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Effect of tooth substrates and different surface treatments of porcelain laminates on their bond strength - An Invitro study

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Abstract

Aim: The current study was done to evaluate the shear bond strength of porcelain laminate veneers when bonded to different tooth substrates after the veneers were subjected to various surface treatments.

Setting and design: Ninety feldspathic porcelain discs were fabricated through conventional powder slurry method. They were subjected to different surface treatment and bonded to maxillary central and lateral incisors prepared at different depths to get only enamel, only dentin and both enamel-dentin as substrates.

Materials and methods: Porcelain discs were fabricated using a stainless-steel die of dimensions 6mm in diameter and 2.5mm thickness. The resultant porcelain discs formed after firing were trimmed and finished to 4mm in diameter and 2mm in thickness. The discs were then subjected to three different surface treatments which include etching with 9.6%Hydrofluoric acid, sandblasting with 50micron alumina particles and a combination of both the above surface treatments. The discs were bonded to prepared surfaces of maxillary central incisors and lateral incisors using a dual cure cement. Thermocycling was done for 500 cycles at 5°C and 55°C for dwell time of 15sec at each water bath. The samples were then subjected to shear bond forces in Instron at 0.5mm/min cross head speed.

Results: ANOVA and TUKEY Post HOC tests were done to know the nature of distribution. P value was found to be statistically significant. The samples surface treated with 9.6% Hydrofluoric acid + sandblasted along with enamel as substrate had the highest shear bond strength.

Conclusion: Though the values of enamel were the highest, the shear bond strength values of dentin after the surface treatments were also within the acceptable range that is required for bonding and so laminates subjected to different surface treatments could be considered as treatment options to bond on dentin.

Keywords: tooth substrates, 9.6% hydrochloric acid, sand blasting

Introduction

The demand for a pleasing and Esthetic appearance to anterior teeth has been there for ages. There are several treatment options for anterior teeth restorations, including full veneer crowns, partial veneer crowns and ceramic laminates. However, the full veneer crown preparation involves extensive preparation and is not safe for pulp and surrounding periodontal tissues[1]. Although the introduction of a total-etch adhesive system and evolvement of hybrid composite resin provided a conservative approach to anterior restoration, the restoration's longevity was limited. Ceramic laminates for anterior teeth is a traditional approach of aesthetically restoring anterior teeth as it requires minimal preparation and has a naturally pleasing appearance. Several studies have proved that longevity and patient acceptance is more when restored with ceramic laminates[2]. The ceramic laminate veneer remains the best treatment option that best compiles present-day Esthetic dentistry.

A veneer is a layer of tooth-colored substance applied to a tooth for restoring localized, large defects or intrinsic stains. It is also known as Porcelain laminate veneers (PLVs), porcelain facets, Horn-type facets, or ceramic facets. Charles Pincus in 1938 was the first to advocate the use of veneers for anterior teeth to improve the looks of movie actors. Faunce in 1970 introduced the use of prefabricated acrylic resin as veneering material. Calami a and Horn were the two clinicians who refined the technique of bonding porcelain by integrating the adhesion principle of Bunocore, and Bowen's improved the mechanical bond between the composite and porcelain[3]. The preparation design for a veneer should include the following criteria; it Should have sufficient space for the technician to veneer porcelain without over contouring the tooth. The tooth preparation must be as conservative as possible. Further studies have also shown that giving an incisal overlap to the veneer preparation provides a single path of insertion and prevents displacement of restoration[4].

The bonding of porcelain on different tooth substrate has been a questionable criterion as studies have proved that porcelain bonded to dentin has no much prognosis. Porcelain also has low surface energy and it restrict the adhesiveness after cementation[5]. Therefore, porcelain is subjected to various surface treatments such as acid etching and air borne particle abrasion to increase its surface energy and aid in better bonding to the tooth substrate[6].

The aim of the present study was to evaluate the bonding of porcelain laminates on different tooth substrates; enamel, dentin, enamel-dentin complex after subjecting them to three different surface treatments which includes etching with 9.6%hydrofluoric acid, air borne particle abrasion with alumina particles and combination of both etching and air borne particle abrasion.

