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Research Article

The Influence of Finishing Technique on the Surface Roughness and Fracture Resistance of Different all Ceramic Crowns

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Abstract

Purpose: The aim of this present study was to examine the effect of various finishing techniques (A: Glazing, B: Re-glazing, C: Polishing) on the fracture resistance and surface roughness of In-Ceram crowns.

Materials and Methods: A total of thirty coping core samples were constructed by using (CAD/CAM system) and divided into two equal groups (15 for each groups), Group A: In-ceram zirconia blocks and Group B: In-ceram Alumina blocks, all samples then veneered by veneering material according to manufacture instructions. Each group was further subdivided according to the type of finishing technique used into three equal subgroups (n = 5): subgroup I (A): Autoglazed samples (control group), subgroup II (G): Re-glazed samples after surface adjustment and subgroup III (P): Polished samples using the recommended polishing kit by the manufacturer. The crowns shaped samples were cemented on epoxy-resin dies and where subject to fracture load testing using universal testing machine. Scanning electron microscopy (SEM) was employed to examine the morphology of the ceramic surface after different finishing techniques. Data were collected and statistically analyzed.

Results: For In-ceram Zirconia crowns the results showed the polishing technique had significant highest mean load at failure than other techniques, while for In ceram Alumina crowns exhibited a significantly higher mean load at failure with the glazing procedures. The results also revealed that In-ceram zirconia crowns had significantly highest mean of surface roughness for re-glazing and glazing techniques, while the polishing technique showed the statistically significant highest mean of surface roughness for In ceram Alumina crowns.

Conclusion: Finishing and polishing of In-ceram zirconia crowns results higher fracture resistance than that produced with the glazing and re-glazing procedures. In-ceram alumina crowns exhibited a significantly higher fracture resistance with the glazing procedures. Glazing and reglazing for In-ceram zirconia crowns results in rougher surfaces when compared with finishing and polishing procedures.

Keywords: In-Ceram Zirconia; In-Ceram Alumina; Fracture Resistance; Surface Roughness; Polishing; Re-glazing and Glazing

Introduction

Dental restorations made of all ceramic materials are usually selectively altered chairside to eliminate occlusal or internal interferences that can impair the mechanical properties of ceramic framework material [1]. New dental material and techniques have been introduced to fabricate esthetic ceramic restorations which improve strength and marginal adaptation. This was considered as an important merit for posterior area in the mouth, where the forces are much higher for anterior area and can reach 522 N in the average individual. One of the most commonly used all ceramic materials is In Ceram zirconia and In Ceram alumina which was introduced to dentistry as a core material for all ceramic restorations One such all-ceramic system, In-Ceram Alumina (Vident), has been progressed. It is based on a slip-casting technique to build the framework of the FDPs fired to an open-pore microstructure. The material derives its strength through infiltration of the lanthanum glass to the microstructures of the open pores of this ceramic [1]. The high flexural strength of glass-infiltrated In-Ceram Alumina (400-605 MPa) has been further improved by adding 33% by weight zirconium oxide [2,3]. In-Ceram Zirconia (Vident) demonstrates a flexural strength of 750 MPa and fracture toughness that is two times higher than that of In-Ceram Alumina [2,3]. Natural glaze is a vitrified porcelain layer that forms on the surface of the porcelain, containing a glass phase when the porcelain is heated to the glazing temperature for the specified time according to the manufacturer [4]. This layer may be deteriorated by clinical adjustment of the final restoration resulting in rough surface resembling a pretreated surface texture [4-7]. Polishing have been shown to improve structural resistance to withstand oral conditions, and ensure optical characteristics of the restoration [8-10].

All-ceramic core materials are covered with suitable veneering ceramics, adequately glazed prior to cementation, and not intended to be exposed in the oral environment [7]. lately, monolithic zirconia FDPs are available that are not covered by a veneering ceramic, but only glazed or colored. Different kinds of surface treatment have been investigated to find the optimal procedure for reducing surface flows. A glass layer can be used to fill in the flaws; or polishing can be used to reduce that highly polished porcelain can even stronger than glazed equivalents.

Materials and Methods

A total thirty In-ceram coping core samples were were fabricated for this study according to the manufacturer's instructions. These were In-ceram zirconia blocks (VITA Zahnfabrik, Bad Säckingen, and Germany) and In-ceram alumina blocks (VITA Zahnfabrik, Bad Säckingen, Germany), all samples then veneered by veneering material according to manufacture instruction (Vita VM7, VITA Zahnfabrik, Bad Säckingen, Germany).

