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Influence of bonding surface and bonding methods on the fracture resistance and survival rate of full-coverage occlusal veneers made from lithium disilicate ceramic after cyclic loading

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ABSTRACT

Objectives. The purpose of this laboratory study was to evaluate the influence of bonding method and type of dental bonding surface on fracture resistance and survival rate of resin bonded occlusal veneers made from lithium disilicate ceramic after cyclic loading.
Methods. Fourty-eight extracted molars were divided into three groups (N = 16) depending on the preparation: within enamel, within dentin/enamel or within enamel/composite resin filling. Lithium disilicate occlussal veneers were fabricated with a fissure-cusp thickness of 0.3–0.6 mm. Restorations were etched (5% HF), silanated and adhesively luted using a dual-curing luting composite resin. Test groups were divided into two subgroups, one using a only a self-etching primer, the other additionally etching the enamel with phosphoric acid. After water storage (37 °C; 21 d) and thermocycling (7500 cycles; 5–55 °C), specimens were subjected to dynamic loading in a chewing simulator (600,000 cycles; 10 kg/2 Hz). Surviving specimens were loaded until fracture using a universal testing machine.
Results. All specimens survived artificial aging, several specimens showed some damage. ANOVA revealed that enamel etching provided statistically significantly ($p \leq 0.05$) higher fracture resistance than self-etching when bonding to enamel and dentin. Self-etching provided statistically significant ($p \leq 0.05$) higher fracture resistance for the enamel-composite group than for the enamel group. Enamel etching provided statistically significant ($p \leq 0.05$) higher fracture resistance for the enamel and dentin group than for groups enamel and enamel-composite.
Significance. Etching enamel improved the fracture resistance of occlusal veneers when bonding to dentin and enamel and increased the survival rate when bonding to enamel.

1. Introduction

The prosthetic restoration of severly abraded teeth plays an important role in dental treatment. The demand for esthetic, biocompatible and minimally invasive methods to replace such defects is at present steadily increasing on the part of

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both dentists and patients. Modern dental ceramics such as lithium disilicate ceramics, for example, enable the minimally invasive replacement of loss of tooth hard substances caused by malfunctions [1] and have high fracture strengths [2,3].

The success of such restorations is influenced by various factors. Fractures of the ceramics are mentioned in the literature as the most frequent reasons for the failure of all-ceramic restorations [3–5]. An important factor influencing the fracture resistance of all-ceramic restorations is the preparation design [5–9]. The thickness of all-ceramic restorations also plays an important role in the fracture resistance of occlusal veneers [10,11]. Studies have shown that occlusal lithium disilicate ceramic veneers with a thickness of 0.6–1.0 mm and 1.2–1.8 mm can resist forces of up to 800 N and 1000 N respectively [12,13]. In a study by Sasse et al. [10] the fracture resistance of occlusal veneers also made of lithium disilicate ceramics was examined. The specimens were produced in different thicknesses and bonded to different substrates. It turned out that the thickness of the occlusal veneers should not fall below 0.7–1.0 mm regardless of the substrate.

The luting technique used for such restorations also plays a decisive role. Adhesively luted all-ceramic restorations have a higher fracture resistance than conventionally cemented restorations [14–21]. Nowadays, adhesives based on bisphenol-A-glycidylmethacrylate are mainly used in clinical routine. However, teeth that require a prosthetic restoration such as occlusal veneers rarely have only one type of hard tooth substance to be restored. The dental surfaces to which these restorations have to be bonded can vary greatly. For example, there are areas in which dentin may be exposed, purely enamel defects or, often also composite fillings. Each of these surfaces influences the fracture resistance of the inserted restorations [2,10,17] and presents the dentist with a wide variety of challenges, especially with regard to the most minimally invasive restorations possible.

Each of these surfaces requires special pretreatment before bonding. Restorations in which enamel and dentin were treated using the total-etch technique achieved bond strengths of up to 28 MPa in enamel [22] and 13–20 MPa in dentin [23]. Etch and rinse systems have proven themselves on purely enamel bonding areas [24]. However, exposed dentin has a negative effect on the fracture resistance of adhesively cemented all-ceramic restorations in the posterior region [25]. Therefore, nowadays more and more self-etching primers are offered to simplify the bonding protocol and improve bonding to the dentin. The primers etch the surfaces and penetrate them simultaneously [26,27]. Self-etching primers seem to be the most promising way to obtain durable bonding to dentin [28].