Materials and Methods

Ninety non-carious teeth were collected from various private dental clinics and from the oral surgery department of GITAM dental college and hospital. All teeth were collected in the last six month of the study and were cleaned and stored in distilled water. Ninety Feldspathic porcelain discs were prepared from vita VMK master (Vita Zahn Fabrik Germany). The adhesive system used was Variolink N (Ivoclar Vivadent) a dual-cure luting cement. A stainless-steel die was made with 6mm diameter and 2.5mm thickness to fabricate discs. A total of ninety ceramic discs were prepared. Depending on the substrate, they were divided into three main groups. The ceramic discs were further divided into three subgroups based on the surface treatments they underwent.

The teeth were mounted in a hollow PVC pipe of 20mm diameter and 20mm length. Radiographs of the teeth were taken to determine the substrate of the teeth. Porcelain disc of 2mm thickness was attached on the labial surface of the tooth using a carding wax. Radiographs were taken along with the disc placed on the labial surface. The actual thickness of enamel was calculated by knowing the actual thickness of porcelain discs to the radiographic thickness of porcelain multiplied with the radiographic thickness of enamel. After determining the enamel thickness, the teeth with enamel thickness greater than 0.8mm were selected to prepare enamel. The teeth with enamel thickness in-between 0.5mm-0.8mm of enamel thickness were selected for dentin substrate preparation. The teeth with enamel thickness greater than 0.8mm and less than 1mm were selected for this category.

Actual enamel thickness=actual thickness of porcelain discs /radio graphic thickness of porcelain× radio graphic enamel thickness

Three different bonding protocols were carried out for bonding of porcelain veneer discs to teeth. The bonded surface of a set of thirty discs were surface treated with 9.6% Hydrofluoric acid (porcelain etch gel, pulp dent) for 90sec followed by thorough rinsing with water and finally, universal primer (MONOBOND S) was applied and air-dried for 10sec. The teeth surfaces that have to be bonded were etched with 37% phosphoric acid (N ETCH, Ivoclar) for 30sec and washed thoroughly. Primer (Te Econom, Ivoclar) was applied and air-dried for 10sec and light-cured. The bonding was done using (VARIOLINK N) dual-cure luting cement according to manufacturer's instructions. Second set of thirty discs was air abraded with 50micron alumina particles under 40 psi pressure for 10sec, universal primer (MONOBOND S) was applied on the sand blasted surface. The teeth bonding surfaces were prepared similarly as mentioned in the above group and bonding was carried out with the same resin luting cement (VARIOLINK N). The final set of porcelain discs was subjected to sandblasting and etching with 9.6% Hydrofluoric acid in a similar manner done in the above two groups on their bonded surface followed by universal primer (MONOBOND N) application. The teeth surfaces were prepared in a similar manner as done in the above groups and bonding was carried out with the same resin luting cement.

All the samples were subjected to thermocycling to simulate the oral environment. The samples were placed in the thermocycler that has two chambers for water at two different temperatures. Samples were placed in thermocycler carrier and thermocycling was done for 500 cycles between 5°C and 55°C with a dwell time of 10min at each temperature.

Testing

The samples were subjected to the shear bond test under Instron universal testing machine with the knife-edge placed perpendicular at the junction between the tooth surface and ceramic disc with a crosshead of speed 0.5mm/min until failure occurred.

The values were obtained in Newton, and shear bond strength was calculated using the following equation:

Shear bond strength = tension / surface area of the disc in (mm^2). The resultant value was obtained in MPa.

The failure modes were analyzed using a light microscope and classified into following category:

1. Cohesive failures in teeth, resin or ceramic discs
2. Adhesive failures at the adhesive interface between the teeth and cement or discs and cement.
3. Mixed failures which are predominantly adhesive failures with less than 40% of cement retained in the bonded area.

