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Comparative Study Between Monolithic Translucent Zirconia (Y-TZP) and IPS Empress 2 in Marginal Fit and Fracture Strength

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ABSTRACT

Purpose : The aim of this study was to compare between Monolithic Translucent Zirconia (Y-TZP) and IPS E.max press in marginal fit and fracture strength. **Materials and methods**, forty ceramic crowns were fabricated, Then divided into 4 groups: **Group A:** Ten monolithic TZI CAD/CAM zirconia crowns N=10 **Group B:** Ten monolithic IPS E.max press crowns N=10**, Group C:** Ten veneered ZI CAD/CAM zirconia core N=10, **Group D:** Ten veneered IPS E.max press core N=10,then Each group was subdivided into two subgroups**: Subgroup 1:** Samples not subjected to thermocycling N=5 as control. Subgroup 2: Samples subjected to thermocycling N=5 The samples were cemented to corresponding epoxy resin dies. The marginal fit was measured and scanned with digital microscope. The fracture strength of the restorations were measured by using universal testing machine with a load 5 KN. The obtained data were collected, tabulated and statistically analyzed. **Results:** The results of marginal fit showed that the vertical marginal gap values of all groups were within the clinically acceptable range. While the Results of fracture resistance showed that fracture strength of monolithic translucent Y-TZP is (3484.28 N) considerably higher than monolithic IPS E.max press (1515.45 N), followed by veneered ZI zirconia (1483.84 N), and finally veneered IPS E.max press (1091.64 N) after thermocycling. **Conclusions:** It was found that veneered crown groups recorded lower gap mean values than monolithic groups. The monolithic crown groups recorded higher fracture load mean values than veneered groups. Monolithic translucent Y-TZP zirconia crowns seem to be a promising treatment alternative, especially for patient with a history of fractured restoration.

KEYWORDS

Monolithic,
Translucent Zirconia,
E.max, press,
CAD/CAM

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INTRODUCTION

The increase of esthetics' demand has led to the development of all–ceramics restoration without metallic components. Dental all- ceramics have many favorable characteristics such as biocompatibility and excellent characteristics of natural teeth [1,2] . In addition to esthetics, marginal fit and fracture strength are essential criteria for clinical success. Increased marginal discrepancies increase the incidence of cement dissolution, micro-leakage, recurrent caries, periodontal problems, and finally failure of the restoration [3].

The materials and techniques have been improved to fabricate esthetic all- ceramic restorations with better strength and marginal adaptation. Among the many ceramic systems that have been developed, Yttria–stabilized tetragonal zirconia polycrystals (Y – TZP) and lithium disilicate glass ceramics have become common form of dental restoration [4].

Pure zirconia is in monoclinic (m) phase at room temp to 1170°C, tetragonal (t) phase from 1170°C to 2370°C and the cubic (C) phase at temperature above 2370°C. The cubic phase shows moderate mechanical properties, the monoclinic phase has reduced mechanical performance and it shows less dense than the other modification of zirconia, and the tetragonal phase has superior mechanical properties. This material has volume expansion of 3% to 5% during cooling after sintering which is due to transformation from tetragonal to monoclinic phase [5].

This transformation is primarily responsible for the superior mechanical properties of zirconia by inhibiting crack propagation but a more extensive t/m phase transformation has a catastrophic effect on the zirconia ceramics [6].

The strength of zirconia is improved when it is combined with yttria between 3: 5% this is referred to as (Y-TZP) yttrium stabilized tetragonal zirconia polycrystals which is composed mostly from T phase at room temperature. Yttria stabilized zirconia has good biocompatibility and excellent mechanical properties which cause this material to be the best material for posterior prosthesis. It also has high thermal resistance, low thermal conductivity, chemical stability and high fracture strength [7].

However, the fracture strength of all-ceramic restoration depend on the core as well as the veneer material [8]. So the using of translucent but brittle porcelain veneer causes increasing the risk of veneering material fracture and these bilayer systems have several disadvantages .These disadvantages can be avoided by using full anatomical crowns, completely milled from the translucent zirconia by using CAD/CAM technology. The fabrication of monolithic crowns provides other advantages such as saved time, cost and minimal steps [9, 10].

Aging of zirconia is due to the gradually uncontrolled transformation of superficial grain of zirconia from the tetragonal phase to the monoclinic phase in presence of water at room temperature due to its metastable nature. This process is known as low temperature degradation (LTD)[11].