However, when using self-ecthing primers in the enamel area, adhesive bonding is compromised compared to etching with phosphoric acid [29] because the self-etching primers are limited in their etching ability. In order to further enhance the bond between the restoration and the tooth structure, additional selective etching of the enamel areas has therefore turned out to be most effective when self-etching primers are used [28,30–32]. Also based on reviews of the literature phosphoric acid etching of enamel is recommended when using self-etching bonding systems in order to achieve optimal bonding to enamel [28,33]. However, whether phosphoric acid etching of enamel improves the outcome when restoring posterior teeth with occlusal ceramic veneers is not known yet [10].

Often occlusal ceramic veneers are bonded to existing occlusal composite fillings. Here also self-etching primer might enhance bonding to this substrate. Bond strength values of 32 MPa to existing composite resin build-ups have been reported [34]. These very high bond strengths are in accordance with the study by Sasse et al. [10] in which it was proven that the highest fracture resistance of occlusal onlays could be achieved when bonding to self-etching primer-conditioned composite resin on the occlusal surface.

However, only few studies have investigated the influence of pretreatment on the fracture strength and survival of occlusal veneers bonded to various dental substrates. In one study the influence of immediate dentin sealing and selective etching was investigated only for bonding to dentin [34], but not for bonding to enamel. In another study [10] only the influence of thickness and substrate was investigated, but not the influence of pretreatment.

Therefore, the aim of the present study was to investigate the effect of the bonding substrates and the bonding technique (self-etching primer used without and with selective enamel etching) on the survival rate and the the fracture resistance of thin (0.3–0.6 mm) occlusal veneers made of lithium disilicate ceramic.

2. Material and methods

2.1. Specimen fabrication

Fourtyeight intact, unrestored human molars, extracted for periodontal or orthodontic reasons, without any caries, fillings or severe abrasions were cleaned and stored in a 0.1% thymol solution for 4 weeks. They were embedded with a standard technique used in previous studies [2,10,35,36]. The root portion apically of the cemento-enamel junction was coated with an artificial periodontal membrane made of gum resin (Anti-Rutsch-Lack, Wenko-Wenselaar, Hilden, Germany) with a thickness of 0.25 mm to simulate the periodontal ligament [37]. The roots of the teeth were then embedded in custom made standard brass cylinders (Ø15 mm) positioned along their long axis with auto-polymerizing acrylic resin material (Technovit 4000, Heraeus Kulzer, Wehrheim, Germany). The enamel-cement junction was located 2 mm above the level of the embedded resin. The roots were secured in the resin by a thin steel bar (Ø 0.9 mm) inserted in the apical third of the root (Fig. 1).

Specimens were divided into three groups (n = 16). All teeth were prepared to receive occlusal veneers with margins in enamel in all groups. An angle of 150 degrees was prepared between the cusps. Fig. 2 depicts the preparation design.

In the first group the preparation was only within enamel with a reduction of about 0.5 mm (group **EN**). In the second group the preparation was extended into dentin (group **ED**) and in the third group the preparation was also extended into the dentin but the dentin core was reduced by 1.5 mm and a composite filling (Tetric EvoCeram, Ivoclar Vivadent, Schaan, Liechtenstein) was placed into the cavity (group **EC**) using a

Fig. 1 – The root portion apically of the cemento-enamel junction was coated with an artificial periodontal membrane made of gum resin, the roots were secured in the embedding resin by a thin steel bar inserted in the apical third of the root (Fig. 1).

three-step bonding system (Optibond FL, Kerr, Charlotte, NC, USA). Finally all preparations and all composite fillings were smoothed and sharp angles were carefully rounded. In all three groups the circumferential outline of the preparation was strictly within the enamel.