Results

The values were entered and statistical analysis was done using SPSS V22 software. Normality was checked by using Kolmogorov Smirnov test and descriptive statistics were done with mean and standard deviation. ANOVA and TUKEY Post HOC tests were done to know the nature of distribution. P value was <0.05 and it was considered as statistically significant. It was found that hydrofluoric acid etched veneers when bonded to enamel had the highest shear bond strength values when compared to dentin substrate and enamel-dentin substrate and the difference is statistically significant with p value <0.05 and it could be represented as:

Enamel > Enamel-Dentin > Dentin (table 1)

In sandblasted group It was found that surface of veneers bonded to enamel had the highest shear bond strength values when compared to dentin and enamel-dentin substrates and the difference is statistically significant with p value <0.05 and it could be represented as:

Enamel > Enamel-Dentin > Dentin (table 2)

In both sand blasted surface and hydrofluoric acid etched, porcelain veneers bonded to enamel had the highest shear bond strength values when compared to dentin and enamel-dentin substrates and the difference is statistically significant with p value <0.05 and it could be represented as:

Enamel > Enamel-Dentin > Dentin (table 3)

It was also found that samples surface treated with Etching+Air-borne particle abraded had the highest shear bond strength followed by air borne particle abrasion and etching.

Etching+Air borne particle abrasion>Air-borne abrasion>Etching

Discussion

Commonly used materials for fabrication of veneers are composite resins or dental ceramic. In a study where the fractured ceramic restorations repaired by composite resin, the restored composites were negatively influenced by external factors such as water sorption, thermal cycling and fatigue which lead to failure of the restoration[7]. Reeh and Ross in their study concluded that the stiffness of teeth could not be restored totally by composite veneer[8]. As veneers are indicated in conditions such as stains resistant to bleaching, teeth that need mor phologic modifications like minor malformations, diastema closure, minor chipping and fractures, extensive preparations may be required for masking the stain and defect and also to provide adequate strength to the restoration. In the present study the shear bond strength of laminate veneers on different tooth substrates after different surface treatments on veneers' intaglio surface was evaluated. Earlier the tooth preparation required for laminates was very minimal preparation or to directly bond on to uncut enamel. However, the current concept suggests that varying degree of tooth preparation is required to remove the top layer of a prismatic and mature enamel[7,8]. The depth of preparation in the present study varies according to the type of substrate required for bonding. The tests used to measure the bond strength of adhesive materials are tensile bond strength and shear bond strength[9]. Grinding, abrasion with diamond rotary instruments, airborne particle abrasion with aluminium oxide, acid etching, and combinations of any of these methods are some of the common surface treatments done on porcelain to increase its bond strength. The surface treatment options adopted in this study are etching with 9.6% Hydrofluoric acid, air borne particle abrasion with 50µ alumina particles and a combination of both the above surface treatments[10]. A controlled etching with 9.6% Hydro fluoric acid for a time duration of 90 seconds was the etching protocol followed for this present study and it is in accordance with studies conducted by Ge et al., Kansu et al, Ozcan and Vallittu et al. and Addison et al. Controlled air borne particle abrasion with 50µ alumina particles was done for the formation of micro-pits and irregular relief pattern on the surface of ceramic. The universal primer used in this study was Monoband N which contains silane methacrylate, phosphoric methacrylate and sulfide methacrylate[10,11,12].

In the study it was found that highest shear bond strength was seen in samples subjected to both etching with 9.6% hydrofluoric acid+air borne particle had the highest bond strength. The above change is due to micro-pitting and dissolution of glass matrix that occur in-case of both the surface treatments which increases the surface irregularities, when compared to only sandblasted and only Hydrofluoric acid etched samples. The above results are in accordance with original study conducted by Kansu et al. and Ozcan et al[10,13].

The bonding of porcelain veneers to different tooth substrates was done to find out the better bonding substrate for porcelain veneers. Three different substrates were chosen for bonding of porcelain laminate veneers which include only enamel, only dentin and a mixed substrate of both enamel and dentin. The veneer preparation was a conventional one without the incisal overlap. The increase in bond strength value for enamel when compared to dentin and enamel–dentin complex is due to the increase in inorganic calcium content which increases the bonding through ionic coupling to form phosphate ester and through chelation[14]. Larger micro-undercuts are formed on the porcelain when compared to the micro-porosities formed on enamel, so there is larger penetration of resin cement into the irregularities of porcelain when compared to resin cement penetration in the enamel. This explains the failures that occurred during testing which were adhesive, mixed and cohesive failures[15]. The cohesive and mixed failures were between the tooth and resin which were mostly seen in enamel and enamel-dentin complex. It might be due the interfacial stresses developed in the substrate or due to the fragility of the extracted teeth after etching. The samples bonded to dentin mostly had adhesive failure due its poor bonding ability[4].

