations are challenging due to salivary contamination.[17,18] The required sintering process frequently leads to a reduced bond strength between the original restoration and the newly added ceramics, or even destruction of the restoration due to remaining microcontamination within the material (e.g., saliva or

color pigments).[18] Although various disinfection and repair techniques have been investigated, a definitive and predictable method has not yet been described.[13]

Therefore, this in vitro study aimed to analyze the efficacy of an experimental surface conditioning liquid, purported to eliminate salivary contaminations in metal-ceramic and all-ceramic restorations, consequently enabling the possibility of reliable ceramic repairs. The first null hypothesis ($H0_1$) tested was that using the liquid would not facilitate a more predictable repair of various saliva-contaminated ceramic materials. The second null hypothesis ($H0_2$) tested was that there would be no difference in the maximum bond strength (MBS) between the original and repaired saliva-contaminated specimens after using the experimental liquid. The third null hypothesis ($H0_3$) tested was that there would be no difference in MBS between repaired specimens whether the experimental liquid was used or not.

Materials and methods

The present comparative in vitro study was performed at the Department of Reconstructive Dentistry, School of Dental Medicine, University of Bern. A total of 168 specimens were fabricated and divided into two experimental groups (control and test, each n = 84). In both groups, seven types of round specimens constructed from one of several prosthetic materials were fabricated. The specimens consisted of an approximately 4 mm high resin base, followed by an approximately 1 mm thick layer of the selected prosthetic material (each n = 12; diameter: 14 mm, total height: 5 mm). The applied prosthetic materials were non-precious alloy (NPA), precious alloy (PA), lithium-disilicate (LD), and zirconia (ZI) containing 3 mol% of yttria. Furthermore, specimens from distinct veneering materials, for simulating repairs with veneering ceramics, were produced using specific feldspathic ceramics for zirconia (VZI), lithium-disilicate (VLD), and metal alloys (VM). An overview of the study groups and the applied materials is given in Table 1. Subsequently, all specimens were preconditioned in view of the addition of ceramic cylinders, following material-specific protocols (Table 2). All ceramic cylinders were hand-layered, analogous to a conventional veneering process, and subsequently sintered, each following the manufacturers' guidelines. The cylinders were then trimmed with diamond burs (Art.-Nr. 111 and 113; HORICO GmbH, Berlin, Germany), resulting in cylindrical shapes of 5 mm height and 2

± 0.1mm thickness, corresponding to the thickness of the incisal edge of a veneered crown. Details of the specimen manufacturing process are given in Table 2. All specimens were manufactured by the same independent master dental technician who was not involved in the subsequent material testing.

All specimens were mounted in a universal testing machine (Zwick/Roell Z1.0 TN, Zwick, Ulm, Germany) to perform shear bond strength (SBS) tests. A customized holding device provided reproducible positioning of all specimens. A steel wire (stainless steel, diameter 0.6 mm) was adjusted around the ceramic cylinders, at a distance of 2 mm from the specimen, and connected to the testing machine's crosshead (Fig. 1). Afterward, SBS tests were performed, pulling with a crosshead speed of 1 mm/min. The ceramic cylinders' maximum force [F_{max} (N)] before breaking was recorded. Subsequently, the maximum bond strength (MBS [MPa]) was calculated [(F_{max} (N)/bonding area (mm^2)], resulting in 12 SBS values for each material.

