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FRACTURE RESISTANCE OF BI-LAYERED AND TRANSLUCENT ZIRCONIA AFTER THERMO-MECHANICAL FATIGUE

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ABSTRACT

Objective: This study aimed to evaluate the fracture resistance of bi-layered and two types of translucent zirconia after thermo-mechanical fatigue. **Materials and Methods:** first upper premolar sound natural tooth was prepared and duplicated into epoxy resin die. Forty two full coverage crowns were fabricated and divided into three groups' n= 14 according to type of ceramic material; Group (SHT): full contoured super-high translucent multilayer zirconia system were constructed using CAD/CAM. Group (ST): full contoured super translucent multilayer zirconia system were constructed with CAD/CAM. Group (BZ): Bi-layered zirconia: Fourteen copings were constructed using Solid ZI white with CAD/CAM and then were conventionally veneered with Vita Vm9 (feldspathic porcelain). Crowns were cemented using self-adhesive resin cement. All samples were subjected to thermal cycling (5o -55o C/10,000 cycle) then to chewing simulator (240,000 cycles, 50N). All samples were subjected to fracture resistance test. **Results:** Fracture resistance values all of the tested groups were (1727.19±311.75 N, 1399.75±130.08 N, 1112.70±195.20N). bi-layered zirconia (BZ) restorations (control group) used in the current study after thermo-mechanical fatigue, showed higher fracture resistance values than the super translucent monolithic zirconia (ST) and super high translucent monolithic zirconia (SHT) group (intervention groups). **Conclusions:** all the crowns tested obtained high fracture resistance (above 1000 N) and could n successfully withstand the average clinical masticatory force in the premolar region. The group of bilayered crowns recorded higher fracture resistance mean value than the two groups of translucent monolithic crowns.

KEYWORDS: fracture resistance; thermo cycling; zirconia.

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INTRODUCTION

Success of ceramic restorations hinge on marginal fit, fracture resistance and esthetics [1]. Zirconia exhibited superior mechanical properties conjunct with satisfactory esthetic appearance achieved by coating it with feldspathic porcelain had permitted it to be used in frameworks fabrication of [1, 2].

Zirconia restorations have been doped with 5 mol% yttria- stabilized zirconia polycrystals which gave it acceptable mechanical properties and optical properties close to that of lithium disilicate [3].

Zirconia is present in three different phases, monoclinic, tetragonal, and cubic [4]. The main disadvantage of partially stabilized zirconia is its increased opacity [5], which can be overcome by veneering it with glass ceramic [6]. However, coated zirconia restorations are highly vulnerable to chipping and veneer cracking [7]. In an attempt to overcome these limitation over-pressing and the digital veneering techniques were introduced [6]. Later, mono-layered zirconia restorations were introduced to overcome drawbacks of the bi-layered [8].

The pre-shade mono-layered zirconia showed inferior optical properties with difficulty in improving its natural look, which was later improved by pre-shade multilayered zirconia mimicking the gradient of natural tooth appearance. Where at the incisal area there is increased translucency and at cervical area there is increased chroma [9].

Although patient's main concern is esthetics, dentists are usually anxious about both esthetics and longevity of restorations in term of strength. Accordingly, this study was designed to assess the fracture resistance of bi-layered and different types of translucent zirconia after thermo-mechanical fatigue. The null hypothesis of this research is that there is no significant difference between fracture resistance of bi-layered and different types of translucent zirconia after thermo-mechanical fatigue.

Aim of the study

This study was designed to assess the fracture resistance of bi-layered and two of translucent zirconia after thermo-mechanical fatigue.

Sample size calculation

A power analysis was intended to have sufficient power to implement a statistical test of the null hypothesis that there is no difference between tested groups. By embracing an alpha level of (0.05) a beta of (0.2) i.e. power=80% and an effect size (f) of (0.5) designed based on preceding results [4, 10]. The predicted sample size (n) was a total of 42 teeth (14 for each group). Sample size calculation was implemented by means of G*Power version 3.1.9.2.An estimated sample of 14 in each group was used for each intervention and the comparison group.