IPS E.max was launched in 2007 as an update generation of lithium disilicate ceramics, with improved physical properties and excellent translucency by using different firing processes. (It have two types E.max press and E.max CAD). It's microstructure contains lithium disilicate crystals (approx. 70%), embedded in a glassy matrix, with needle-like shape and 3 to 6 μm in length [12].

MATERIALS AND METHODS

Samples grouping

Forty upper 1st premolar ceramic crowns were fabricated: twenty crowns by CAD/CAM technique and twenty crowns by heat pressing technique. They were divided into 4 groups: group A**:** Ten fully anatomical monolithic TZI CAD/CAM zirconia crowns N=10, group B**:** Ten fully anatomical IPS E.max press crowns N=10 group C**:** Ten veneered ZI CAD / CAM zirconia core

N = 10, group D**:** Ten veneered IPS E.max press core N = 10. Each group was further subdivided into 2 subgroups**:** Subgroup1**:** Samples not subjected to thermocycling N = 5 as control while subgroup 2**:** Samples subjected to thermocycling N = 5.

Samples fabrication

Master die construction and duplication

Stainless steel die with Teflon cylindrical base representing an all- ceramic crown preparation for the maxillary first premolar tooth was machined in standardized manner using an engineering Lathe machine. Duplication of stainless steel die with silicon duplicator. The silicon molds were poured by epoxy resin material (chema poxy 150 CMB Group) on laboratory vibrator to eliminate voids and air bubbles.

Forty epoxy resin dies were left for 24 hours to ensure complete setting and then were separated from their silicon molds.

Samples construction

TZI monolithic Translucent zirconia crowns construction.

Ten fully anatomical Zr crowns were fabricated from TZI Translucent zirconia blocks by using CAD/CAM technique. The Prepared epoxy dies were sprayed using a reflective powder (opti spray) to be read by inEos blue digital scanner, crown bio generic was chosen as well as the tooth to be restored .The second step was to outline the epoxy die and locating its finish line. The spacer thickness was adjusted (50 μm) and the full anatomic coping was adjusted (1.5mm) in thickness. The milling process started by spraying a copious amount of coolant and lubricant. A minute counter was showing on the milling machine (in Lab MCXL milling machine) LCD display the time elapsed was around 6 minutes for each coping**.** A conventional sintering furnace was used to sinter the milled crowns. Intended temperature for sintering in Coris TZI blocks reaching around 1600°C. The cycle takes around 7 hours to be terminated (Sirona inFire HTC sintering furnace).

ZI core construction

Ten cores were fabricated from inCoris ZI zirconia block by CAD/CAM technique. The core made of inCoris ZI were veneered using vita VM9. Silicon index was used To make standardization of veneering thickness, silicon index of previously constructed monolithic TZI crown was used to guide the veneer contouring and its dimension.

IPS E.max press monolithic crowns construction

Ten fully anatomical crowns were fabricated from e.max press ingot by combination of lost wax and heat - press techniques. Wax pattern construction was done by applying die lubricant to the epoxy die and then using dip wax technique to form wax coping. An axial sprue of 3mm diameter and 4 mm length was attached to constructed wax copings then attached to ring base with an angle of 45° –60° in the direction of flow of ceramic material, in order to achieve unimpeded flow of viscous ceramic material**.** Investing was carried out with the IPS Empress II special investment material. Investment ring was preheated in conventional preheating furnace (Burn out heating furnace Vulcan – Degussa – Ney Dental) following the manufacturer's instruction. The investment ring with the ingot and plunger were placed in center of press furnace (EP 600 press furnace).

IPS E.max press (core) and veneering construction.

Ten cores were fabricated from IPS E.max press in similar way as for monolithic E.max. To standardize the thickness of core. We used the silicon index of previously milled ZI core.

Cementation of the samples

Preparation of zirconia crowns before cementation were made by surface treatment of inner surface of zirconia using air – blasted with

50μm aluminum oxide (Al_2O_3) particles at 1 bar pressure, from a distance of 10mm for 5 seconds using an airborne – particle – abrasion device (Basic classic – Renfert GmbH, Hilzigen, Germany). Then the samples washed with water for 1 minute and cleaned in ultrasonic device for 10 minutes, then air dried(Bransonic ultrasonic cleaner 3510 E-DTH;Branson).