Working model construction

Stone master die supplied by the manufacture representing lower second premolar was used with dimensions 7 mm occluso-gingival height at bucual cusp and 5 mm at lingual cusp, 4 mm external cervical diameter, 5 mm internal cervical diameter, 4 mm occlusal diameter, 6 degrees convergence angle and 1 mm thickness shoulder finish line. A rubber base impression was taken for the die and cast into base metal alloy for construction of master die.

Fabrication of in-ceram coping materials

The dies were coated by opaque powder coating, which was applied to give dies a sufficient reflectivity to generate a suitable image on the computer screen. The dies were placed for scanning on the scan holder of the optical in Eos scanner, which was used with sirona cerec in-lab system then designing the In Ceram restoration was done by using the in-lab 3D software, version V 3.01 of Sirona's 3D software. After designing the In Ceram restoration, the milling processes then start to get 15 crown shaped samples of In-Ceram Alumina and another 15 crown shaped samples of In-Ceram zirconia.

Glass infiltration of the VITA In-ceram substructures

Desired In-Ceram zirconia glass powder was with distilled water mix according to the manufacturer's instruction to obtain a thin consistency for Zirconia cores material and Mix desired In-Ceram alumina glass powder with distilled water according to the manufacturer's instruction to obtain a thin consistency for Alumina cores material. A uniform coat of glass applied to the outer surfaces of the framework with a thickness of 1-2 mm using a brush. The inner surfaces must not be coated. An area of approx. 1 mm of the margin not be coated to prevent liquid glass from flowing into the inner surfaces. The samples were then placed on thermal cotton pad and were introduced in the Inceramat furnace. The temperature was raised from 200 C TO 1140 C in 50 minutes and held on at 1140 C for two and half hours, until infiltration took place. The glass infiltrated samples were allowed to cool down to 400 C with the firing chamber closed, after that was opened to allow cooling to room temperature.

Finally, the excess glass removal was done using diamond abrasive at low speed, after which sandblasting was performed using alumina powder (50 µm) at pressure of 3 bars for 30 seconds. The glass-infiltrated samples were then fired again in the Vita Vacumat furnace. The temperature was raised from 600º C to 1000º C in five minutes and held on at 1000º C for five minutes. Then the samples were sandblasted again.

Grouping of samples

Samples were classified into two equal groups (n = 15) according to the material of construction

- **Group A:** In-ceram zirconia blocks and
- **Group B:** In-ceram zirconia blocks. Each group were further subdivided into three equal subgroups (n = 5) according to the type of finishing technique.
    - **Subgroup I (A):** Glazed by heating the samples to the glazing temperature prescribed by the manufacturer and holding it at that temperature for 5 minutes.
    - **Subgroup II (G):** At first, these specimens were glazed as described in control group; they were then ground with fine and extra fine diamond burs to break the glazed layer. Next, the surfaces were smooth using white stone and a second glaze cycle was carried out, as a firing cycle described in control group.
    - **Subgroup III (P):** The polishing kit was applied to the specimens using a low-speed hand piece as advised by manufacture. The adjustment kit consist of a 4-step process: A white stone and three different polisher were used, one at a time, for 20 seconds. Then the polishing stick and polishing past were directly placed onto the specimen's surface and were applied using a rubber cup for 20 seconds.

Scanning electron microscopy

Scanning electron microscopy (SEM) was employed to examine the morphology of the ceramic surface after the different finishing techniques were performed. The ceramic sputter coated with 300-500 A@ gold using sputter coating machine. The surface for each ceramic was analyzed by scanning electron microscopy and the result were recorded and tabulated.

Roughness measurements

Specimens were photographed using (SEM) connected with an IBM compatible personal computer using a fixed magnification of 250X. A 3D image of the surface profile of the specimens was created. Three 3D images were collected for each specimen, both in the central area and in the sides at area of 10 µm ×10 µm WS x M software was used to calculate average roughness expressed in µm which can be assumed as a reliable indices of surface roughness.

Fatigue failure (cyclic loading test)

A universal-testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a load cell of (5 KN) and data were recorded using computer software (Instron® Bluehill Lite Software) was used for cyclic loading test by means of a metallic rod with round tip (5.8 mm) diameter which was attached to the upper movable compartment of the machine was applied occlusally at the middle of crown, with tin foil sheet in-between to achieve homogenous stress distribution and minimization of the transmission of local force peaks.

Compressive fatigue limits at (5,000) load cycles were determined by testing according to the "staircase" or "up and down" method [21]. In this method, tests were conducted sequentially, with the maximum applied load in each succeeding test being increased or decreased by a fixed amount, according to whether the previous stress resulted in a failure or no failure. The Fatigue failure for the specimen was calculated in Newton's.

Results

Results of the Fracture resistance

Means, standard deviations of fracture resistance of the two main tested groups are listed in (Table 1) (Figure 1).

