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Effect of Surface Treatment and Preparation Design on Fracture Resistance of CAD/CAM Monolithic Zirconia Laminate Veneers: In-Vitro Study

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Abstract:
Aim: *This in-vitro study investigated the effect of surface treatment and preparation design on fracture resistance of zirconia laminate veneers.*
Materials and methods: *Two natural teeth prepared with 2 designs (L, C) and the corresponding two dies were used to fabricate twenty-eight fiber reinforced resin abutment (14 for each design). Twenty-eight laminate veneers milled from KATANA UTML to corresponding abutment. Each main group was subdivided into 2 equal subgroups (n=7) according to type of surface treatment (LS, LF, CS, CF). All veneers were cemented, thermocycled and universal testing machine was used to access fracture resistance.*
Results: *Kruskal Wallis test showed no statistical difference in the median load was found among LS, LF, CS, and CF.*
Conclusion: *Preparation design and type of surface treatment didn't influence fracture resistance.*
Key words: *Monolithic translucent zirconia, laminate veneers, fracture resistance.*

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I. Introduction

Restorations should reproduce the physiologic behavior of the natural tooth as far as possible, with biologic, biomechanic, aesthetic and functional integration.[1] When esthetic adhesive restorations are required in anterior region, different treatment options may be considered as composite restorations, composite or ceramic laminate veneers and metal free crowns. There are several factors that affect the choice of direct and indirect restoration such as patient age, esthetic demands, financial cost and tooth vitality preservation. Indirect techniques are indicated in the following cases: complete crown fracture, uncooperative patients, major shape modifications and multiple complex restorations. Among indirect techniques, the use of ceramic laminate veneer is mandatory because the preparation design of laminate veneers is less invasive than complete coverage crown preparation.[2]

No preparation or minimally invasive veneers is the ideal choice to achieve best aesthetic and conserve tooth structure compared with conventional preparation veneers. This minimally invasive veneer has a thickness of 0.3-0.5mm.[3]

Zirconia based ceramics are much stronger and tougher than glass-based ceramics because it isn't containing glass. All atoms are packed into regular crystalline arrays so it is difficult to drive a crack. Yttrium oxide partially stabilized zirconia (Y-TZP) has high fracture toughness and high mechanical strength.[4] The main advantage of zirconia is higher fracture resistance compared to feldspathic and lithium disilicate veneers. However, there is a possibility of debonding of zirconia veneers because there is less adhesion with resin cement. To increase the adhesion of zirconia to cement, different methods of surface treatment can be used.[5] Fractures alone account for up to 67% of recorded ceramic veneer failures during the clinical observation period of up to 15 years.[6] The null hypothesis of current study was that preparation design and type of surface treatment may affect fracture resistance of monolithic zirconia laminate veneers.

II. Materials And Methods

1. Tooth preparation and replication of abutment:

Two maxillary upper central incisors were selected. Two preparation designs were done. In first design the tooth the tooth was prepared with butt joint preparation with a 1.5mm incisal reduction, 0.5mm labial reduction and proximal reduction was placed just beyond mesial and distal line angles (L). The second design is the same but proximal reduction was placed in middle of mesial and distal contact area (C). Each one of two prepared teeth was fixed in (DOF Full HD scanner, Korea). Each tooth was scanned by DOF scan application to give STL file (Figure 1). The prepared abutments and their sprues were distributed virtually over the blank and the fiber reinforced resin blank was fixed in holder of the milling machine (IMES ICORE 350 PRO, Germany). Milling order was sent through CAM software with dry milling. The time needed for each abutment is 15 minutes. The sprues were cut using tapered diamond stone and high-speed hand piece with water coolant after complete milling of abutments**.**

Figure 1: (A,B) Showing scanning of tooth from different angles.