Preparation of E.max press samples before cementation, all samples were cleaned for 15 minutes with distilled water and dried, then using 5% hydrofluoric acid (IPS ceramic etching gel; Ivoclar Vivadent) for 20 seconds to etch the inner surface of crown, then washed with water and dried. Silane coupling agent was applied to the inner surface for 6 sec and dried again (Monobond-S;Ivoclar Vivadent).

Cementation Technique

Cementation was accomplished according to the manufacturer's instruction. Rely x unicem (self – Adhesive resin cement 3 M ESPE, see feld, Germany) was used.

Thermal cycling procedures

All samples in subgroup 2 were subjected to thermocycling. The number of cycles used was 20,000 cycle. Dwell times were 25 s. in each water bath with a lag time 10 s. the low-temperature point was 5^{o}C. The high-temperature point was 55^{o}C (Robota automated thermal cycle, BI 1GE, Turkey). After thermocycling we measured the marginal gap, fracture resistance in the same manner.

Marginal gap assessment:

The vertical marginal gap was measured by using USB Digital microscope with a built-in camera to photograph each crown margins by using a fixed magnification of 45x. Shots of the margins were taken for each crown. The obtained data were collected, tabulated and then subjected to statistical analysis.

Fracture Resistance assessment:

Fracture resistance were measured by using a computer controlled materials testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a load cell of 5 KN with cross head speed of 1mm/min and data were recorded using computer software (Instron® Bluehill lite software.

Analytical statistics:

Data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Student t-test and ANOVA were used to study the effect of thermal aging, marital and veneer on mean values. Tukey's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. The significance level was set at $P \leq 0.05$ and 95% Confidence interval.

RESULTS

Vertical marginal gap

The mean values and standard deviation of vertical marginal gap (μm) for both ceramic group types as function of veneer before and after thermal aging are summarized in table 1 and graphically drawn in figure 1. **Table 1** Vertical marginal gap results (Mean values± SDs) for both ceramic group types as function of veneer before and after thermal aging.

Fracture resistance

The mean values and standard deviation of fracture resistance N for both ceramic group types as function of veneer before and after thermal aging are summarized in table 2 and graphically drawn in figure 2.

Variables		Monolithic		Veneered	
		Non- aged	**Thermally aged**	**Non-aged**	**Thermally aged**
Ceramic group	**Zr**	29.28±3.36	38.22±5.71	23.22±2.62	37.52±5.49
	E.max press	30.53±10.62	47.65±8.37	24.06±2.59	36.42±4.79
Statistics	**P value**	0.7160 ns	0.007*	0.4959 ns	0.6831 ns

**; significant ($p < 0.05$) ns; non-significant ($p>0.05$)*

Table 2 *Fracture resistance results (Mean values± SDs) for both ceramic group types as function of veneer before and after thermal aging*

Variables		Monolithic		Veneered	
		Non-aged	**Thermally aged**	**Non-aged**	**Thermally aged**
Ceramic group	**Zr**	4273.69±44.62	3484.28±145.42	1955.37±74.13	1483.84±114.99
	E.max press	1572.66±223.24	1515.54±337.21	1271.55±206.04	1091.64±144.21
Statistics	P value	0.004*	0.007*	0.0012*	0.009*

**; significant ($p < 0.05$) ns; non-significant ($p>0.05$)*

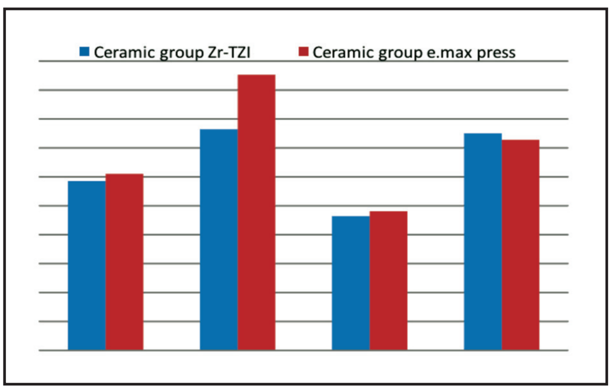

Figure (1) Column chart of vertical marginal gap means values for both ceramic group types as function of veneer before and after thermal aging