After tooth preparation, impressions were made with trays for single impression (Miratray-Mini, Hager & Werken, Duisburg, Germany) using a simultaneous dual-mix technique with polyether material (Permadyne Penta H und L, 3 M ESPE, Seefeld, Germany). The impressions were poured with die stone type 4 (Hydrobase300, Dentona, Dortmund, Germany). The teeth were then stored in water until adhesive luting. The master casts were sent to a commercial milling center (Neue Zähne, Osnabrück, Germany). The casts were scanned (3Shape Scanner D 700, 3Shape A/S, Kopenhagen, Danmark) and the occlusal veneers were then milled (VHF N4 grinding machine, VHF, Ammerstein, Germany) out of lithium disilicate blocks (IPS e.max.CAD in Lab HT, Ivoclar Vivadent, Schaan, Liechtenstein). In order to achieve a constant ceramic thickness the occlusal surface received a semi-anatomic shaping. In the CAD/CAM software the occlusal surface of the tooth was virtually elevated and then reduced again in the fissure area until the desired thickness of 0.6 mm at cusps and 0.3 mm in fissures was obtained. After milling, the veneers were checked and fitted to the prepared teeth. Afterwards the restorations were sintered in a furnace (Programat EP 5000, Ivoclar Vivadent) according to the manufacturer's instructions.

2.2. *Bonding procedure*

All teeth of groups **EN**, **ED** and **EC** were divided into two subgroups according to the etching procedure: In the first group soley a self-etching primer was applied (**SE**), in the second group enamel was additionaly etched (**EE**) using phosphoric acid prior to the primer application.

In the self-etching group (**SE**) a self-etching primer (Adhese Universal, Ivoclar Vivadent, Schaan, Liechtenstein) was applied. The bonding surfaces were pretreated according to the following protocol: in groups **EN** and **ED** the primer was scrubbed onto the bonding surface of the tooth with a brush for 20 s, gently air-dried and light-cured for 10 s (500 mW/cm, Bluephase, Ivoclar Vivadent, Schaan, Liechtenstein). Since the teeth with composite fillings in group (**EC**) were not restored with veneers immediately after preparation and filling procedure, the composite fillings were roughened with a diamond bur (8368.314.016 VPE 5, Gebr. Brasseler GmbH & co.KG, Lemgo, Germany; 20,000 rpm) as recommended for repairs of composite fillings before bonding [38]. Then the primer was applied on enamel and composite for 20 s, gently air-dried and light-cured for 10 s.

In the selective enamel-etching group (**EE**), the enamel surrounding was etched using phosphoric acid (37%) for 15 s, then thoroughly rinsed with water spray for 60 s and air-dried. The pretreatment of the etched enamel and the surfaces in the other groups were the same as described for the self-etching technique.

The bonding surfaces of the restorations were etched for 20 s using 5% hydrofluoric acid etching gel (IPS Ceramic Ätzgel, Ivoclar Vivadent). The etched ceramic surface was thoroughly cleaned using water spray for 60 s. After air-drying

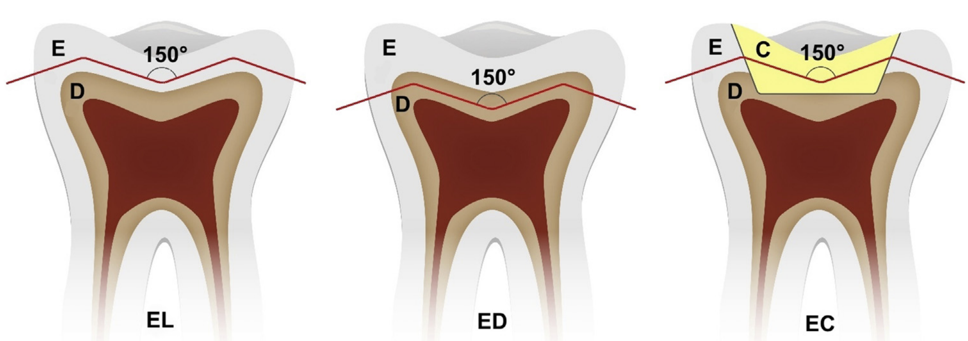

Fig. 2 – Preparation design of the test groups (E-Enamel, D-Dentin, C-Composite resin filling).