Next, all fractured specimens underwent an artificial aging process using thermal cycling (10,000 cycles, 5 - 55°C, dwelling time 5 sec) simulating roughly one year of use,[19] and subsequent storage in artificial saliva for 30 days in an incubator (37°C). The composition of the saliva was: 0.213g $CaCl_2 2H_2O$, 0.738g KH_2PO_4, 0.381g NaCl, 1.114g KCl and 2.2g mucin, in 500ml H_2O.[20,21] Following artificial aging, all specimens received a new ceramic cylinder. Prior to cylinder replacement, all specimens were physically cleaned using aluminum oxide air abrasion (grain size: 50 µm, pressure: 2.5 bar) and 90% alcohol. In the control group, the specimens received new ceramic cylinders as described before (Table 2). Test group specimens received additional chemical cleaning using the surface conditioning liquid (SH-Fix Ceramic Conditioner, DentaVision GmbH, Berg TG, Switzerland) for 40 minutes in an ultrasonic bath at a constant temperature of 30 °C. According to the manufacturer, the liquid consists of several inorganic substances from the ammonia group in an alkaline aqueous environment. After application of the surface conditioning liquid, the specimens were cleaned with 90% ethyl alcohol and dried before cylinder replacement. The cylinders were replaced using procedures identical to those used in the control group. If a repair was not successful in the first attempt, the repair procedures were repeated once. If the second attempt was also unsuccessful, the repair was regarded as a failure. Finally, all repaired control- and test group specimens were again subjected to SBS testing, as described above.

The failure mode of each specimen was determined after the first and second SBS testing by using 2.5× magnification loupes (ExamVision ApS, Samsø, Denmark). Furthermore, a tactile test was performed with a dental exploration probe, and failure modes were classified as: 1) cohesive failure within the specimen, 2) adhesive failure between the ceramic cylinder and the specimen, 3) cohesive failure in the ceramic cylinder, or 4) mixed failure (combinations of failure modes 1 to 3). The evaluation was performed by two investigators independently, and in case of disagreement, the failure mode was determined after discussion.

Mean maximum bond strengths (MBS) and mean changes in MBS (post – pre) were calculated, as well as the respective standard deviations. Linear regression with robust standard errors was used to estimate pre- and post- mean MBS and its change (difference post – pre) with 95% confidence intervals for each group separately. Whether the two groups differed at baseline with respect to mean maximum bond strength was tested by t-test for independent groups. Evaluating $H0_2$, one-sample t-tests were used to test for the pre-post difference within each group. Evaluating $H0_3$, linear regression with robust standard errors adjusted for baseline value was used to test whether the test and control group differed with respect to pre-post differences. Data were analyzed separately for each of the seven materials. All statistical tests were two-sided at a significance level of 0.05. Stata/IC 16.1 for Unix was used for statistical analysis (StataCorp, 4905 Lakeway Drive College Station, TX 77845, USA).

Results

The highest pre-repair MBS was observed in the NPA groups (Control: mean 40.4 ±7.6 MPa; Test: 35.0 ±5.8 MPa). The pre- and post-repair MBS data of the seven materials of both groups (test and control) are given in table 3 (Table 3). In the test group, two specimens (one each in the LD and VZI groups) required a second repair procedure, but the repair was finally successful in all test specimens. In the control group, 55 specimens (6 in the PA group, 7 in the VLM group, 8 in the NPA, LD, and VZI groups, 9 in the ZI and VLD groups), required a second repair procedure. Of those specimens, 18

repairs failed due to debonding of the cylinder from the specimen (n = 11), or "explosion" during the sintering process (n = 7)

Comparing pre-MBS values, a significantly stronger MBS was found in the test group for ZI ($p < 0.001$) and VLD ($p = 0.038$), but a weaker MBS was found for VZI ($p = 0.001$) and VM ($p = 0.009$) relative to the control group (Tab. 3). Comparing the MBS post-repair, the MBS was significantly higher in the NPA specimens of the test group ($p = 0.017$). No other significant differences were observed between the test and control groups (Table 3). In the test group, MBS increased significantly after repair of the VZI ($p = 0.004$) and VM specimens ($p = 0.008$). In the control group, the MBS increased significantly in the ZI specimens ($p < 0.001$) but decreased in the NPA specimens ($p = 0.004$). No other significant changes were observed within the test and control groups (Table 3, Fig. 2). Comparing the change in MBS between the test and control groups, the decrease in MBS for the repaired NPA specimens was significantly greater in the control group (mean difference 11.8 MPa, $p = 0.017$), but not in any other groups ($p > 0.076$). The failure modes in the test group were similar pre- and post-repairs, whereas a change in the failure modes was obvious in the control group, with an increased number of adhesive failures (Table 4).

