



INFLUENCE OF ALUMINA AIR ABRASION AND ACID ETCHING ON THE MECHANICAL PROPERTIES OF LITHIUM DISILICATE CERAMIC LAMINATE MATERIAL

Prosthodontics

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ABSTRACT

Background: Lithium disilicate ceramic has received tremendous popularity in dentistry, especially in the fabrication of laminate veneers. However, adequate surface treatment is seminal to the overall longevity of the laminate veneers. The most commonly employed surface altering methods are alumina abrasion and hydrofluoric acid etching. Hence, the purpose of this study was to gauge the alterations in the mechanical properties of lithium disilicate ceramic upon alumina air abrasion, hydrofluoric acid etching and a combination of both.

Materials and Methodology: Circular specimens measuring 15mm diameter by 2 mm thickness were fabricated with lithium disilicate ceramic. Further, divided into four groups based on the employed surface treatment upon the specimens. Microtopography of the specimens were visualized under scanning electron microscope. Surface roughness and biaxial flexural strength were determined using a profilometer and universal testing machine respectively.

Results: Microphotographs revealed surface alterations post treatment. The data were analyzed using one-way ANOVA and tukey's test (p-value<0.05). A significant deterioration in the biaxial flexural strength and enhanced surface roughness was identified with all the surface treatments.

Conclusions: HF etching produced optimum surface roughness with least reduction in flexural strength. Clinically, 5%HF etching for 20 seconds can be recommended as a surface treatment of choice for ceramic laminates.

Keywords: Lithium Disilicate Ceramic, Alumina Abrasion, Hydrofluoric Acid Etching, Flexural Strength

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Introduction

Porcelain veneers present a conservative means of improving aesthetics or modifying contour, eliminating the need of a full crown. Currently, porcelain laminate veneer is most often considered as the treatment of choice for anterior teeth.¹ Also, all-ceramic restorations have gained popularity among clinicians. This could be attributed to their superior esthetics and the possibility of conservative tooth preparations.² Among the ceramic laminate materials, lithium disilicate (pressable) is commonly used for the fabrication of veneers because it provides natural aesthetics and excellent mechanical properties.³

Porcelain veneer is a thin shell of porcelain which is bonded to a minimally prepared tooth surface. This bonding is primarily achieved with dental adhesives and resin cement.⁴ Hence, it is imperative to enhance the surface area of porcelain laminate veneer available for bonding to the tooth structure. This is accomplished primarily by any of the two methods viz sandblasting with alumina particles and hydrofluoric acid etching. Both of these surface treatments have demonstrated the ability to alter the morphologic topography and mechanical properties of the laminate ceramic material. Various authors have suggested that the resultant micro-porosities induced by these surface treatments were responsible for an increased surface area of porcelain which created undercuts that enhanced the adhesive bond strength to the composite resin.^{5,6}

Sandblasting substantially increase the surface area and enhance the potential for micromechanical retention, and increases the bond strength of the ceramic veneer on the tooth.⁷ Few of the manufacturers of lithium disilicate based ceramic veneer recommends a very specific etching time of only 20 seconds with 5% HF.^{8,9} This study is an attempt to understand the influence of alumina abrasion, HF etching and a combination of both on lithium disilicate (pressable) laminate material; with the primary focus on the changes in surface

topography, surface roughness and biaxial flexural strength of the pressable ceramic material. Also, to appreciate the potential of each as a surface treatment of choice for clinical application.

Methodology

Fabrication of lithium disilicate IPS Empress pressable specimens:

Forty five wax patterns measuring 15 mm diameter and 2 mm thickness were obtained using the same vinyl polysiloxane mould, which were sprued and invested in phosphate bonded investment (HINRIVEST KB, Germany) using a size 1 ring. 100 g of powder was mixed with 28 ml of pure Ernst Hinrichs GmbH Rapid cure Investment