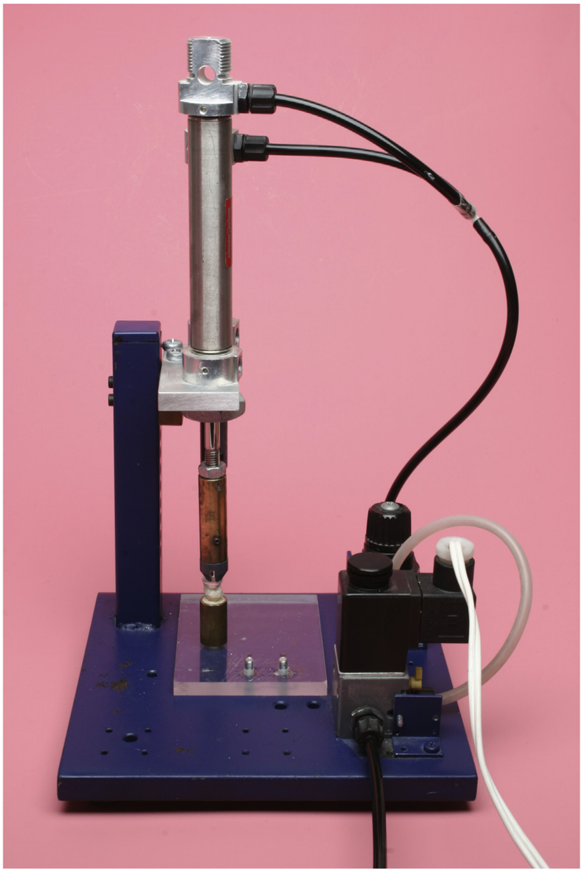

Fig. 3 – Bonding apparatus.

a silane containing restorative primer (Monobond Plus, Ivoclar Vivadent) was applied and air-dried again after 60 s.

A dual-curing luting composite (Variolink esthetic DC, Ivoclar Vivadent) was dispensed from the automix syringe onto the bonding surface of the restoration and onto the fissure area of the tooth. The restoration was positioned by hand and kept in place by a special loading apparatus with a constant force of 10 N (Fig. 3). The excess material was light-cured for 2 s by running the light probe along the cement line, the excess cement was then removed with a scaler. The restoration margins where then covered with glycerine gel (Liquid Strip, Ivoclar Vivadent). Then all margins were again light-cured for 10 s (1000 mW/cm) (Fig. 4).

The specimens were removed from the loading apparatus, the margins were polished and the specimens were stored in water for 21 days at 37 °C.

2.3. Cyclic loading and fracture load

After water storage for 21 days all specimens were first thermocycled in a thermocycling machine (Willytec, Munich, Germany) 7,500 times between 5 and 55 °C in tap water with a 30 s dwell time at each temperature. After thermocycling, the specimens were subjected to a computerized dynamic load test in a multifunctional chewing simulator (Chewing Simulator CS4, SD Mechatronik, Feldkirchen-Westerhan, Germany) combined with integrated thermocycling (60 s dwell time) for 600,000 cycles at 10 kg load. A loading cycle frequency of 2.0 Hz with a lateral sliding component of 0.3 mm towards the central fissure was chosen to simulate conditions in the oral cavity. The descending velocity was 30 mm/s, the ascending velocity was 55 mm/s and the vertical motion was 6 mm. The antagonistic tooth was simulated by a steatite ceramic ball 5 mm in diameter (Hoechst Ceram Tec, Wunsiedel, Germany) which was positioned so that at first it contacted the supporting cusp and then slided down for 0.3 mm.

Following masticatory simulation all specimens were examined using a stereomicroscope (Wild, Heerbrugg, Switzerland) and they were photographed (Leica DC 100, Leica Microsystems, Cambridge, UK) in order to record possible signs of damage.

All surviving specimens were then loaded until fracture in a universal testing machine (Zwick Z010/TN2A, Ulm, Germany). A steel bar with a 6 mm ball end was centered on the main fissure of each specimen in order to apply the load evenly to the triangular ridges of the cusps. Additionally a 0.6 mm tin foil was placed between the ball end and the specimen in order to distribute the load homogenously. The steel bar descended at a crosshead speed of 2 mm/min while computer software (testXpert II, Zwick, Ulm, Germany) recorded the maximum load until fracture in Newton.