Discussion

The current in vitro study evaluated the maximum bond strength (MBS) between core and veneering materials of various metal-ceramic and all-ceramic materials, using a shear bond strength test. Furthermore, the effect on MBS of a new surface conditioning approach (using a repairing liquid) for repairing saliva-contaminated restorations was tested. The surface conditioning liquid facilitated the repair of all saliva-contaminated specimens (test group), whereas repairs were not possible in every specimen when the liquid was not used (control group). Therefore, $H0_1$ was rejected. Using the surface conditioning liquid, a significant increase in MBS was observed in the NPA group, but not for any other groups. Hence, $H0_2$ was rejected. Significant differences were found between MBS of the specimens repaired with and without the liquid. Consequently, $H0_3$ was rejected.

This is the first study to evaluate the efficacy of the applied surface conditioning liquid for the repair of chipping fractures. Ceramic chipping is the most prevalent technical complication (followed

by framework fractures) among fixed dental restorations.[1-3,18] In single-implant crowns, the 5-year incidence data reported in the literature shows veneering ceramic chipping rates of 2.9% for metal-ceramic and 2.8% for zirconia-ceramic restorations.[9] The additional economic and temporary costs can negatively affect patient quality-of-life, especially when the restorations must be re-manufactured.[8] Taking these conditions into account, the possibility of repair is a quick and relatively inexpensive option.[9-11] Various direct and indirect techniques have been proposed, such as re-bonding the detached fragment, the manufacture of a new fragment, or re-veneering with a composite resin.[9-12] Nevertheless, as mentioned before, the main problem described is salivary contamination of the surface, making these repair methods unpredictable, even when using composite resin.[13] By the combined mechanism of its capillary action and the ultrasonic bath, the applied surface conditioning liquid could penetrate into small cracks and porosities, removing contaminants that would otherwise prevent proper fusion of the ceramic surfaces. Furthermore, the most superficial contaminated ceramic layer was corroded, widening the cracks and exposing deeper, uncontaminated ceramic layers. Thanks to this expansion and cleaning of the cracks, the ceramic particles could be re-fused during the subsequent firing process without creating stresses within the material. In this sense, the experimental liquid may be an effective alternative for overcoming the unpredictability of repairs following salivary contamination.

Looking at the main results of the study, it can be assumed that repairs to the full set of test specimens within a group were possible only upon treatment with the conditioning liquid. Relative to the test group, every material in the control group included specimens that could not be repaired, even though an identical repair protocol was used except for application of the surface conditioning liquid. The reliability of the liquid is also demonstrated by the fact that the MBS for all material combinations of the test group did not decrease significantly relative to the initial value. Accordingly, the failure modes pre- and post-repair were similar across test groups but not across the control groups. In the case of veneering ceramics on zirconia and metal, the MBS even increased, although all specimens underwent prior thermal cycling and salivary contamination simulation. Even though only the non-precious alloy group showed a significant difference in MBS between the test and control samples, the post-repair MBS for all materials investigated were higher in the test group. Although the

present study cannot be directly compared for its originality, the results obtained are in agreement with the literature, indicating that superficial decontamination of reconstructions is beneficial for subsequent repair processes.[23] Other studies confirm the results of the present study, demonstrating that surface cleaning or decontamination has a positive effect on repairability in terms of bond and fracture strength, in metal-ceramic and full ceramic restorations.[24] In future studies, cyclic loading could be added to the in vitro testing in order to determine samples' load-bearing capacity, and to evaluate the longevity of repaired restorations.[25] Furthermore, it may be interesting to investigate an eventual effect of the liquid on pristine non-saliva contaminated specimens, as some groups even showed an increase in MBS after treatment with the liquid. Potentially, the liquid could even provide a pretreatment method for the initial veneering of framework materials, increasing the MBS between the veneering ceramic and the framework.

