A COMPARATIVE EVALUATION OF RETENTION OF ALL – CERAMIC ONLAYS ON WORN OUT TEETH SUBJECTED TO DIFFERENT SURFACE TREATMENTS

KC. Mariamma¹, Kavitha Janardhanan², Lovely M², Vini K Varkey²

¹Department of Conservative Dentistry and Endodontics, ²Deptartment of Prosthodontics

Sree Mookambika Institute of Dental Sciences, Kulasekhararam, KK District, Tamil Nadu.

Correspondence to: minikc14@yahoo.com, kavithajanardanan@yahoo.co.in, mlovely@gmail.com, vinikvarkey@yahoo.co.in

Abstract

Onlays can be considered as a conservative alternative for teeth that exhibit a considerable amount of dentinal hypersensitivity due to cuspal wear resulting from attrition, abrasion, or erosion. However, the main drawback of an onlay restoration is the lack of retention due to decreased axial wall height. The use of adhesive cements increases the retention of any restoration. Various surface treatments have been applied on the intaglio surface of all-ceramic onlays to enhance their retention to an adhesive cement.

Aim: The objective of the study was to compare the retention of all-ceramic onlays
that were subjected to different surface treatment regimens.

Materials and Methods: Twenty-four intact molars were divided into 4 groups and mounted in autopolymerizing acrylic resin blocks. All selected teeth had similar dimensions for the crown and were prepared along the occlusal half for receiving an onlay. All-ceramic onlays, with a thickness of 1.5 mm on the occlusal surface and 1-mm thickness along the axial wall, were fabricated from IPS e.max (Ivoclar Vivadent, Amherst, NY) pressable ceramic. For the purpose of testing, a rectangular handle (4 × 3 × 10 mm) was extended from the centre of the occlusal surface, which was later embedded in acrylic resin. Group I samples were luted with resin cement (Calibra, Dentsply, Caulk) without any surface treatments, and they served as the control. Group II samples were treated with 9% hydrofluoric acid for 1 minute before preparation for cementation. Group III samples were treated with sintered hydroxyapatite (250 µm) and hydrofluoric acid for 1 minute, and Group IV samples were treated with titanium oxide particles (250 µm) and hydrofluoric acid for 1 minute before luting. Specimens were tested in a Universal Testing Machine at a crosshead speed of 10,000 mm/min in a direction perpendicular to the occlusal surface. Tensile loading was applied at 5 kN, and peak load to break (kN) was measured for each specimen.

Results: Analysis of variance (ANOVA) revealed that both Group II and Group III had significantly higher retentive values than Group I. However, there was no significant difference between Group I (control) and Group IV in the retention in the presence of tensile loading. Notably, in Group III samples, the load at break values recorded were attributed to the fracture of acrylic handles and not the debonding of the onlay. Hence, hydroxyapatite surface treatment with chair-side etching may be expected to yield still higher values.

Conclusion: The various surface treatments on an onlay can influence the resistance to tensile loading. It was found that the retention of an all-ceramic onlay with immediate hydrofluoric acid etching prior to cementation, as well as sintered hydroxyapatite blasting followed by hydrofluoric acid etching, is significantly better than that achieved with the standard treatment. Compared to the standard treatment, titanium oxide surface treatment did not produce any significant increase in retention.

Introduction
Tooth wear is increasingly being encountered, and conservative management of the condition can prevent or retard further progression of the disease process. The excessive differential wear of teeth has significant deleterious effect on the biological, functional, and aesthetic conditions of the masticatory system. Wear of teeth may result from physical forces of attrition and abrasion; non-bacterial chemical action, such as erosion; and from the flexure of the root and crown of the tooth due to abfraction. Physiological tooth wear results in very slow progressive loss of tooth substance, beginning with the flattening of the occlusal cusp tips. With the exposure of the soft dentin, the rate of wear is accelerated. The rehabilitation of such a tooth is indicated when the appearance of the teeth becomes unacceptable; normal function becomes affected; and loss of tooth structure results in increasing incidence of tooth hypersensitivity, with progressive loss leading to pulpal necrosis.\textsuperscript{1}

Initial restorative treatment should be conservative, using adhesive resin-based surfaces to restore appearance and adequate function. The fabrication of a conventional crown for such a tooth will necessitate the increased reduction of tooth structure as well as surgical procedures, such as crown lengthening, to increase the axial height. Conservative and aesthetic rehabilitation of a molar with short occlusogingival dimensions can be achieved with onlays fabricated from composite resin or ceramic. Since ceramic onlays provide long-term occlusal stability, they are preferred over indirect composite onlays.\textsuperscript{2}

The classic preparation for onlay requires an intracoronal component, usually a mesioocclusodistal inlay, along with cuspal reduction. However, when the tooth surfaces are worn out, further intracoronal reduction may necessitate endodontic therapy, thereby weakening the teeth. Hence, only occlusal reduction was applied in the current study. The use of adhesive bonded ceramic restoration will provide not only retention but also resistance to the onlay. Therefore, in the present study, various surface treatments were employed to compensate for the lack of intracoronal retention.