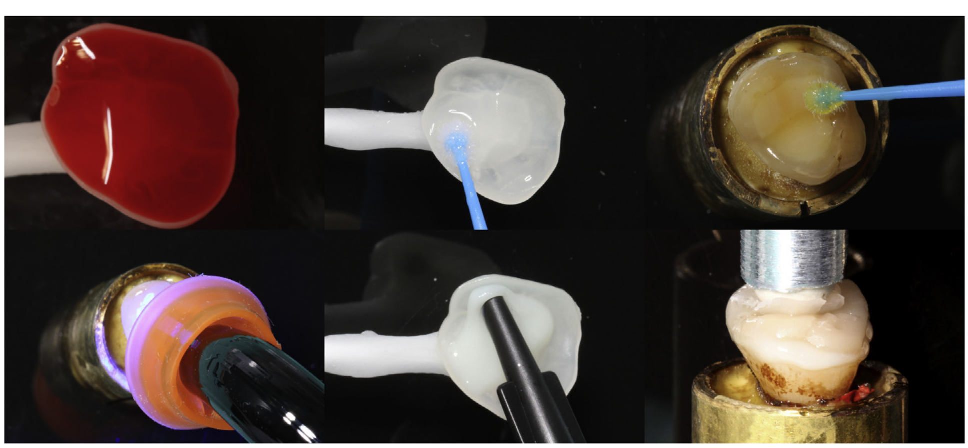

Fig. 4 – Pretreatment of ceramic and dental surface (etching, silanisation, application of self-etching primer, light-curing and application of composite luting resin, positioning of specimens in a special bonding apparatus).

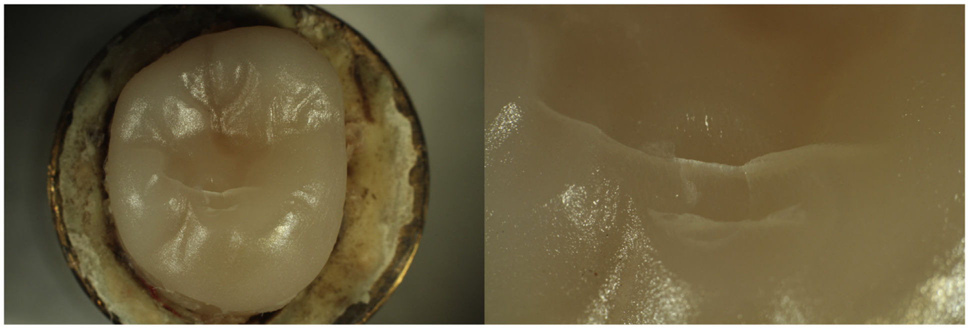

Fig. 5 – Overview and stereomacroscopic view at ×16 magnification of the occlusal surface of a restoration showing microcrack formation after dynamic loading.

Table 1 – Survival rates after dynamic loading.

Bonding surface		Bonding method	
		SE ($n = 24$)	EE ($n = 24$)
EN ($n = 16$)	Survival rate unharmed (%)	12.5	87.5
ED ($n = 16$)	Survival rate unharmed (%)	62.5	62.5
EC ($n = 16$)	Survival rate unharmed (%)	25.0	37.5

Table 2 – Mean fracture resistance (N) of groups, minima, maxima for static loading and influence of the bonding surface and the bonding method. Means with the same upper case superscript letter within the same row (=different bonding method) are not statistically different ($p > 0.05$). Means with the same lower case subscript letter within the same column (=different bonding surface) are not statistically different either ($p > 0.05$).

Bonding surface		Bonding method	
		SE ($n = 24$)	EE ($n = 24$)
	Mean	1631.3^{A}_{a}	2131.3^{A}_{a}
EN ($n = 16$)	Min	1100	1080
	Max	2430	2880
	Mean	$2132.5^{A}_{a,b}$	3391.3^{B}_{b}
ED ($n = 16$)	Min	1540	1850
	Max	3160	4390
	Mean	2618.8^{A}_{b}	2536.3^{A}_{a}
EC ($n = 16$)	Min	1690	1620
	Max	3430	3360

2.4. *Analysis of results and statistics*

Statistical analysis was performed using the statistical software SPSS 16 (SPSS Inc., Chicago, IL, USA). The Shapiro–Wilk test was performed on all groups to determine normal distribution of data. The Shapiro–Wilk test was used because it has a relatively high test strength for small sample sizes. In addition, normal Q–Q plots and detrended Q–Q plots were evaluated. After the normal distribution of mean fracture resistance values was confirmed, the Levene's test was performed on all groups and revealed equality of variances.