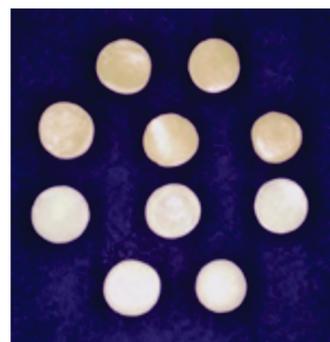


Fig.1 Ceramic specimens

liquid and was allowed to set for 45 minutes. The mould was prepared using the lost wax technique. For the burnout, the ring was placed in the furnace where it was heated from 200oC to 900oC in 1 hour and maintained at the latter temperature for 30 min. Meanwhile, the pressing furnace was preheated to 700oC for 45 minutes. IPS Empress Ceramic ingots (IPS Emax Press, Ivoclar Vivadent, Germany) and the

plunger were then heated in the burnout furnace for 5-10 minutes. The heated ingots and plunger were introduced in the heated mould and placed in the pressing furnace. The temperature was increased at the rate of 60oC per minute till it reached 1075oC and was maintained for 20 minutes. At the end of this cycle the plunger pushed the ingots into the mould which was completed in 6-7 minutes. The ring was then placed under the fan for cooling for a period of 45 minutes. The ceramic casting was divested to retrieve the pressable ceramic discs (Fig 1). Polishing was carried out using noritake polishing paste and rubber wheel.

Specimens were surface treated as tabulated in table I. pC was the control group. Group pS were alumina air abraded in a sandblaster (EASYBLAST, BEGO, and Germany). Alumina particle size of 50µm was propelled towards the ceramic surface under 20psi air pressure from a distance of 2cm. The distance between the nozzle and surface was standardized with the help of a custom made tool.10 Group pE were etched with 5% hydrofluoric acid for 20 (PULPDENT PORCELAIN ETCH GEL; Pulpdent Corp). Group pSE specimens were exposed to alumina abrasion followed by HF etching.

After surface treatment all the specimens were washed thoroughly in running water and then placed in an ultrasonic cleaner for 10 minutes. Each disc was dried with a tissue paper and hot air for 1 minute.

Scanning electron microscopy analysis

In order to perform a qualitative micromorphologic examination of ceramic surface one specimen from each of the group was sputter-coated with gold (fig 2) and analyzed using a scanning electron microscope SEM (-Fujitu DX 2100, Cambridge Instruments, UK) . Photomicrographs of representative areas for the surface treatments carried out on ceramic surface were obtained under magnification of 1.00 K.



Fig.2 Gold-sputtered specimens

Surface roughness analysis

A contact profilometer (Wyko NT1100, Veeco,UK) was used for the evaluation of surface roughness(Ra values). The specimens were placed below the stylus of the profilometer and the stylus was moved for a specified distance of 1.5mm in one direction followed by a second direction perpendicular to the first, again for 1.5mm. A standardized contact force was of 15gms was used. An analogue signal was generated with the change in position of the diamond stylus, which was converted into a digital signal, stored, analyzed and displayed. The average surface roughness was stored as Ra value in millimeters.

Biaxial flexural strength testing

It is the most reliable and widely employed method to assess the strength of brittle materials. Strength of the ceramic discs was determined by the ball-on-ring test method, using a universal testing machine (Instron 6022; Instron Limited, High Wycombe, United Kingdom) at a cross-head speed of 0.5mm/min at a room temperature of 25°C. Specimens were sequentially placed on a support with a span of 10mm for a ball on ring test to determine the flexural strength. A flexural load was applied at the midpoint of each supported specimen using a universal testing machine (Model 6025 Instron, UK) at a crosshead speed of 5mm per minute. The flexural strength was recorded in MPa. The center of each disk was marked as the correct place for the loading ball before testing.¹¹

Results and Statistical Analysis

SEM analysis showed that the surface treatments altered the surface

topography of the ceramic in comparison to the control group (fig 3). This alteration was primarily in the form of shallow to deep irregularities which were not evident in the control. Loss of surface structure was also evident with sandblasted specimens (fig 4).

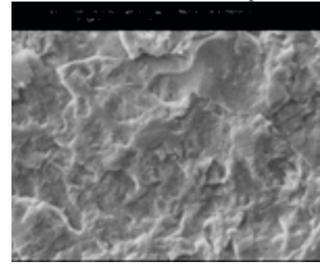


Fig.3 SEM - Control

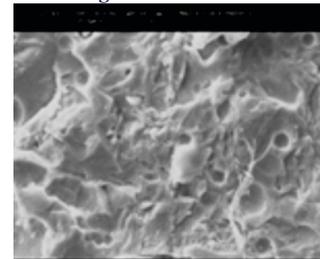


Fig.4 SEM – Sandblasted

Table I: Surface treatment and results obtained

| Groups | Surface treatment | Mean surface roughness/Ra value ± SD (µm) | Mean Flexural strength± SD (MPa) |
|--------|--|---|----------------------------------|
| Pc | Control | 1.84±0.24 | 81.19± 2.24 |
| Ps | 50 µm,20psi,5cm | 3.10±0.43 | 64.18± 2.62 |
| Pe | 5%HF, 20 sec | 2.99±0.26 | 70.59± 1.98 |
| Pse | Combination (50 µm,20psi,5cm + 5%HF, 20 sec) | 3.08±0.56 | 60.10± 2.52 |

A porous surface of variable-sized porosities was seen with HF treated specimens (fig 5). Specimens which were alumina abraded and later etched with hydrofluoric acid revealed prominent deep porosities (fig 6). The mean surface roughness (Ra) and

bi-axial flexural strength are presented in table I. One way ANOVA and tukey's test were used to find out the statistical significance (P<0.05) among the tested groups.