2. Fabrication of ceramic laminate veneers:

Each abutment was scanned by (3shape D710 Dental Scanner, Denmark**),** the ceramic veneers were designed using (3shape dental designer) software**.** The laminates with their sprues were arranged virtually on the blank. Ultra-translucent multi layered NORTAKI blank (14×98mm) was fixed in holder of milling machine (Roland DWX-30, Japan) and milling was done by the aid of Roland milling tool 1mm diameter. The CAM software was used to mill veneers by using the milling machine. Finishing and separation of sprues using zirconia finishing kit and straight hand piece. The veneers were sintered in ceramic furnace (MIHM-VOGT HT SPEED). Sintering was done by elevation of temperature up to 1550^0C with the rate of 10^0C/min within 3 hours and holding time for 2 hours, then cooling to room temperature. Finishing of veneers with diamond finishing bur**.** Glazing was done by (CERABIEN ZR Noritake Japan)**.**

3. Specimen grouping:

Group L:(n=14)
Group C:(n=14)
Each main group (n=14) was subdivided into 2equal subgroups (n=7) according to type of surface treatment:
Subgroup LS: Selective infiltration etching.
Subgroup LF: Fusion sputtering.
Subgroup CS: Selective infiltration etching.
Subgroup CF: Fusion sputtering.

4. **Surface treatment of zirconia laminate veneers**:

a. Selective infiltration etching:

The fitting surface of veneer was coated with thin layer of infiltration agent by using sand blaster. The specimens were heated in open air to 750^0C (60^0C/min), cooled to 650^0C for 1 minute (60^0C/min), reheated to 750^0C for 1 minute, then opening the door of the furnace to allow cooling to room temperature. All specimens were placed in 5% hydrofluoric acid solution in ultrasonic path (TRANSISTOR/ULTRASONIC T-14) for 15 minutes.

b. Fusion sputtering:

In a glass jar 10grams of zirconia powder were added to 10 ml of 50 % ethyl alcohol and the mixture was placed in ultrasonic shaker. The solution was placed in container used to spray paint; the air pressure was adjusted to 1 bar. The spraying nozzle was kept at a constant distance from the veneer (1cm). The fitting surface of veneer was sprayed for 5 S. The veneers were stored at 60^0C for 2 h to allow drying, sintering program at 950^0C for 4 min.

5. Surface treatment of abutment:

Phosphoric acid 37% (Eco-Etch, Ivoclar Vivadent, USA) was applied to prepared surface of abutment for 15 sec. Then rinsed and gently dried. Bonding agent was applied (Tetric N- Bond Universal, Ivoclar Vivadent) and gently dried with air then light cured for 20 sec according to manufacture instructions.

6. Cementation of veneers:

A mixture of the two pastes of self-adhesive resin cement was applied using auto mixing tips on the fitting surface of veneers. Cementation device was used to aid in seating of veneers on their abutment and to ensure uniform thickness of cement. Curing was done to margins of veneers for 2-3 seconds and the excess cement was removed using a scalpel (No.15). Light curing was completed for 20 seconds using light cure unit (Demi plus, Kerr U.S.A) **(**Figure 3).

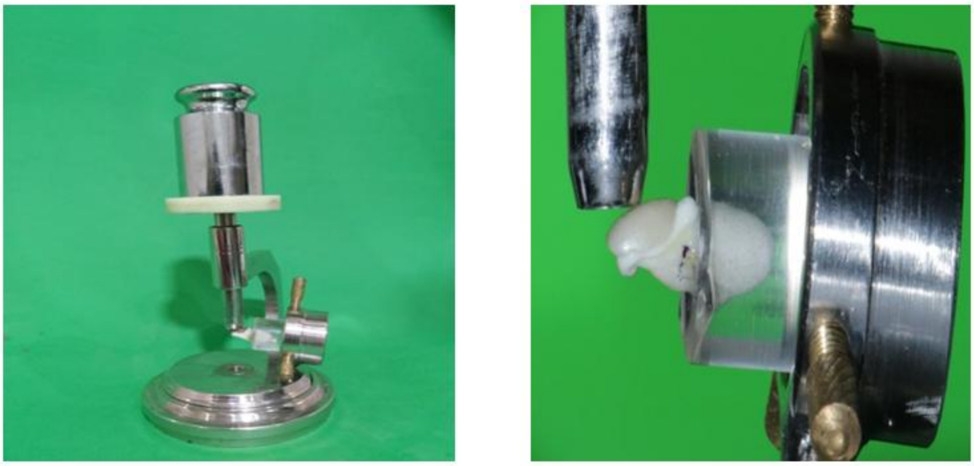

Figure 3: Showing specimen cementation in a specially designed loading device.