For In-ceram zirconia group: The polishing technique showed the statistically highest mean load at failure (1063 N), while there was no statistically significant difference between auto-glazing and re-glazing techniques; both showed the statistically significantly lowest mean load at failure values (784.3 N, 763.2 N) respectively.

While for for In-ceram alumina group: The auto-glazing technique showed the statistically highest mean load at failure (922.3

Ceramic type	Finishing technique	Mean	SD	*P*value
In ceram Zirconia	*Auto-glazing*	784.3 [b]	21.7	<0.001 *
	Polishing	1063 [a]	134.1	
	Re-glazing	763.2 [b]	79.9	
In ceram Alumina	*Auto-glazing*	922.3 [a]	25.9	
	Polishing	649.1 [c]	49.4	
	Re-glazing	585.6 [d]	31.3	

Table 1: Comparison between load at failure (N) of different variables' In Ceram crowns.

*: Significant at P ≤ 0.05, Different letters are statistically significantly different.

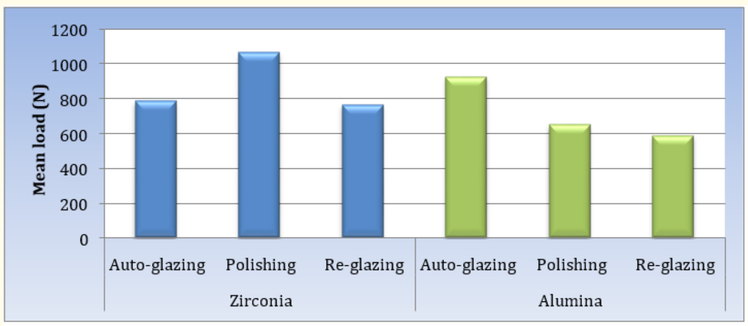

Figure 1: Bar chart representing mean values for comparison between load at failure of the different In Ceram crowns.

N) this was followed by polishing technique (649.1 N), while the Re-glazing technique showed the statistically significantly lowest mean load at failure (585.6 N).

Results of the Surface roughness measurements (Ra)

Means, standard deviations of fracture resistance of the two main tested groups are listed in (Table 2) (Figure 2).

For In-ceram zirconia: the re-glazing and auto-glazing techniques; both showed there was no statistically significant difference; both revealed the statistically significantly highest mean (Ra) values (0.255 um, 0.250 um respectively), while the polishing technique showed the statistically significant lowest mean (Ra) values (0.247 um).

While for In ceram alumina: the re-glazing and auto-glazing techniques; both showed there was no statistically significant difference; both revealed the statistically significantly lowest mean (Ra) values (0.248 um, 0.249 um respectively), while the polishing technique showed the statistically significant highest mean (Ra) values (0.254 um).

Discussion

The effect of surface roughening during finishing and polishing is important, as nearly every dental restoration is selectively adjusted chairside in order to eliminate occlusal or internal interferences. The objectives of finishing and polishing procedures are to obtain the desired anatomy, achieve proper occlusion, and reduce the roughness.

The appeal of ceramics as structural dental materials was based on their esthetics, low density, high hardness, chemical inertness, and wears resistance. A major goal of ceramic research and development is to produce stronger, tougher ceramics and structurally reliable in dental applications.

Ceramic type	Finishing technique	Mean	SD	*P*-value
In ceram Zirconia	Auto-glazing	0.250 um [b]	0.005	0.001*
	Polishing	0.247 um [b]	0.008	
	Re-glazing	0.255 um [a]	0.006	
In ceram Alumina	Auto-glazing	0.249 um [b]	0.008	
	Polishing	0.254 um [a]	0.005	
	Re-glazing	0.248 um [b]	0.007	

Table 2: Comparison between surface roughness (Ra) of different variable's In Ceram crowns.

*: Significant at P ≤ 0.05, Different letters are statistically significantly different.

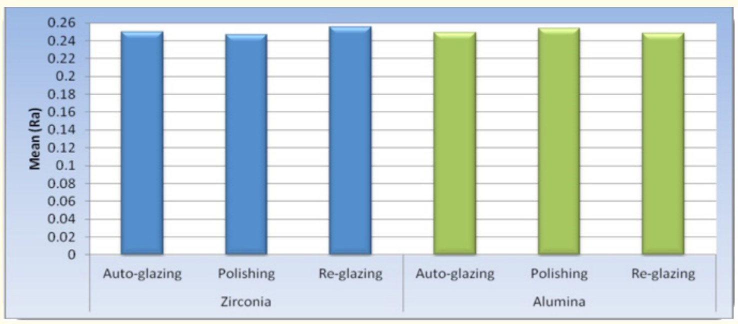

Figure 2: Bar chart representing mean values for comparison between (Ra) of the different In Ceram crowns.