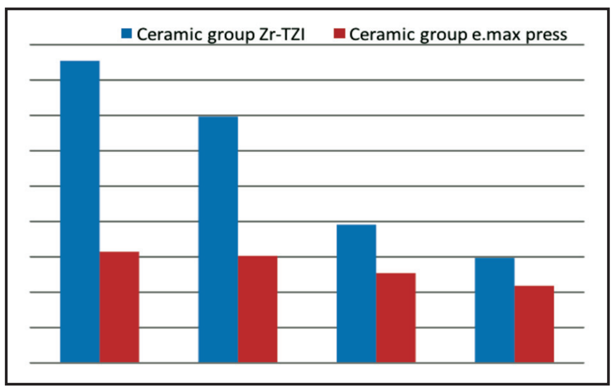

Figure (2) Column chart of fracture resistance means values for both ceramic group types as function of veneer before and after thermal aging

DISCUSSION

Thermocycling and cyclic pre-loading in a wet environment were used to simulate aging, also combination of methods commonly used in in-vitro studies[13,14]. Therefore, the number of cycles varies between 100–50,000 cycles in different studies. According to an ISO standard[15]. The cycles number in this study was (20,000) cycles, a number frequently used regarding to ISO standarization. Samples were fabricated as crowns, A stainless steel die was fabricated as a master die for the duplication of the epoxy resin dies which were used in substitution to natural teeth As natural teeth, represent great variations in the time and type of storage and also individual structure which make the standardization of sample very difficult [16].

During fracture resistance testing, epoxy dies were used instead of a metal die to obtain fracture resistance values simulating clinical conditions, as the epoxy resin material has modulus of elasticity close to that of dentin [17]. The spacer thickness of the crown was selected as 50µm thickness of the die spacer that affects the seating and fit of restoration [18]. For a standardization the veneering layer thickness, silicon index of previously milled monolithic crown was made and was used to guide the veneer contour and external dimension [19].

A self- adhesive resin cement was selected for crown cementation as it has enhanced mechanical, physical and adhesive properties rather than conventional cement material. Moreover, they improved the fracture resistance and provide adequate stability for all-ceramic restoration.

The marginal adaptation was measured by using direct view method instead of sectioning technique. The vertical marginal gap measurement was preferred as the most frequently used to quantify the marginal adaptation of fit of a restoration [20]. In the literature the clinically acceptable size of marginal gap varies .Previous study, stated that a marginal discrepancy of 120 µm should be the limit of clinical acceptability[21]. While other found anywhere form 50-100 µm to be acceptable [22].

Irrespective of ceramic material or crown type, totally it was found that thermally- aged subgroup recorded higher gap mean values than non-thermally-aged subgroup mean value. This was significantly ($P < 0.05$) as indicated by three – way ANOVA .In this study significant increase in vertical marginal gap values of thermally aged subgroup was observed agreeing with previous studies , which were revealed significant increase in marginal discrepancies after aging as the degradative effect of thermocycling in an aqueous condition on ceramics[23].

Another studies were concluded that, thermal fatigue in artificial saliva for 30.000 cycles increased the degradation of lava zirconia specimens [24, 25].

Other study was found, that, the thermo-mechanical loading increased the vertical marginal gap due to the luting cement. Some parts of the cement film were washed out during the aging procedures, particularly, when using water-soluble cement such as glass-ionomer [26]. On contrary, no significant effect on marginal discrepancy after aging was reported by others [27]. This different results can be reported due to the different ceramic materials and luting cement being used .However, other also reported no significant difference in marginal discrepancy although they used glass – ionomer cement and this can be due to different parameters of mechanical loading [28].

Regardless to veneering or thermal aging, totally it was found that, E.max press group recorded higher gap mean values than zirconia group mean values. This was significantly ($p<0.05$) as demonstrated by three – way ANOVA. . In present study, the vertical marginal gap values of E.max press groups recorded higher vertical gap values than zirconia. These results were in agreement with a previos study which was showed that, the mean marginal gap of CAD/CAM zirconia were significantly lower than those of pressable lithium disilicate. This is due to advancement in scanning methods, correct software design with improved margin detection and precision milling technologies[29]. While these results were in disagreement with other, who concluded that, the lithium disilicate crowns had significantly lower marginal gap than the CAD/CAM zirconia crowns [30].