According to Stacey et al. The bond strength of porcelain and teeth complex was around 63MPa while the bond between composite and enamel was about 31MPa and between composite and porcelain alone was 33MPa which was in accordance with the current study[4]. The acceptable range of shear bond strength given by the present-day dental adhesives was 17-20MPa and this is the required value to resist polymerization shrinkage forces in the composite resin[16]. The current study's shear bond strength ranges from 19MPa to 62MPa and these values are in accordance with the studies conducted by Stacey et al. and Eick et al.

Conclusion

The shear bond strength of veneers on all the substrates when they were subjected to both air borne abrasion and etching with Hydrofluoric acid had highest range of shear bond strength values which could compensate the polymerization shrinkage of the luting cement. So it could be said for the longevity of porcelain laminate veneer though requires enamel as substrate acceptable shear bond strength values was obtained in dentin and mixed substrate for both sandblasting and Hydrofluoric acid etched surfaces and, porcelain laminate veneers bonded with above two surface treatments could be considered as a viable treatment option even in conditions where there is need for extensive preparations.

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Legend Tables and Figures

Table 1: Comparison of shear bond strength of porcelain laminate veneers when bonded on all three substrates after surface treating it with 9.6% Hydrofluoric acid.

	HF acid etched				P-value
	Minimum	Maximum	Mean	SD	
Enamel	25.68	44.82	29.94	7.82	
Dentin	19.96	25.74	22.58	1.71	
Enamel and Dentin	18.87	27.73	24.77	2.82	0.007*

Table 2: Comparison of shear bond strength of porcelain laminate veneers when bonded on all three substrates after surface treating it with 9.6% Hydrofluoric acid.

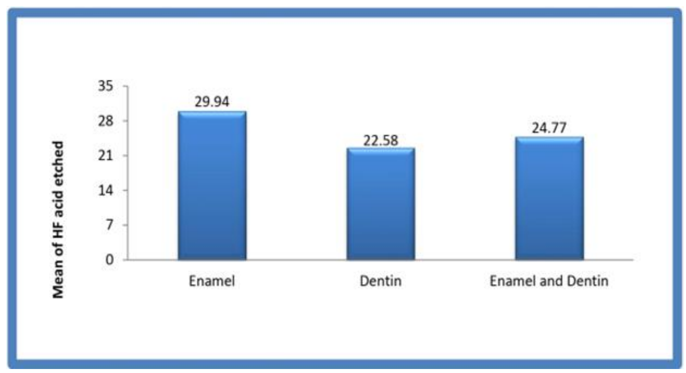
	Sandblasted surface				P-value
	Minimum	Maximum	Mean	SD	
Enamel	19.75	33.57	29.30	3.98	
Dentin	20.42	26.31	23.75	1.86	
Enamel and Dentin	22.19	28.65	25.19	2.66	0.001*

Table 3: Comparison of shear bond strength porcelain laminates when bonded on all three substrates after both sand blasting and etching with 9.6%Hydrofluoric acid on porcelain surfaces.

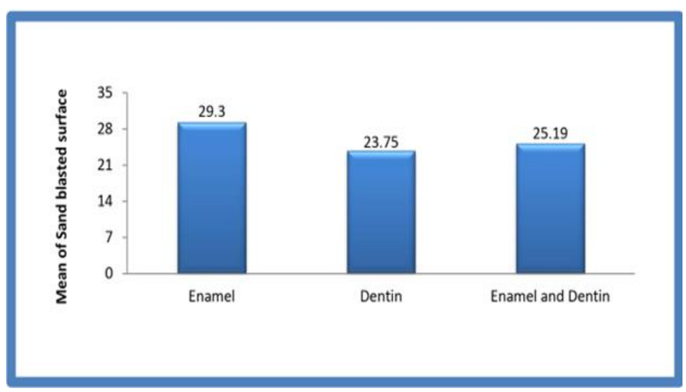
	HF acid etched + Sand blasted				P-value
	Minimum	Maximum	Mean	SD	
Enamel	35.29	62.26	40.32	7.92	
Dentin	20.98	29.29	24.62	2.51	
Enamel and Dentin	27.42	31.39	30.30	1.42	0.000*

