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Effect of Surface Treatments on the Shear Bond Strength of Indirect Esthetic Restorative Materials to Dentin

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Abstract

AIM: The purpose of this research was to evaluate the influence of air abrasion, hydrofluoric acid, and combination of air abrasion and hydrofluoric acid on the shear bond strength between dentin and CEREC, VITA VM7, and E-max.

MATERIAL AND METHODS: Ninety extracted human lower molars were used. The teeth were divided into three groups (n = 30) according to the surface treatment (air abrasion, hydrofluoric acid, and air abrasion + hydrofluoric acid). Each group was then subdivided into three subgroups (n = 10) according to the ceramic material (CEREC, E-max, and VITA VM7). Shear bond strength was determined by the compressive mode of force applied at the ceramic-tooth interface. The collected data were analysed using two-way analysis of variance (ANOVA), and Tukey's post-hoc test statistical significance was set at $P < 0.05$.

RESULTS: The highest mean shear bond strength value was recorded with the CEREC group treated by hydrofluoric acid (8.01MPa). While the least mean shear bond strength was recorded with the Cerec group but when treated by air abrasion alone, it was 4.33MPa.

CONCLUSION: Hydrofluoric acid etching for various types of ceramic restoration improved the bond strength to dentin.

Introduction

The prime concern of nowadays practice is to restore teeth and recovering esthetic with maximum preservation of the remaining tooth structure as much as possible. In this field, indirect ceramic restorations accomplish this concept [1]. The superior esthetic of all-ceramic restorations has resulted in the increased demand for these restorations [2]. Computer-aided design/computer-aided manufacturing (CAD / CAM) techniques are used frequently nowadays, not only for simple veneer but also for more complicated fixed prostheses [3], [4]. The pressed ceramic IPS Empress has emerged strongly in the field of all-ceramic restorations due to its high resistance to fracture and wear [5]. Even though the introduction of modern systems for indirect ceramic restoration conventional layering ceramic is still in service [6]. Long-lasting esthetic restoration is the main goal of both dentists and patients. To achieve a strong bond of the adhesive to the ceramic surface, micromechanical interlocking to the ceramic surface is essential. This requires surface activation for the ceramics [7]. Many surface treatments are used nowadays to create a surface alteration of the esthetic restorations to enhance bonding to the tooth structure. To create such alteration the surface of the restoration may be etched, silanated, or sandblasted. [8]. Etching the ceramic surface with hydrofluoric acid produces a porous surface with a larger surface area available for bonding. These pores facilitate the penetration of the adhesive to create micro retention [7]. Also, sandblasting is used to produce the same effect with different techniques [9]. Application of silane coupling agent has resulted in better wetting of the ceramic surface allowing for better bond strength [10]. All the techniques mentioned above are used solely or in combination with each other to increase the bond strength of indirect ceramic restoration to the prepared tooth structure. Obtaining good bonding between the restoration and the prepared tooth structure has its positive reflectance to decrease the marginal discolouration. Also, microleakage will be decreased with its associated dilemma. In case of good bonding, tooth and restoration will act as one unit (tooth-restoration complex) so; the fracture resistance will be higher.

The purpose of this paper was to assess the shear bond power of triple ceramic materials bonded with the prepared teeth with three different techniques. The null hypothesizes tested are: 1) there is no effect of the ceramic type on the bond strength to the prepared tooth; 2) there is no effect of bonding technique on the bond strength to the prepared tooth, and 3) the interaction between ceramic type and bonding technique has no effect on the bond strength to the prepared tooth.

Material and Methods

Ninety freshly extracted human lower molar teeth were selected. The inclusion criteria were extracted molars free of caries or restorations and free of any developmental defects. The exclusion criteria were any carious molars or molars that have the previous restoration or developmentally affected. The teeth were manually scaled to remove any calculus or soft tissue remnants and stored in normal saline solution at room temperature during the study (not more than 3 months). All teeth were embedded into auto polymerising resin limited to the cervical line. The occlusal third of the teeth was grounded using a diamond stone under water coolant to make a flat dentin surface ready for cementation (Figure 1).

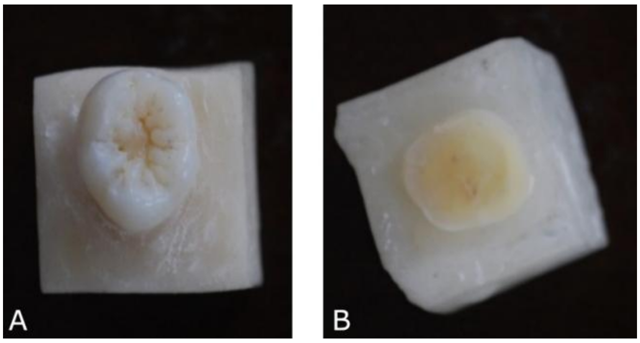

Figure 1: A photograph showing the tooth A) before, and B) after removal of the occlusal third to make a flat dentin surface ready for cementation

The teeth were then randomly divided into three groups according to the type of surface treatment (n = 30). The first group was subjected to air abrasion, the second group was subjected to hydrofluoric acid, while the third group was subjected to both air abrasion and hydrofluoric acid. Successively, each group was further subdivided into three subgroups (n = 10) according to the type of ceramic. The first subgroup was restored with Cerec, the second subgroup was restored with I.P.S. Empress, while the third subgroup was restored with VM7. For all tested materials, a standardised 30 discs were prepared with 5 mm diameter and 3mm height. Al materials used in this study are listed in the Table 1.