The In-Ceram zirconia (Vita Zahnfabrik) was developed by adding 33 wt% of partially stabilized zirconia to the initial compound, In-Ceram alumina (Vita Zahnfabrik), to provide a stronger and tougher core material to resist fracture loads. The In-Ceram zirconia (Vita Zahnfabrik) was used because of reputation of having exellant mechanical performance, superior strength and fracture resistance as compared to other ceramics [1]. In our study, CEREC inLab system was used for designing and milling the In-cerams alumina and In-ceram zirconia substructures. Since 1993, it's possible to fabricate crown and FPD frameworks from industrially prefabricated blocks using CAD/CAM milling.

For fracture resistance testing, the constructed crowns samples were bonded to supporting epoxy-resin die materials. High filler resin die has been used previously in comparable studies and was selected because it has a modulus of elasticity (12.9 Gpa) similar to that of human dentine (14.7 Gpa). This was in agreement with the studies and finding of [12] The fracture resistance test was performed to materials in this study because it can be defined as the critical stress intensity factor, at which the preexisting crack will propagate and lead to catastrophic failure under tension. The fracture resistance tests of ceramic materials are important to gauge their probability of failure [13]. SEM examination was performed in the present study to perform a qualitative morphological examination of ceramic surface changes induced by different finishing techniques and to determine the surface roughness of the ceramic materials.

Concerning the effect of the finishing techniques on the fracture resistance for the In ceram zirconia group (A), the polishing technique Subgroup (III) recorded the highest mean load at failure (1063 N), while there were no differences between auto-glazing Subgroup (I) and re-glazing Subgroup (II); both recorded the lowest mean load at failure values (784.3 N, 763.2 N) respectively, regardless of finishing techniques used, and this might be due to the irregular scatters and porosities which were removed on the superficial ceramic surface after polishing procedure.

This data was also supported by SEM evaluation which showed that the polished Subgroup (III) did not produce a retentive surface features on the ceramic surface in comparison with other surface techniques (I, II) and the surface roughness analysis of polishing Subgroup (III) recorded the lowest mean (Ra) values (0.247 um) regardless of finishing technique used.

This finding concurs with [14] who reported that, polishing of all the ceramic materials tested significantly increased flexural strength and the application of a glaze to the feldspathic porcelain may significantly increase flexural strength, but this increase is still significantly less than that obtained from polishing. Also, this study agreement with [15,16] who demonstrated that, polishing of ceramic specimens can produced smoother roughness on the ceramic surface comparable to glazing and the flexural strength was decreased on the glazing zirconia.

For In ceram alumina group (B) significantly decreased the fracture resistance when compared to in ceram zirconia group (B). Within the groups, The auto-glazing Subgroup (I) showed the highest mean load at failure (922.3 N) this was followed by polishing Subgroup (III) (649.1 N), while the Re-glazing Subgroup (II) showed the statistically significantly lowest mean load at failure (585.6 N), and this might be due to applied glaze lead to seal microscopic pores present on the ceramic surface that produced glossy and a satisfactory surface for ceramic restoration. This data were also supported by SEM evaluation, which showed the re-glazing Subgroup (II) was slight scatters and roughness were observed on ceramic surface in comparison with other surface techniques (I, II). And the surface roughness analysis of glazing Subgroup (II) recorded the lowest mean (Ra) values (0.248 um).

The result of this study is agreement with [17,18] who reported that, the polished group recorded lower strength than glazing group as the application of glazing material was believed to increase strength because it decreases the depth of the cracks on the surface and founded that the re-glazed ceramic surfaces were smoothest, and the polished surfaces were roughest surface. Based on the result of this study there was no relation between the fracture resistance and surface roughness because the surface roughness is not the only factor that determined strength.

The result of this study agreement with [14] who concluded that the strength is affected by surface roughness is not accepted. They explained also that, the stress concentration could be initiated not only from the surface roughness but also from other factors such as internal stress, porosity, inherently developed cracks and thin sectional areas close to tensile stresses. In contrast the results of the current study with [20] who concluded the surface roughness determined the strength of ceramic material and correlation was found between the roughness of ceramic materials and the biaxial strength and that were explained by that surface roughness will concentrate an applied stress resulting in lower flexural strength.

Conclusions

Within limitation of this study, the following could be concluded

- Finishing and polishing of In-ceram zirconia crowns results higher fracture resistance than that produced with the glazing and re-glazing procedures.
- In-ceram alumina crowns exhibited a significantly higher fracture resistance with the glazing procedures.
- Finishing and polishing for In-ceram alumina crowns results in rougher surfaces than that with glazing procedures.
- Glazing and re-glazing for In-ceram zirconia crowns results in rougher surfaces than that with finishing and polishing procedures.

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