In the present study, an artificial aging process based on thermal cycling and artificial saliva storage was conducted. The thermal cycling was performed using 10,000 cycles, representing approximately 1 year of clinical function.[19] It was previously reported that the thermal cycling process can create micro-cracks in the restoration surfaces into which saliva can penetrate,[26] compromising the structural integrity. Therefore, the current experimental set-up was specifically chosen to simulate salivary contamination within the specimens.

In the absence of a well-established standardized decontamination protocol,[27] the present study did not compare the conditioning liquid with other techniques.[10,28] However, existing material-specific pretreatment protocols have been used for each material. As the repair liquid can currently only be used under laboratory conditions and not intraorally, the application is limited to reconstructions that can be removed from the mouth, i.e., screw-retained implant superstructures. Future research should evaluate the flexural resistance and fatigue behavior of repaired bilayer restorations.

Conclusion

The investigated liquid leads to a more predictable repair of saliva-contaminated metal-ceramic and all-ceramic materials. All specimens could be repaired following pretreatment with the liquid. The maximum bond strength between the core material and the veneering ceramic did not drop below the initial value for any of the tested materials when the conditioning liquid was used during repair.

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Tables

Table 1. Study materials

Specimen material	**Product name (Manufacturer)**	**Veneering ceramic (Manufacturer)**
Precious alloy (PA)	Esteticor Spezial (Cendres & Metaux, Biel, Switzerland)	Creation CC® (Cendres & Metaux Biel, Switzerland)
Non-precious alloy (NPA)	NP Metal Rexilium (Pentron, Orange CA, USA)	Creation CC® (Cendres & Metaux Biel, Switzerland)
Lithium Disilicate (LD)	IPS e.max press (Ivoclar Vivadent, Schaan, Liechtenstein)	IPS e.max ceram (Ivoclar Vivadent, Schaan, Liechtenstein)
Zirconia (ZI)	In-Ceram YZ (VITA Zahnfabrik, Bad-Säckingen, Germany)	Creation ZI-CT (Creation Willi Geller International GmbH, Meiningen, Austria)
Veneering ceramic for zirconia (VZI)	Creation ZI-CT (Creation Willi Geller International GmbH, Meiningen, Austria)	Creation ZI-CT (Creation Willi Geller International GmbH, Meiningen, Austria)

Veneering ceramic for lithium disilicate (VLD)	IPS e.max ceram (Ivoclar Vivadent, Schaan, Liechtenstein)	IPS e.max ceram (Ivoclar Vivadent, Schaan, Liechtenstein)
Veneering ceramic for metal alloys (VM)	Creation CC® (Cendres & Metaux Biel, Switzerland)	Creation CC® (Cendres & Metaux Biel, Switzerland)

Overview and composition of applied materials

Table 2. Overview of cylinder fabrication procedures for each specimen material.

Specimen	**Veneering process**
PA; Casted at 1200 °C	Degassing of the metal framework at 980 °C; vacuum 96% Air abrasion 2.5 bar, 50 µm aluminum oxide 5 minutes temperature holding No temperature holding First sintering at 910 °C; vacuum 96% 1 minute temperature holding under vacuum Second sintering 908 °C; vacuum 96% 0.2 min temperature holding under vacuum Glaze sintering 905 °C; no vacuum No temperature holding time
NPA; Casted at 1380°C	Degassing of the metal framework at 980 °C; vacuum 96% Air abrasion 2.5 bar, 50 µm aluminum oxide 5 minutes temperature holding First opaquer sintering at 920 °C; vacuum 96% No temperature holding First sintering at 910 °C; vacuum 96% 1 minute temperature holding under vacuum