Materials and Methods

Twenty-four recently extracted human molar teeth with almost similar mesiodistal and buccolingual dimensions (9.5 mm) were immersed in 10% formalin for 7 days for disinfection and stored for 48 hours in distilled water before experiment was begun. After removing calculus and soft tissue deposits with a hand scaler (Gracey curette SG 17/8; Hu-Friedy, Chicago, III), the teeth were mounted in autopolymerized acrylic.
blocks with the cementoenamel junction 2 mm above the surface of the acrylic resin (Acralyn ‘R’, Asian Acrylates., Mumbai, India). The teeth were divided into 4 groups so that each group comprised 6 samples.

Preparation of the teeth

To mimick the worn-out tooth surface, a round bur with a diameter of 3 mm was used to create a fossa on the centre of occlusal surface to half the depth of the bur. The central depression continued onto the mesiodistal and buccolingual direction to create a saucer-shaped occlusal surface. The cusps were reduced by 1.5 mm and rounded. Axial reduction was done with a straight fissure diamond bur (TPS2-12, Brasseler, Komet) of length 3 mm and diameter 1 mm, parallel to the long axes of the tooth. The functional cusp bevel was placed using a medium grit-tapered diamond bur (6847-016, Brasseler, Inc). A shoulder margin of width 1 mm was created and finished with an end-cutting bur of the same dimension (Figure 1).

Fabrication of onlay

The all-ceramic onlays were fabricated from IPS e.max (Ivoclar Vivadent, Amherst, NY) pressable ceramic. An impression of the prepared tooth surface was made using polyvinyl siloxane impression material (Virtual VPS, Ivoclar Vivadent, Amherst, NY) and poured in Type IV die stone (Gyproc, Rajkot, India). A wax pattern of the prosthesis was made with a thickness of 1.5 mm on the occlusal surface and 1-mm thickness along the axial wall and the margins. A rectangular extension of dimensions 4 × 3 × 10 mm from the centre of the occlusal surface was also waxed up to create a handle for further testing procedures.

Group I served as the control. It comprised 6 samples, which were fabricated in the conventional manner. The wax pattern was invested in a suitable investment material (IPS Pressvest, Ivoclar Vivadent) and burn-
A comparative evaluation of retention of all-ceramic onlays on worn out teeth subjected to different surface treatments

out was carried out at 900°C for 1 hour. Following burn-out, the mould was placed in an e-max pressing machine (EP600 Press, Ivoclar Vivadent). At a temperature of 1140°C, the ingot was softened and pressed into the mould space. Thereafter, the pattern was retrieved from the investment, and the excess was cut off and sandblasted with glass beads (Ivoclar Vivadent). It was then cleaned ultrasonically in the investment liquid supplied by the manufacturer, before the application of low-fusing ceramic powder, (E-max Ceramic, Ivoclar Vivadent). After ceramic firing was completed in a furnace (Programat P500, Ivoclar Vivadent), the samples were steam cleaned at 300°C for 15 minutes. The intaglio surface of the onlays was then etched with 5% solution of hydrofluoric acid for 1 minute. The polished surface of all the onlays were embedded in acrylic resin blocks (Acralyn “R”, Asian Acrylates, Mumbai, India) at a height of 12 mm from the central fossa so that the handle of the onlay is fully covered with acrylic. Cervically, the acrylic extended to a point 1 mm above the finish line of the restoration. (Figures 2 & 3)

Cementation

In Group I, the specimens were prepared for cementation without further chair-side etching. The lab-etched porcelain intaglio surface was treated with a silane coupling agent (Monobond S, Ivoclar Vivadent, Amherst, NY) for 1 minute and gently air-dried for 5 seconds. The bonding agent (Prime & Bond NT Dual Cure, Dentsply,
Caulk) was then applied onto the bonding surface of the restoration, immediately air dried for 5 seconds, and then cured in a hand-held light-curing unit (Bluephase, Ivoclar Vivadent) for 10 seconds. The intaglio surface of Group III samples were blasted with hydroxyapatite (250 µm) and Group IV were blasted with titanium oxide particles (250 µm) in a sandblaster (Dual Blaster, Delta Labs, Chennai, India) at a pressure of 60 psi and source-sample distance of 4 cm for 4 minutes. Samples of Groups II, III, and IV were etched chairside with 9% hydrofluoric acid (Ultradent Porcelain Etch, Ultradent Inc., USA) for 1 minute before the application of the silane coupling agent and bonding agent.