A two-way ANOVA was conducted that examined the effect of bonding method and bonding surface on the mean fracture resistance. Since there was a statistically significant interaction between the effects on the mean fracture resistance ($p = 0.010$) a simple main effects analysis was conducted (Bonferroni adjusted). Pairwise comparisons were also made using the one-way ANOVA to assess the differences among the bonding method within each of the different bonding surface groups. One-way ANOVA was conducted to analyze the effect of the bonding surface within each bonding method. Post hoc multiple comparisons were conducted by using Ryan–Einot–Gabriel–Welsch range test. *P*-values less than 0.05 were considered statistically significant.

3. Results

All specimens survived artificial aging, but often specimens showed some damage in the form of micro-cracks in the ceramic. They were rated as partial failure when crack formation occurred (Fig. 5) and specimens were rated as a success when they did not show any macroscopic damage after masticatory simulation.

The results regarding survival after dynamic loading are shown in Table 1. The results for mean fracture resistance of the different groups are presented in Table 2.

Fractured surfaces were examined to evaluate mode of failure and classified as follows: (I) fracture within ceramic and tooth structures without chipping, (II) fracture of ceramic with chipping, (III) crack formation within ceramic without chipping. Failure mode analysis is shown in Table 3 and depicted in Fig. 6.

Table 3 – Failure modes after fracture strength testing. Percent failure for each group: (I) Fracture within ceramic and tooth structures without chipping, (II) fracture of ceramic with chipping, (III) crack formation within ceramic without chipping.

	Group	Mode of failure (%)		
		I	II	III
SE	EN		100	
	ED	12.5	87.5	
	EC	12.5	87.5	
EE	EN	100		
	ED	87.5		12.5
	EC	37.5	37.5	25

Simple main effects analysis showed a significantly higher mean fracture resistance when bonding with the selective enamel etching technique in comparison to bonding with self-etching primer only to enamel and dentin ($p \leq 0.001$), but there were no differences between the bonding methods when bonding solely to enamel ($p > 0.05$) or to enamel and composite ($p > 0.05$).

Restorations bonded with self-etching primer only showed significantly higher ($p \leq 0.01$) mean fracture resistance when bonded to enamel and composite in comparison to bonding solely to enamel, but not in comparison to bonding to enamel and dentin ($p > 0.05$). Restorations bonded with the selective enamel etching method showed significantly higher ($p \leq 0.001$) mean fracture resistance when bonded to enamel and dentin surface in comparison to the other bonding surface groups. Groups with bonding surfaces restricted to enamel and within enamel and composite showed no significant differences within the selective etching group ($p > 0.05$).

4. Discussion

The preparation design of the occlusal veneers was selected based on previous studies [2,10] and general preparation guidelines [39,40]. In order to simulate the physical loads to which dental restorations are clinically exposed, a thermocycling load was applied. This was used in particular to subject the adhesive bonding zone to artificial aging. In order to simulate mechanical loading and thus increase the clinical relevance of the study [41], the specimens were loaded in a biaxial chewing simulator. As in previous studies [2,10,35] 600,000 chewing cycles were performed with 3,500 thermal cycles, which corresponds to a clinical service time of about 2.5 years [42,43]. All specimens that successfully survived artificial aging were subjected to quasi-static loading until fracture [2,10,44]. All specimens that survived the chewing simulation unharmed were considered a success and all specimens that only showed microcracks were considered a partial success [44,45]. So far there have been no studies that have shown that such pre-damaged restorations have a shorter lifetime than undamaged restorations. It might be possible that the cracks in the ceramic behave similarly to cracks in the enamel and thus do not lead to increased failure rates of affected teeth [46]. With average fracture strengths of 1631.3–3391.3 N the ultra-thin occlusal veneers in the current study resisted considerably higher loading forces than generally required for restorations in the posterior region [47]. All specimens of all groups survived the chewing simulation. Not a single catastrophic failure was identified, although microcracks did occur in all groups. Comparing these results with similarly designed studies [2,10], which also examined the fracture strength of occlusal veneers made of lithium disilicate ceramic, it can be concluded that the fracture strength values in these studies also clearly exceeded the values required for dental restorations. In the study by Sasse et al. [10] different substrates and different thicknesses of occlusal veneers were investigated. In contrast to the present study, only a self-etching primer was used without separate etching of enamel. The fracture strength values of the enamel bonded veneers with thicknesses of 0.3–0.6 mm were in a significantly lower range (610 N) in the cited study. In the present study, a newly developed so-called universal bonding system was used, which could explain the improved fracture strengths. In the study by Clausen et al. veneers were made from a pressable lithium disilicate ceramic and with considerably higher thicknesses (1.5–2 mm) which explains their reported higher fracture strength values.