MATERIALS AND METHODS

Materials

TABLE (1) Ceramic materials used in this study

Material	Manufacturer	Composition	BatchNo.
Super high translucentmultilayer zirconia (5Y-PSZ) (Ceramill Zolid FX)Shade (A2)	Amann Girrbach, Koblach, Austria	1-ZrO_2 + HfO_2 + Y_2O_3: ≥ 99.0% 2-Y_2O_3: 8.5 – 9.5% 3-HfO_2: ≤ 5% 4-Al_2O_3: ≤ 0.5% 5-Other oxides: ≤ 1%	1909002
Super translucent multilayer zirconia (4Y-PSZ) (Katana STML) Shade (A2)	Noritake, Kuraray,Japan	1- ZrO_2 + HfO_2: 87-92% 2-Y_2O_3: 7-10% 3-Other oxides: 0-2%	1253152
Low translucent zirconia (3Y-TZP) for core of bilayered crown (Ceramill ZI)	Amann Girrbach, Koblach, Austria	1- ZrO_2 +HfO_2 +Y_2O_3 : >99,0% 2-Y_2O_3: 4.5 – 5.6% 3- HfO_2: ≤ 5% 4- Al_2O_3: ≤ 0.5% 5- Other oxides: ≤ 1%	1802002
Ceramic veneering (Liquid, Base dentine, Transpa dentine and Enamel) (Vita VM9) Glazing (powder and liquid) (Vita AKZENT plus) Shade 2 M2	Vita Zahnfabrik, Bad Sackingen, Germany	1-SiO_2 (60%–64%) 2-Al_2O_3 (13%–15%) 3-K_2O (7%–10%) 4- Na_2O (4%–6%) 5-TiO_2 (< 0.5%) 6- CeO_2 (< 0.5%) 7-ZrO_2 (0%–1%) 8- CaO (1%–2%) 9- B_2O_3 (3%–5%) 10- BaO (1%–3%) 11- SnO_2 (< 0.5%) 12-Mg, Fe, and P oxides(<0.1%)	65228, 65837, 65987, 67875, 88151

Table (2): Materials used for surface treatment and cementation

Material	Manufacturer	Composition		Batch No.
Z-PRIME Plus (Zirconia primer)	Bisco, inc., Schaumburg,IL, USA	MDP/carboxylic acid monomer/biphenyl dimethacrylate/ ethanol		2000003009
Dual cured self-adhesive resin cement (Rely X U200)	3M Deutschland GmbH, Germany	Base paste	Catalyst paste	
		Methacrylate monomers containingphosphoric acid groups	Methacrylatemonomers	
		Methacrylatemonomers	Alkaline (basic) fillers	6687019
		Silanated fillers	Silanated fillers	
		Initiator components	Initiator components	
		Stabilizers	Stabilizers	
		Rheologicaladditives	Catalysts	

METHODS

Dies fabrication:

The base was constructed to have suitable fit throughout the mechanical fatigue and fracture resistance test. Impression* was taken for sample holder of chewing simulator. The addition silicon** was mixed as per the manufacturer instructions under 4 bar pressure units for 30 minutes attempting to improve the dimensional accuracy of the mold. Addition silicon mold was fabricated for the impression and metal rod with 3mm diameter was imbeded inside the impression hole. Soft wax was used to fix the master die with the analyzing rod of the surveyor*** to keep it centralized and to position the finish line of the master die 2mm away from the base (15). The base was fabricated out of gypsum****.

A mold of the master die was duplicated by using polyvinyl siloxane irreversible addition impression material. The impression material was mixed as per manufacturer instructions. The mold was then subjected to 4 bar pressure units for 30 minutes to improve dimensional accuracy of the mold. Epoxy resin material was then mixed in a ratio of 3:1 by weight. It was then poured into the mold under vibration*****.

The mix was then introduced into a pressure vessel for 24 hours under 4 bar pressure units to ensure maximum void elimination. After duplication, polymerized epoxy resin was stored for 7 days to reach the maximum strength. Each die was then measured for bucco-lingual and mesio-distal dimensions using digital caliper. Measurements were recorded as follows, bucco-lingual: 7.1mm, mesio-distal: 3.8mm.