	Second sintering at 908 °C; vacuum 96% 0.2 min temperature holding under vacuum Glaze sintering at 905°C; no vacuum No temperature holding time
ZI: Milled with Siron X5 Sintered at 1530 °C	Air abrasion 2.5 bar, 50 µm aluminum oxide Liner sintering at 920 °C; vacuum 96% 2 minutes temperature holding under vacuum First sintering at 910 °C; vacuum 96% 1 minute temperature holding under vacuum Second sintering at 908 °C; vacuum 96% 0.2 min temperature holding under vacuum Glaze sintering at 908 °C; no vacuum No temperature holding time
LD: Pressing temperature 930°C	Air abrasion 2.5 bar with 50 µm aluminum oxide Liner sintering at 750 °C; vacuum 96% 2 minutes temperature holding under vacuum First sintering at 750 °C; vacuum 96% 1 minute temperature holding under vacuum Second sintering at 749°C; vacuum 96% 0.2 min temperature holding under vacuum Glaze sintering 749 °C; no vacuum No temperature holding time
VZI	Adhesive liner sintering at 920°C; vacuum 96% 2 minutes temperature holding under vacuum First sintering at 910°C; vacuum 96% 1 minute temperature holding under vacuum Second sintering at 908 °C; vacuum 96% 0.2 min temperature holding under vacuum

VLD	Adhesive liner sintering at 750 °C; vacuum 96% 2 minutes temperature holding under vacuum First sintering at 750°C; vacuum 96% 1 minute temperature holding under vacuum Second sintering at 749 °C; vacuum 96% 0.2 min temperature holding under vacuum
VM	Opaquer sintering at; 920 °C; Vacuum 96% No temperature holding time First sintering at 910 °C; vacuum 96% 1 minute temperature holding under vacuum Second sintering at 908 °C; vacuum 96% 0.2 min temperature holding under vacuum

Abbreviations: PA = precious alloy, NPA = non-precious alloy, LD = lithium-disilicate, ZI = zirconia, VZI = veneering ceramics for zirconia, VLD = veneering ceramics for lithium-disilicate, VM = veneering ceramics for metal alloys.

Table 3. Mean maximum bond strength (MBS [MPa]) and 95% confidence intervals (CI): Comparison among the groups before (pre) and after (post) the repairs.

		pre	T vs. C	post	Post-Pre	Post vs. Pre	Post-Pre, T vs. C	
		MBS (95% CI)	*p*-value	MBS (95% CI)	MBS (95% CI)	*p*-value	MBS (95% CI)	*p*-value
PA	Test	28.8 (22.2; 35.4)	0.384	30.4 (22.3; 38.6) (n = 12)	1.6 (-5.8; 9.1)	0.640	7.6 (-0.9; 16.0)	0.076
	Control	33.3 (24.2; 42.5)		24.0 (19.8; 28.2); (n = 11)	-9.3 (-19.4; 0.7)	0.065		
NPA	Test	35.0 (31.3; 38.6)	0.113	33.8 (29.6; 38.1) (n =12)	-1.1 (-6.6; 4.4)	0.667	11.8 (2.4; 21.2)	0.017
	Control	40.4 (33.4; 47.5)		25.0 (13.6; 36.3) (n =7)	-15.5 (-24.0; -7.0)	0.004		
LD	Test	25.6 (21.2; 30.0)	0.763	25.0 (22.7; 27.4) (n = 12)	-0.6 (-6.4; 5.3)	0.835	0.4 (-3.6; 4.4)	0.843

	Control	26.6 (20.4; 32.8)		24.7 (21.2; 28.1) (n = 10)	-1.9 (-7.2; 3.4)	0.435		
ZI	Test	32.6 (28.8; 36.3)	<0.001	30.2 (27.9; 32.4) (n = 12)	-2.4 (-6.0; 1.2)	0.169	0.4 (-5.5; 6.4)	0.884
	Control	17.4 (15.0; 19.8)		24.1 (21.2; 27.0) (n =11)	6.7 (4.6; 8.8)	<0.001		
VZI	Test	14.9 (12.3; 17.6)	0.001	23.0 (18.5; 27.5) (n = 12)	8.0 (3.2; 12.9)	0.004	2.8 (-7.3; 12.8)	0.567
	Control	24.7 (19.7; 29.7)		19.3 (16.1; 22.6) (n =8)	-5.4 (-12.7; 1.9)	0.126		
VLD	Test	25.3 (20.6; 29.9)	0.038	28.5 (20.9; 36.2) (n = 12)	3.3 (-6.3; 12.9)	0.468	3.6 (-9.2; 16.4)	0.566
	Control	20.2 (18.5; 22.0)		26.1 (17.1; 35.0) (n = 9)	5.8 (-3.0; 14.7)	0.168		
VM	Test	28.1 (23.7; 32.4)	0.009	37.8 (33.1; 42.6) (n = 12)	9.8 (3.1; 16.4)	0.008	4.0 (-3.7; 11.7)	0.295
	Control	37.7 (31.7; 43.8)		34.1 (28.5; 39.8) (n=10)	-3.6 (-11.4; 4.2)	0.325		