Graphs

Graph 1: Schematic representation of shear bond strength of porcelain laminate veneers bonded to three different teeth substrates after surface treated with Hydrofluoric acid.

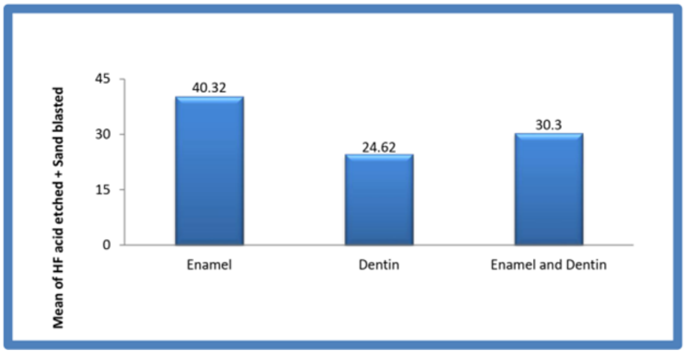


Graph 2: Schematic representation of shear bond strength of porcelain laminates bonded on three different teeth substrates after sand blasting the porcelain surface.



Graph 3: Schematic representation of shear bond strength of porcelain laminates when bonded on three

different teeth substrates after sandblasting and etching with Hydrofluoric acid on the porcelain surfaces



Figures

Figure 1: Feldspathic porcelain powder

Figure 2 and Figure 3: Stainless steel die

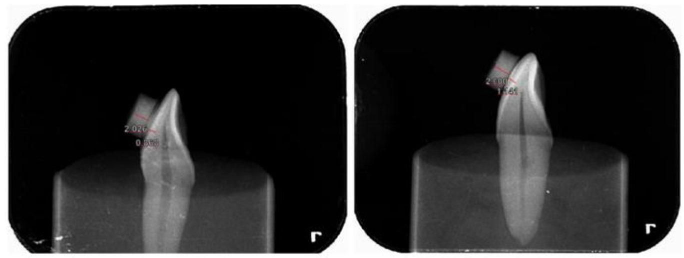


Figure 4: Radiographs to determine substrate thickness

Figure 5: Samples divided into three main groups

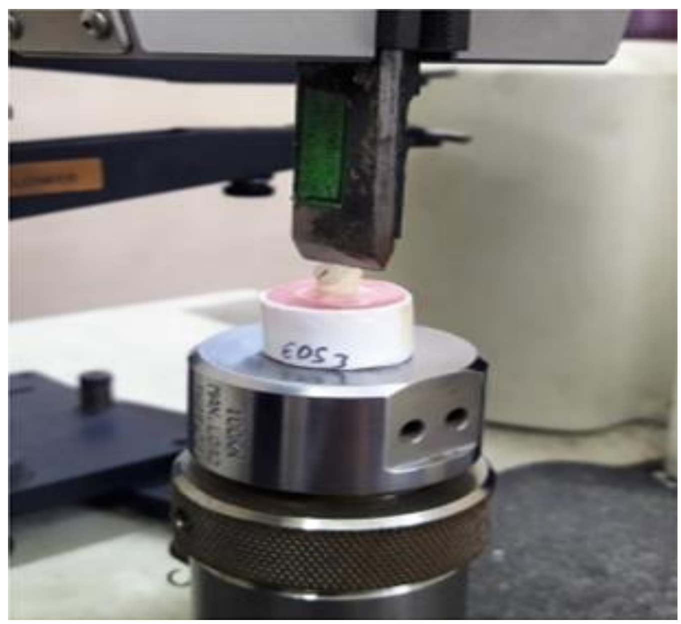


Figure 6: Testing of the sample