Table 1: The materials used in the study

No	Material	Specifications	Manufacturer	Batch No.
1	CEREC Blocs Ceramics for CEREC	CAD CAM CEREC system	Sirona the dental company Germany https://www1.dentsplysirona.com	11810
2	VITA VM7	The VITADURVEST powder	Bad Sackingen, Germany https://www.vita-zahnfabrik.com	10200801
3	E-max press medium opacity	Empress 2	(Ivoclar Vivadent. Schaan, Liechtenstein www.ivoclarvivadent.com	0346
4	Ultradent Porcelain Etch	Hydrofluoric acid	Ultradent Products, South Jordan, UT, USA. https://www.ultradent.com	10050
5	Ultradent Silane	Silane coupling agent	Ultradent Products, South Jordan, UT, USA. https://www.ultradent.com	110403
6	Dyract Cem plus	Adhesive resin cement (chemically cured)	Dentsply Germany http://www.dentsply.eu/	050103

Preparation of ceramic samples

For Cerec samples, the discs were prepared by direct grinding of the ready-made blocks. While for I.P.S. samples, the wax pattern was constructed then invested in phosphate bonded investment. While for VM7 a brass split counter die was constructed to provide a 5 x 3 mm mould space, and compensation for the shrinkage was done by adding another coat of porcelain, resulting in a full-thickness of 3 mm verified with a digital calliper.

Procedures of cementation

For each group, the samples have been separated randomly into three subgroups, according to the surface treatment. For the first subgroup, the bonding surface of the ceramic block has been treated with 0.9 HF for 4 minutes. The bonding surface of the second subgroup was air abraded with 50 μm grain-sized aluminium oxide particles at 200 kPa pressure for 14 sec. The third subgroup has undergone air abrasion with 50 μm grain-sized aluminium oxide particles at 200 kPa pressure for 14 sec and then etched with 9% hydrofluoric acid for 4 min.

All the treated samples were at that point flushed with tapping water for 10 sec silanated with a silane coupling agent and air thinned for 5 seconds. The prepared tooth surfaces were then etched for 20 seconds with 35% phosphoric acid gel, rinsed for 10 seconds, and slightly dehydrated with minimum air to guarantee that the dentine surface remains wet. The prepared dentin surfaces of the teeth were then primed.

The silanated ceramic discs were then bonded to the dentin surface using auto polymerising resin cement (Dyract cem plus). The ceramic was placed on the centre of the dentin surface, and a fixed vertical load (5 kg) was applied to the ceramic surface to create a steady cement layer. The excess cement was removed with a sharp hand instrument, after the initial setting of the cement. The shear bond test was done after 24 hours.

Shear Bond Strength Test procedure

A circular interface shear test was planned to assess the bond quality. All tests were mounted on computer-controlled materials testing machine (Model LRX-*P*lus; Lloyd Instruments Ltd., Fareham, UK) with a load cell of 5 kN and data were recorded using computer software (Nexygen-MT; Lloyd Instruments) (Figure 2). Shear bond quality was decided by the compressive mode of force applied at the ceramic-tooth interface using a monobevelled chisel-shaped metallic rod connected to the upper movable compartment of the testing machine travelling at a cross-head speed of 0.5 mm/min.

Figure 2: Universal Testing Machine

Statistical analysis

The collected data were analysed using a two-way analysis of variance (ANOVA). Tukey's post-hoc test was used for comparison between the means when the ANOVA test is significant. For all groups, the significance level was set at $P \leq 0.05$. Statistical analysis was performed with SPSS 20.0 for windows.

Results

The results of mean shear bond strength values and standard deviations of all groups are listed in Table 2. The highest mean shear bond strength value was recorded for the Cerec group treated by hydrofluoric acid (8.01 MPa) while the least shear bond strength was also recorded for the Cerec group but when treated by air abrasion alone 4.33 MPa (Figure 3).