Monolithic crown group recorded higher gap mean values than veneered crown group mean values. This was significantly ($P < 0.05$) as indicated by three-way ANOVA. These results were in agreement with Different studies which were demonstrated that, manually veneered Y-TZP crowns resulted better marginal fit when compared to monolithic crowns made by CAD/CAM system[31,32]. Another study concluded that, the ICE zirconia (veneered) crowns showed better internal adaptation values when compared to prettau (monolithic) zirconia crowns with both finish line designs. They explained in their results that samples fabricated by soft milling of partially sintered Y-TZP blanks were subjected to a linear shrinkage in the range of 15% to 20 when sintered to full density at high temperature [(33)].

Then, the fully sintered coping being veneered by manual method with a compatible veneering ceramic had a positive effect on marginal adaptation.

While these results were in disagreement with the study that ,was proved that the firing of veneering porcelain has negative effect on the marginal adaptation of different all- ceramic restorations and induced marginal misfit[(34)].

Regarding the effect of thermal aging on fracture strength. It was found that, thermally – aged subgroup monolithic translucent zirconia TZI recorded lower Statistically significant fracture load mean values (3484N) than non-aged subgroup mean value (4273 N)..And also thermally-aged subgroup veneered zirconia ZI recorded statistically significant lower fracture load mean values (1483 N) than non-aged subgroup mean values (1955 N). More reasonable explanation of this result suggests that it is due to "low temperature degradation" (LTD) of zirconia. This occurs due to metastable nature of zirconia-based materials. Which are due to the transformation of zirconia to unfavorable phase at room temperature. This causes surface roughness and formation of micro crakes, making water penetration which causing more phase transformation and consequent loss of mechanical strength .These results were in agreement with different studies [(35.36).]

In the present study, it was found that, thermally-aged subgroup monolithic E.max press recorded lower fracture load mean values (1515 N) than non-aged subgroup mean value (1572 N) this was statically non-significant. And thermally – aged subgroup veneered E.max press recorded lower fracture load mean value (1091 N) than non-aged subgroup mean value (1271 N) this was statistically significant.

These results have been reported in other studies due to the detrimental effect of thermocycling on all - ceramics. Which are subjected to slow crack growth during thermocycling, especially in presence of water molecules which causing stress corrosion at the cracktip [(37).]

Regarding the effect of ceramic material on fracture strength, it was found that thermally aged subgroup monolithic translucent zirconia recorded higher fracture load mean value (3484 N) than thermally aged subgroup monolithic E.max press (1515 N). This was statistically significant while thermally aged subgroup veneered zirconia recorded higher fracture load mean value (1483 N) than thermally aged subgroup veneered E.max press (1091 N). This was statistically significant.

A reasonable explanation of these results is due to difference in composition and properties of these two materials. Lithium disilicate don't have similar fracture toughness as zirconia based material which stop crack propagation by phase transformation. Also this can be caused by zirconia which have high crystalline content than E.max press . Small porosities and flaws in the microstructure of pressed lithium disilicate crowns may be resulted through fabrication process of the material, this may act as stress raisers leading to a catastrophic effect on the fracture resistance of these crowns. These results were in agreement with other [(38-40).]

Regarding the effect of veneering on fracture strength, it was found that. Thermally aged subgroup monolithic translucent zirconia recorded higher fracture load mean value (3484 N) than veneered subgroup mean value (1483 N) this was statistically significant.

These results were due to the improved performance of the monolithic crowns may be caused by the elimination of weak interface between core and veneer which is the weak link in bilayer systems . Some factors affect the risk of veneering material fracture, such as the difference in mechanical properties of the core and veneer material, design, thermal conductivity and differences in the thickness ratio and the coefficient of thermal expansion between the core and veneer material. These results were in agreement with another previous studies[35,36,41].

In the present study, it was found that thermally aged subgroup monolithic E.max press recorded higher fracture load mean values (1515N) than veneered subgroup mean value (1091 N) this was statistically significant and coincide with study which[42] was concluded that, veneer application resulted in significantly lower fracture load values compared to monolithic lithium disilicate crown[42].

CONCLUSIONS

It was found that veneered crown groups recorded lower gap mean values than monolithic groups. The monolithic crown groups recorded higher fracture load mean values than veneered groups. Monolithic translucent Y-TZP zirconia crowns seem to be a promising treatment alternative, especially for patient with a history of fractured restoration.

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