The statistical evaluation showed that a significantly higher fracture resistance (3391 N) was obtained in the group ED when using the selective etching technique in comparison to the self-etching technique (2132 N). This result also coincides with a study by Frankenberger et al. [28]. They revealed that the marginal stability of adhesively bonded restorations in the enamel area increased when using the selective etching technique compared to the self-etching technique.

In another study [10] the mean fracture resistance for dentin bonded lithium disilicate occusal veneers with a thickness of 0.3–0.6 mm without selective enamel etching was 2370 N and thus in a range comparable to the present study (2132 N). In a study conducted by Yazigi et al. [44] lithium disilicate veneers with a thickness of 0.5–0.8 mm were bonded to enamel-framed dentin of premolars using various adhesive protocols. The fracture resistance of these veneers ranged from 1122 N to 1853 N, whereas it increased significantly through the application of IDS (immediate dentin sealing). With this technique, the dentin is immediately sealed with a bonding agent after preparation and before impression taking [48–50]. It is therefore reasonable to assume, that IDS could further increase the fracture resistance of thin occusal veneers when bonded to dentin. However, the fracture resistance values recorded in the cited study [44] cannot be directly compared with the fracture resistance values in the present study as premolars were used.

When the self-etching technique was used (SE), the statistical evaluation showed significantly higher fracture resistance values for the enamel-composite-bonded specimens (2618 N) than for the enamel bonded specimens (1631 N).

This in turn matches the results of a study in which the fracture strength of occlusal veneers was evaluated. The specimens, made of lithium disilicate, were bonded to enamel, enamel and dentin and to enamel and composite [10]. Here, too, the highest fracture strength was determined in the group bonded to enamel and composite (2765 N). The values here were in a range comparable to the present study; this can probably be attributed to the almost identical study design with regard to the selection of teeth, the preparation design

Fig. 6 – Fracture modes after fracture strength testing: (I) fracture within ceramic and tooth structures without chipping, (II) fracture of ceramic with chipping, (III) crack formation within ceramic without chipping.

and the thickness of veneers. These results also correlate with another study evaluating the bond strength of different adhesives to different substrates [34]. The bond strength between Multilink Automix and composite fillings were in the range of 32 MPa. There are only a few other studies that investigated the bond between composite adhesive and restorative composite. A study by Müller et al. [51] showed that the marginal sealing of ceramic inlays when bonded to composite is comparable to bonding to dentin. Therefore it can be assumed that with appropriate pretreatment bonding to enamel-framed composite fillings is promising. Within the group in which the enamel area was additionally etched (EE), the fracture resistance for group ED was significantly higher than for groups EC and EL. This contradicts results with older bonding systems showing that the fracture resistance of enamel bonded restorations are higher than that of dentin-bonded restorations [52,53]. A study comparing bonding to enamel with different pretreatments (selective etching and application of different self-etching primers vs total etch) revealed that the pretreatment with self-etching primer and selective etching did not always result in comparable bond strengths as the application of the total-etch technique [54]. The lower fracture strength values on enamel in the recent study could be due to the improved dentin bond of the new self-etching primer.