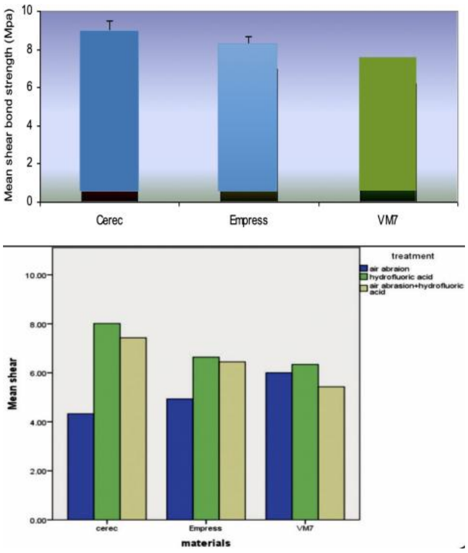

Figure 3: The effect of different surface treatment on the shear bond strength of the tested material to dentin

Regarding the tested materials, two-way ANOVA revealed no significant difference among the material groups ($P > 0.05$). However, the Cerec group yielded the highest mean shear bond strength value, while VM7 group showed the least mean shear bond strength value. For surface treatment subgroups, two-way ANOVA revealed a significant difference among different surface treatments ($P < 0.001$). Post hoc Tukey test showed a significant difference between subgroups treated with air abrasion and subgroups treated with hydrofluoric acid ($p < 0.001$), as well as subgroups treated with air abrasion followed by hydrofluoric acid ($p < 0.05$), while there was no statistically significant difference between subgroups treated with hydrofluoric acid and subgroups treated with air abrasion followed by hydrofluoric acid ($p > 0.05$). Regardless of the tested materials, surfaces treated with hydrofluoric acid showed the highest mean shear bond strength value, while those treated with air abrasion alone gave the lowest mean shear bond strength value. Two-way ANOVA revealed a significant effect of the interaction between the materials and surface treatments on the mean shear bond strength values ($p < 0.05$).

Table 2: Descriptive statistics for shear bond strength values

Ceramic	Surface treatment	Mean	SD
Cerec	Air abrasion	4.33	0.61
	Hydrofluoric acid	8.01	1.62
	Air abrasion and Hydrofluoric acid	7.43	0.98
Empress	Air abrasion	4.93	0.76
	Hydrofluoric acid	6.64	1.00
	Air abrasion and Hydrofluoric acid	6.45	0.54
VM7	Air abrasion	6.00	0.42
	Hydrofluoric acid	6.34	0.92
	Air abrasion and Hydrofluoric acid	5.43	0.77

Discussion

Nowadays, there are increased demands for esthetic restorations. Despite the increased use of CAD / CAM system, some limitations face the dentist due to its high cost and limited materials. On the other hand, it offers an easy and time-saving technique to fabricate indirect esthetic restoration [11]. IPS Empress also has been used successfully for single unit restoration or even three units fixed bridge [12]. To improve the bond strength between indirect ceramic restoration and tooth structure, the silane coupling agent is advocated. Application of a silane coupling agent to the pretreated ceramic surface gives a chemical covalent and hydrogen bond.

Moreover; it is a major factor for a sufficient resin bond to silica-based ceramic. Silanes are bifunctional molecules that bond silicone dioxide with the OH groups on the ceramic surface. They have a degradable functional group that copolymerizes with the organic matrix of the resin [13]. The ceramic bonding systems are mainly mechano-chemical bonding between the luting cement and the ceramic surface [12]. Many studies had reported high bond strength of ceramics to dentin when the ceramics were treated by hydrofluoric acid [12], [14], [15]. This was in agreement with our study. They explained this result by attacking the residual glass in the ceramics by the hydrofluoric acid leaving behind a surface of rod-shaped crystals, which enhances the mechanical interlocking possible. Other studies [14] correlates this result to the preferential dissolution of the glassy phase from the ceramic matrix that generates a micro mechanically retentive surface texture and promotes the formation of the hydroxyl group on the ceramic surface. Another study used atomic force microscopy to investigate the surface of ceramics after treatment with hydrofluoric acid. They found a very distinct surface texture enhances the bond strength [15]. The air abrasion technique showed the lowest mean bond strength value. This result was in disagreement with another study [16] who inferred that air abrasion technique could produce good bond strength. This disagreement may be due to their study was performed to repair fractured porcelain with flowable composite while this study investigated the bond between the ceramics and tooth structure. The explanation of our result may be due to the high hardness of the ceramic surface to be efficiently etched with air abrasion technique. The resulted abraded surface was smoother than those obtained after etching with hydrofluoric acid (HF) with subsequent lower bond strength values. Though HF acid was reported to provide good bond strength, it is one of the foremost hurtful compounds to handle for clinical as well as for laboratory use [12].

Regarding the ceramic material the highest mean bond strength values were obtained for the Cerec system. This was in disagreement with other studies that found no difference between the dentin bond strength of the Cerec and IPS Empress [17]. The main difference between our study and the afford mentioned one was that they performed their samples on standardised mesio-occlusal cavities, while we performed this study on a flat dentin surface. The geometry of the bonded area may affect the bond strength strongly.

In conclusion, hydrofluoric acid etching for various types of ceramic restoration results in the highest shear bond strength to dentin. The shear bond strength of the ceramic materials to dentin depends to a great extent on the surface treatment.

Data Availability

Data will be available upon request.

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