Abbreviations: PA = precious alloy, NPA = non-precious alloy, LD = lithium-disilicate, ZI = zirconia, VZI = veneering ceramics for zirconia, VLD = veneering ceramics for lithium-disilicate, VM = veneering ceramics for metal alloys. Test (T) vs. the control group (C): t-test for independent samples. Post vs. Pre: t-test for dependent samples. Post-Pre, T vs C: linear regression analysis adjusted for baseline (pre), t-test for independent samples.

Table 4. Distribution of failure types

		Pre-SBS				Post-SBS				
		Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4	F
PA	Test	0	100%	0	0	0	100%	0	0	0
	Control	0	100%	0	0	0	91.66%	0	0	8.33%
NPA	Test	0	100%	0	0	0	100%	0	0	0
	Control	0	100%	0	0	0	58.33%	0	0	41.66%
LD	Test	16.66%	58.33%	16.66%	8.33%	8.33%	75%	16.66%	0	0
	Control	8.33%	75%	16.66%	0	8.33%	25%	33.33%	16.66%	16.66%
ZIR	Test	91.66%	8.33%	0	0	100%	0	0	0	0
	Control	91.66%	8.33%	0	0	0	66.66%	25%	0	8.33%
VZI	Test	0	100%	0	0	0	91.66%	8.33%	0	0
	Control	0	100%	0	0	0	66.66%	0	0	33.33%
VLD	Test	75%	0	25%	0	75%	0	25%	0	0
	Control	91.66%	0	8.33%	0	25%	33.33%	16.66%	0	25%
VM	Test	91.66%	8.33%	0	0	100%	0	0	0	0
	Control	100%	0	0	0	66.66%	16.66%	0	0	16.66%

Failure types resulting from shear bond strength (SBS) tests before (pre), and after repairs (post). Abbreviations: PA = precious alloy, NPA = non-precious alloy, LD = lithium-disilicate, ZI = zirconia, VZI = veneering ceramics for zirconia, VLD = veneering ceramics for lithium-disilicate, VM = veneering ceramics for metal alloys.

Figure legends

Figure 1: Schematic drawing of the shear bond strength tests: The specimens were clamped in the universal testing machine. A stainless-steel wire was adjusted around the ceramic cylinders, at a distance of 2 mm from the specimens, and connected to the testing machine's crosshead, moving upwards