Discussion

An important factor responsible for the longevity of the laminate is the bonding of the laminate to the tooth surface. The intaglio surface of the laminate ceramic is modified in order to enhance the surface available for bonding. All the groups under investigation suffered from a substantial inevitable reduction of strength along with an increase in surface roughness. In this study,

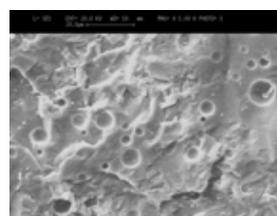
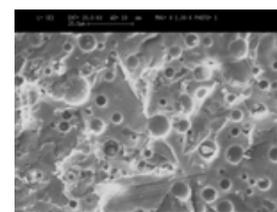


Fig.6 SEM – Combination

the degradative effect of surface treatments on the mechanical

properties of the laminate ceramic material is in accordance with the published literature.^{10,12} The observed reduction in the bi-axial flexural strength can be attributed to the loss of ceramic structure.¹²

The combination of various parameters of alumina abrasion used in this study was based on the findings of a previous study.¹⁰ 50µm alumina particle size, 20psi air stream pressure and 2cm distance between the nozzle and the ceramic surface was the recommended combination of alumina abrasion parameters which produced optimum surface roughness with reduced loss of flexural strength of ceramic.¹⁰ Alumina particle air abrasion resulted in the creation of a radically altered surface texture when compared to the control surface.¹³ Hydrofluoric acid etching induces topographical changes, dissolution of the glassy phase of ceramic at higher concentrations and thereby enhances the micromechanical retention and the bond with the resin cements.^{14,15,16} The variation in the mean biaxial strength among the experimental groups can be primarily attributed to stress concentration caused by roughness, surface defects, or internal stresses.¹⁷ The present study showed that acid etched specimens exhibited higher flexural strength than the samples which were subjected to alumina particle abrasion or their combination.

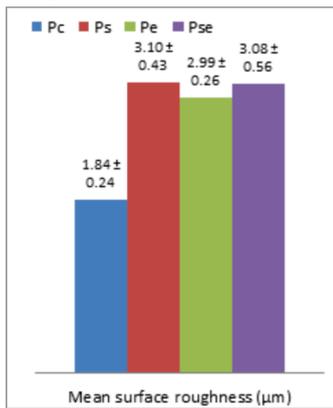


Fig.7 Mean surface roughness

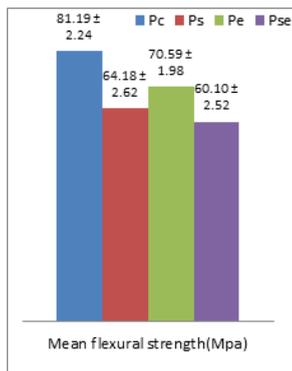


Fig.8 Mean flexural strength

Morphological alterations in the form of pits, grooves and other surface irregularities were observed on SEM

evaluation of the specimens.¹⁸ Many authors have also documented similar results in their studies.^{19,20}

Conclusions

In the current study of the influence of alumina particle abrasion, HF etching and combination of both on the properties of lithium disilicate ceramic material, a significant deterioration in the biaxial flexural strength was identified with all the surface treatments. However, the effect was the least with HF etching compared to alumina abrasion or their combination. This difference in the mean biaxial flexural strength was found to be statistically significant.

A definitive increase in surface roughness and alteration in surface topography in the form of shallow to deep irregularities, pits and grooves was facilitated by the surface treatments employed. However, the differences in surface roughness induced by various surface treatments were not statistically significant. HF etching produced

optimum surface roughness with least reduction in flexural strength.

Within the limitations of this study, it can be concluded that, clinically, 5%HF etching for 20 seconds can be recommended as a surface treatment of choice over alumina abrasion in order to enhance the surface area of a laminate ceramic to improve the bonding with the cement and the underlying tooth structure.

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