The results of the present study are consistent with another study [12], in which the survival rates of CAD/CAM-manufactured composite and ceramic occlusal veneers with a thickness of 1.2–1.8 mm were compared. Occlusal lithium disilicate ceramic veneers withstood the load test (185,000 cycles with an increasing load from 200 N to 1400 N) at 800 N to 100% and at 1400 N to 30%. In this study, however, the teeth were pretreated using the total-etching technique, while in the present study a self-etching primer or the additional selective etching of the enamel areas was used to condition the tooth surfaces. The occlusal veneers were adhesively luted with a restorative composite resin. Based on their results, the authors concluded that veneers with thinner thicknesses could also be used to restore occlusally worn dentitions. The results of the present study support this conclusion.

In another study with an identical test design [13], the survival rate of CAD/CAM-manufactured occlusal composite and ceramic veneers with thicknesses of 0.6–1.3 mm was evaluated. The ceramic veneers made of a CAD/CAM-manufactured lithium disilicate ceramic showed cracks earlier than the composite veneers. None of the ceramic specimens survived the entire load test of 185,000 cycles undamaged, but withstood loads up to 800 N. The authors concluded that the restorations can also be used in these thicknesses under normal occlusal loading. Our results suggest that the thickness of lithium disilicate ceramic occlusal veneers could be reduced even more and still be clinically successful.

In another study [55] the difference in fracture resistance values of pressable and CAD/CAM-manufactured lithium disilicate restorations with a thickness of 1.5 mm was investigated. It was found that the fracture resistance of the CAD/CAM restorations was lower than that of the pressed restorations. This corresponds to the slightly lower flexural strength values of 360 MPa for e.max CAD compared to 400 MPa for e.max Press. Furthermore, they investigated the influence of the bonding technique on the fracture resistance. Part of the specimens were pretreated with the total etch technique, the other part of the specimens only with the Multilink Primer A and B. The restorations bonded with the Multilink Primer showed significantly lower fracture resistance. The selected design of the restorations was also different in this study, the teeth were restored with an onlay that did not cover the entire occlusal surface. The mean fracture resistance determined for CAD/CAM restorations was 1584.1 N after pretreatment with the self-etching primer (Multilink Primer A and B) and 2356.5 N after pretreatment with the total etch technique. This result is in line with the result of the present study, which also showed that selective etching of the enamel area increased the fracture resistance of restorations and increased their survival rate. Due to the different adhesive systems and study designs of the cited studies, these values cannot be directly compared.

However, when considering the current results, the survival rate and the fracture mode of the specimens must also be taken into account. The survival rate of completely undamaged specimens after chewing simulation increased from 12.5% to 87.5% due to the additional etching in group EN. The pretreatment also had a considerable influence on the fracture mode after static loading: without selective etching, the ceramic chipped in all cases, while after additional etching of the enamel, no more chipping occurred. These results are consistent with those of other studies [10,56]. In one of the studies, enamel was etched when bonding occlusal veneers in addition to the application of a self-etching primer (Multilink Primer A/B); these restorations survived chewing simulation completely unharmed. The survival rate of specimens in group ED was not influenced by the bonding techniques (62.5% undamaged). Considering the fracture mode after static loading, no chipping of the ceramic occurred after etching the enamel areas, while without previous enamel etching 87.5% of the specimens showed chipping. This indicates a better bond due to additional etching and also explains the higher fracture strength values. In group EC enamel etching only led to a slight improvement of the survival rate, but again the number of specimens that showed chipping after static loading decreased.

Therefore, it can be concluded that even if the final fracture resistance between the selective etching groups and the self-etching groups did not differ significantly in all groups of the current study, the durability of ultrathin restorations can still be increased by using the selective etching technique. Etching the enamel increased the survival rates in group EN and also slightly in group EC. Fracture resistance was significantly improved by selective etching in the dentin bonded group ED, but there was also a tendency of improvement in the enamel bonded group EN. Due to the additional etching of the enamel areas, there was a clear reduction of chipping after static loading in all groups.

5. Conclusions

Additional etching of enamel improved the fracture resistance when bonding to dentin and enamel and increased the survival rate when bonding to enamel. A treatment with occlusal ceramic veneers with a minimum thickness of 0.3–0.6 mm seems to be a promising option for clinical use.

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