The tooth preparations were etched using 37% phosphoric acid (IvoclarVivident) for 20 seconds, rinsed for 15 seconds, and blotted dry with a moist cotton pellet. One to two drops of adhesive (Prime & Bond NT, Dentsply, Caulk) and an equal number of drops of self-cure activator (Self Cure Activator, Dentsply, Caulk) were dispensed into a mixing well and mixed thoroughly with a new brush tip. Prime & Bond NT Dual Cure mixture was applied to thoroughly wet the tooth surfaces. It was then gently air-dried for 5 seconds to give a uniform, glossy appearance. It was then light-cured (Bluephase, Ivoclar Vivadent) for 10 seconds. Following this, the base and regular high-viscosity catalyst paste of the dual cure composite resin cement (Calibra, Dentsply, Caulk) were dispensed for equal lengths and mixed for 10–20 seconds on a mixing pad, until uniform. A thin layer of the cement was then applied to the all-bonding surface of the restoration. The restoration was seated slowly, while maintaining a downward pressure. The excess cement was removed from the marginal areas with a dry brush. It was then ‘pre-cured’ for 10 seconds at the margins, as per the manufacturers’ instructions, to facilitate the easy removal of excess cement and clean-up. Once stabilized, all marginal areas were light-cured for 20 seconds from the buccal, lingual, and occlusal aspects. Moderate pressure was applied throughout the 6-minute self-cure set time. Finishing burs were used to remove excess composite and create a smoother surface.

After bonding, the teeth were stored in water at room temperature for 2 days. They were taken out 1 hour before the procedure and then tested for retention in a Universal Testing machine (Model1125; Instron Corp, Canton, Mass), which had a maximum load capacity of 5 kN. The acrylic resin blocks at the either end of the sample were engaged in the two halves of the machine at a distance of 20 mm to exert tensile or pulling force in
the opposite direction, at a crosshead speed of 10 mm/min (Figure 4). The maximum load at break (Figure 5) was recorded for each of the sample.

![Tensile testing of ceramic onlay](image1)

**Figure 4.** Tensile testing of ceramic onlay

![Ceramic onlay after decementation](image2)

**Figure 5.** Ceramic onlay after decementation

Analysis of Variance or ANOVA was the statistical tool employed to analyze the data to determine whether any significant differences existed between the 4 groups with regard to the maximum load recorded before decementation.

**Results**

The results of the study are detailed in table 1. ANOVA was used to compare the differences in the maximum load at the tensile fracture between the four groups tested. ANOVA revealed that significant differences existed in the fracture values between the groups tested. It can be observed from Table 1.1 that the highest load at tensile fracture was exhibited by Group III, followed by Group II; the values in both groups were statistically higher than those in Groups I and IV. However, no statistically significant difference was noted when Groups II and III were compared. Similarly, Groups I and IV had no significant difference.

**Table 1.** ANOVA to compare the differences between the four groups tested in maximum load at tensile fracture.

<table>
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<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Mean square</th>
<th>F</th>
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<td>Between treatments</td>
<td>3</td>
<td>0.1815</td>
<td>32.41**</td>
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Health Sciences 2013;2(2):JS005

*An Open Access Peer Reviewed E-Journal*
Within treatments  

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean values of Load at Break (kN)</th>
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<tr>
<td>Treatment I</td>
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<tr>
<td>Treatment II</td>
<td>0.823</td>
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<tr>
<td>Treatment III</td>
<td>0.889</td>
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<tr>
<td>Treatment IV</td>
<td>0.553</td>
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<td>0.0306</td>
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<tr>
<td>CD (.05)</td>
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</table>

** significant at 1% level

**Table 1.1.** Mean values of maximum load at decementation in kN for the four groups tested.

**Discussion**

Wear of tooth is a surface phenomenon, unlike caries, which might have a surface and a subsurface component. Hence, restoration of a worn-out tooth in the early stages requires a surface covering to prevent further tooth tissue loss. This surface
covering or onlay can be made aesthetic and retentive by making use of an all-ceramic material that is adhesively luted to the tooth surface. The adhesion between the restoration and the luting adhesive cement is the result of a physiochemical interaction at the ceramic-resin interface involving chemical bonding and micromechanical interlocking. The physical component of adhesion is dependent on the surface treatment and surface topography of the substrate. Micromechanical retention can be enhanced through acid etching, bur abrasion, or air-borne particle abrasion. The chemical component of the bond is represented by silane coupling agents, which are bifunctional molecules capable of reacting with the inorganic part of the ceramic through the inorganic radical (OH group) and copolymerizing with the resin cement through the organofunctional radical (methacrylate group).