7. Thermal cycling:

Thermal cycling was performed for 1200 cycles altering between 5-55^0C, with a dwelling time of 20 seconds in each water bath and transferring time of 10 seconds**.**

8. Fracture resistance test:

Universal testing machine (Instron 3345, USA) was used to perform fracture resistance test. The specimens were mounted on a specially designed holder providing an angle 135^0 with long axis of the testing arm. The load was applied at a cross head speed of 5mm/min till fracture of the laminates. By the aid of (Bluehill Universal Software) the data was recorded in newton.

III. Results

Kruskal Wallis test showed a non-significant difference between LS, LF, CS, and CF in median as listed in **table 1**.

Table1. Comparison of median fracture resistance (N) among KATANA groups between Line angle Selective Infiltration Etching, Line angle Fusion Sputtering, Middle of the contact Selective Infiltration Etching and Middle of the contact Fusion Sputtering.

	LS (n=7)	LF (n=7)	CS (n=7)	CF (n=7)	Test of significance
Median (range)	**236.81 (152.63-369.37)**	**191.11^A (148.78-264.9)**	**262.1^A (185.58-269.72)**	**214.82 (154.28-269.29)**	**KW P=0.179**

IV. Discussion

Upper central incisor was used as they have flat labio-lingual width and it is the most common tooth restored with laminate veneer. [7] Free hand preparations may result in variable depth of preparation which leads to variances in veneer thickness. Therefore, artificial abutments can be more accurate and standardized. In this study, fiber reinforced resin abutments (TRINIA) were used.[8]

Modulus of elasticity of TRINIA CAD/CAM blank is 18.8GPa,[9]which is comparable to that reported for human dentin 11.59 to 27.30GPa.[10] Regarding depth of preparation, depth limiting burs were used to standardize the depth of preparations to ensure equal preparations of about 0.5mm depth labially,cervically and 1.5mm incisal reduction such preparation depth were make sure that the whole prep was confined to enamel .[6]

Regarding the design of preparation, basic types are the window, the butt joint and incisal over lapped preparation feather.[11,12,13,14] Theoretically, veneers should be subjected to minimal occlusal load and only used to restore esthetic, not function.[15] However, Friedman [16] found that veneers with appropriate incisal length could provide valid anterior guidance. As a result, improving the mechanical behavior of veneer is critical, especially the most appropriate preparation design.

CAD/CAM technology reducing the time of fabrication of ceramic restorations and allowing fabrication of ceramic restorations efficiently.[17]

Regarding surface treatment, particle abrasion has become the most recommended surface treatment method of zirconia and long-term stability was observed when combined with phosphate monomer.[18]

Surface damage produced by particle abrasion and also extends up to 50 µm deep under the surface of material, which lead to reduction in flexural strength of zirconia.[19] Fusion sputtering doesn't require any special equipment to perform and simple method of surface treatment. The created surface beads create 3 dimensional under cuts to provide micromechanical retention with resin cement.[20]

Another type of surface treatment Selective Infiltration Etching which differ from the common surface treatment methods. SIE occurs on the ultra-structural grain level without creation of structural defect or material loss and creates 3-dimensional retentive features where the adhesive resin can infiltrate.[21] Thermal cycling regime was conducted to stimulate intra oral temperature changes.[22]

The present study evaluated effect of two preparation designs and two types of surface treatment on fracture resistance of KATANA UTML veneers. There was no significant difference in fracture resistance values between line angle and middle of the contact preparations. Group C recorded higher fracture resistance mean values (232.91±37.63) than Group L (219.49±60.51). Alghazzawi et al. claimed that the mean fracture load of fractured zirconia laminate veneers was 163 N.[8]

Regarding to the two types of surface treatment used in this study, there was no significant difference between Line angle Selective Infiltration Etching (LS), Line angle Fusion Sputtering (LF), Middle of the contact Selective Infiltration Etching (CS), and Middle of the contact Fusion Sputtering (CF) in median. There was significance difference between LF, CS in median.

Group CS recorded highest median value 262.1(185.58-269.72 N) followed by LS 236.81(152.63-369.37 N), CF 214.82(154.28-269.29) and then LF 191.11(148.78-264.9). Based on the results obtained, selective infiltration etching resulted in improvement of fracture resistance of zirconia laminate veneers because the surface transformed into highly retentive, highly reactive Nano porous surface.[23]

V. Conclusion

Type of surface treatment and preparation design didn't affect fracture resistance of monolithic zirconia laminate veneer.

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