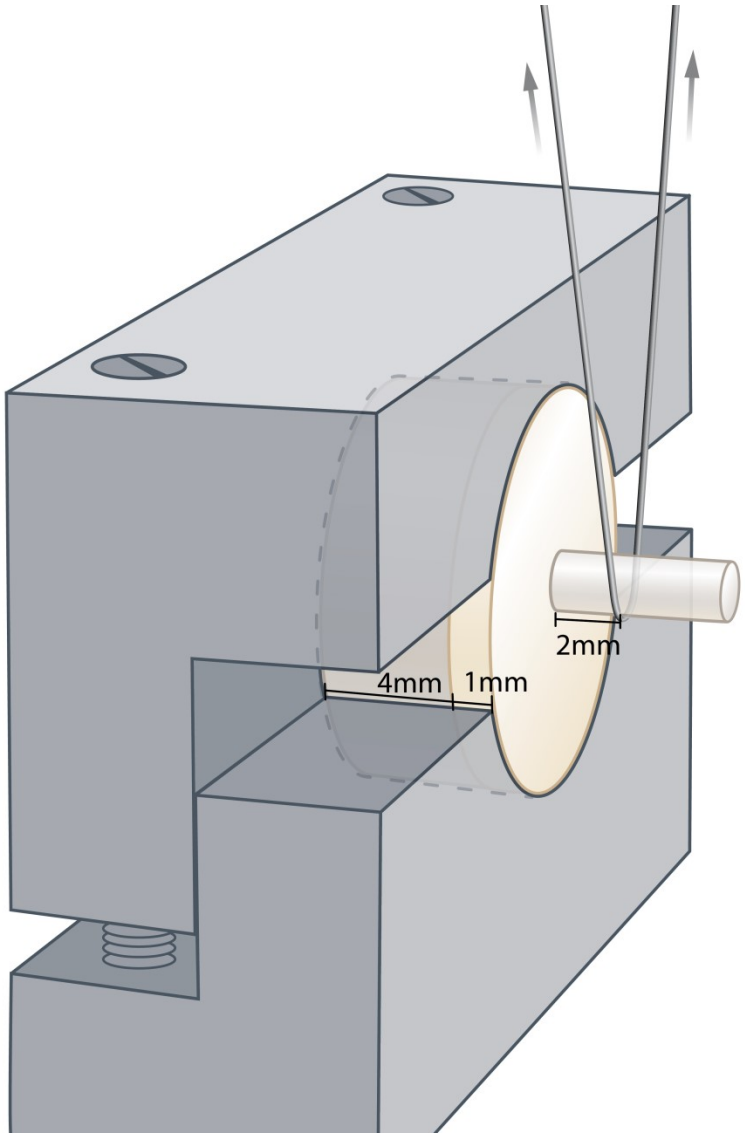
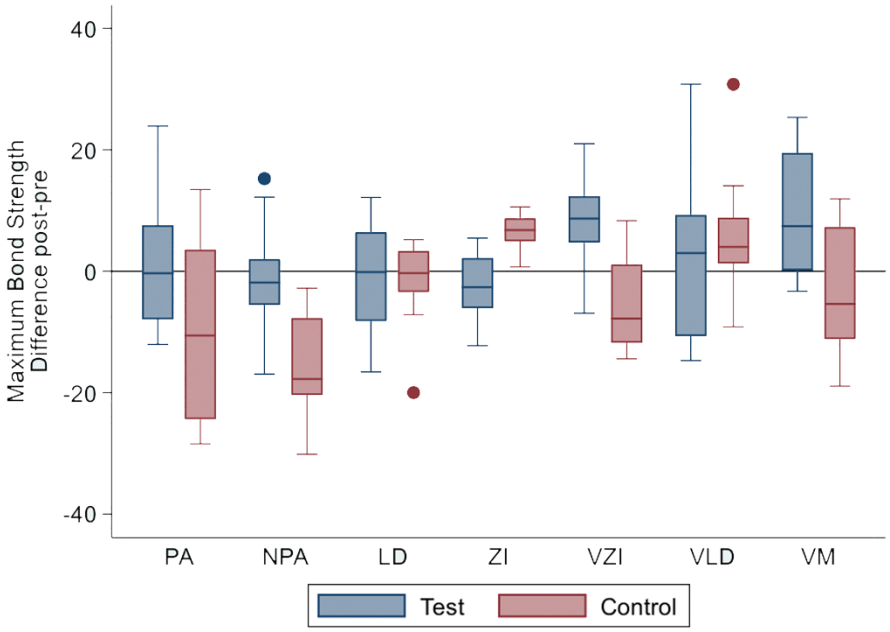


Figure 2: Difference of maximum bond strength (MBS [MPA]) post-pre repair: the decrease of MBS was significantly in the control groups' NPA specimens (p = 0.017), but not in any other group.



Abbreviations: PA = precious alloy, NPA = non-precious alloy, LD = lithium-disilicate, ZI = zirconia, VZI = veneering ceramics for zirconia, VLD = veneering ceramics for lithium-disilicate, VM = veneering ceramics for metal alloys.