The cementation process of an all-ceramic restoration varies according to the composition. In the current study, IPS e.max (IvoclarVivadent, Inc) lithium disilicate glass ceramic was employed. The microstructure of pressable lithium disilicate (Li$_2$Si$_2$O$_5$) contains approximately 70% volume of lithium disilicate crystals and smaller amounts of lithium orthophosphate that are crystalized in a glassy matrix with an approximate crystal length of 3–6 µm. The fitting surface of ceramics that are constructed on a refractory die is inherently rough due to the grit blasting process used to remove the refractory. Air-abrasive systems deliver a fine, precisely controlled, high-pressure stream of either medium-grit or large-grit alumina particles to bring about the effect. Acid etching of acid-sensitive ceramics, such as lithium disilicate, can be done with either hydrofluoric acid (HF), ammonium bifluoride, or acidulated phosphate fluoride. Application of hydrofluoric acid at concentrations of 9.5% for 20 seconds followed by washing for 1 minute is the recommended practice. The application of HF acid to the fitting surface of these ceramics enhances the surface roughness even more, due to the preferential removal of either the crystalline phase or the glassy phase. The result of the chemical reaction between HF acid and silica phase of the feldspathic ceramics is a salt named hexafluorosilicate, which is removed by water spray. The macrorough surface produced by grit blasting is superimposed by microrough surface created as a result of acid etching. The particle abrasion and etching of ceramic surfaces result in an increase in the surface area and wettability of the substrate.

The exposed silica crystals after acid etching are then treated with organosilane coupling agent, which promotes chemical
covalent bonding\textsuperscript{12} with the Si-OH groups of the ceramic by condensation reaction with release of water. The methylmethacrylate double bonds of silane provide bonding to the adhesive. A silane-coated surface is organophilic to the adhesive and, hence, wetting of the ceramic surface by the adhesive can be improved.

The tooth surface can be roughened by the application of 37\% phosphoric acid, which increases the surface energy of dentin by removing the smear layer and promoting dimineralization of the most superficial layer of hydroxyapatite crystals. Resin composite cements contain inorganic fillers and resin monomers, such as BisGMA, UDMA, and TEGDMA. Their composition is similar to that of conventional restorative composites, but usually with less amount of fillers and higher flowability.\textsuperscript{13} They are usually dual-cured resins that can be light-activated and self-cured. The resin monomers infiltrate the water-filled spaces between collagen fibers, which results in a hybrid layer composed of collagen, resin, residual hydroxyapatite, and traces of water.\textsuperscript{14}

Lithium disilicate ceramics attained higher bond strength values when blasted with 50-\(\mu\)m-thick alumina particles for 10 seconds followed by acid etching for 20 seconds.\textsuperscript{15,16} The teeth selected for this study were worn out. An ideal onlay restoration gets part of its retention from the intracoronal preparation. Here, since the retention is intracoronal, additional methods of adhesion by either mechanical or chemical treatments are to be considered. Contamination by saliva and blood can influence the bond between dentin and lithium disilicate ceramics. Although many cleaning methods have been described, re-etching with hydrofluoric acid is considered most effective in removing contamination with saliva.\textsuperscript{17} Further, surface blasting, in addition to increasing the surface roughness, removes surface contaminants and increases the surface reactivity of the substrate. Hence, additional surface blasting with hydroxyapatite and titanium oxide of size 250 \(\mu\)m each, followed by chair side etching with hydrofluoric acid, was done and compared for tensile bond strength with a normal laboratory-fabricated ceramic onlay.

The lithium disilicate onlays, which were only etched chair side with 9.5\% hydrofluoric acid for 20 seconds (Group II) and which were grit-blasted with hydroxyapatite particles and then etched chair side (Group III), showed significantly higher pull-test values than the standard ones. Although the readings recorded no significant differences between Groups II and III, it should be noted that the mean 0.889 kN break-point value of Group III did not result in decementation, but instead
resulted in the fracture of the acrylic blocks (Figure 6). Thus, we found that Group III specimens had bond strength considerably greater than the other specimens tested. Group IV specimens, *i.e.*, those that were titanium oxide blasted and acid-etched, did not show any remarkable increase in tensile bond strength, when compared to the standard ones.

**Figure 6.** Fracture of acrylic blocks of Group III specimens

**Conclusions**

Retention of an all-ceramic onlay on a worn-out tooth can be improved by surface treatment of intaglio surface of the onlay. Chair side acid etching with hydrofluoric acid 9.5% alone or sintered hydroxyapatite (250 µm) grit blasting followed by etching with 9.5% hydrofluoric acid for 20 seconds at the chairside significantly increases the retention of lithium disilicate-based acid-sensitive ceramics. However, grit blasting with titanium oxide did not yield any substantial increase in retention.

**References**


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Original Article: A comparative evaluation of retention of all-ceramic onlays on worn out teeth subjected to different surface treatments