Certain criteria were followed in this study for crowns construction including the following:

Inclusion criteria:

1. Dies shouldn't have voids.
2. Dies should have intact finish line.
3. Dies should have similar dimensions"mesio-distal" and "bucco-lingual".

Exclusion criteria:

1. Dies with cracks or fractures.
2. Dies that doesn't fulfil the previous mentioned dimensions.

All anomalous dies were discarded and repeated for mold construction and epoxy resin duplication.

Grouping:

Forty-two resin dies were fabricated then, randomly divided into three groups (n=14) according to the material used.

- *Group (SHT):* Full contoured super-high translucent multilayer zirconia system were constructed using CAD/CAM.
- *Group (ST):* Full contoured super translucent multilayer zirconia system were constructed with CAD/CAM.
- *Group (BZ):* Bi-layered zirconia: Fourteen copings will be constructed using Solid ZI white with CAD/CAM and then were conventionally veneered with Vita Vm9 (feldspathic porcelain).

Die scanning

The master die was sprayed with an optical reflection medium to enable scan sof the die. After

* Condensation silicon Silaxil, Lascod, Sesto Fiorention, Florence, Italy.
** Ecosil, Dentaurum, Ispringen, Deutschland.
*** Paraflex, Bego, Bremen, Deutschland.
**** Fujrock, Leuven, Belgium.
***** Vibrax 220V, Renfert, Hilzingen, Germa

the scanning, data was transferred to the computer by an installed scanning software* for creation of a 3D virtual die.

Designing

The computer aided design (CAD) software exocad program (version 6136) was aided to outline margins of the restoration and select the best design. The die spacer was set to 50µm and away from the finish line by 1mm [14].

1- **First design (full contoured SHT and ST crown):** The anatomical crown was designed with axial wall and occlusal thickness of 1.2mm and 1.5mm respectively.

2- **Second design (coping of BZ):** The coping was designed with thickness of 0.5mm.

The two designs were later saved as stereo lithographic (STL) files. The STL files were send to the milling machine**.

Milling:

Two software's, Dentalcam and Dental CNC were used to regulate the milling process. The Dental CNC (computerized numerical control) program controlled the drive of the milling tools in harmony to the design decided by the exocad software to produce the required coping and full-contoured crown. For all groups the same five axis dry milling machine was used. The Zolid FX block (SHT) of the desired size (99x14mm) was selected and screwed on the right position of the milling device table then the milling procedure was started. After milling, the blank was removed without touching the restorations. Restorations were separated and smoothening of the connector area was performed without touching the pre-sintered margin. The residual milling powder was removed from surface of the restoration with air pressure and a large brush. The final shape of the pre-sintered zirconia was 20% to 25% larger than the real restoration size for compensating the firing shrinkage during sintering.

Firing

Following the manufacturer's recommendations, firing was performed in special furnace*** was performed.

Sandblasting

Sandblasting of the external outward of the full contoured crowns was performed**** and then cleaned using a steam cleaner*****. The restorations were then air dried using oil/water free compressed air. The full contoured crowns were glazed with materials commended by the manufacturers.

Firing parameters were set following the manufacturer's recommendations. The firing process was performed in a programat furnace****** to achieve a complete full contoured crown.

The external of the cores (BZ) were sandblasted and then cleaned with a streamer. In addition, zirconia cores were subjected to heat treatment. In order to standardize the veneered crowns final thickness a silicon index impression mold was taken from one finalized full contoured restoration for replicating the anatomy of completed full contoured restoration with total dimensions of 1.5mm occlusally and 1.2mm cervically [16, 17].

Glazing

The silicon mold was torn apart into two splits (buccal-lingual). Veneering porcelain thickness

* COILab scan, Medit, Seoul, Korea
** Vhf, K5, Ammerbuch, Deutschland.
*** Tegra Speed, Yenadent, Istanbul, Turkey.
**** Basic eco Dental sandblaster, Ranfert, Hilzingen, Germany.
***** MS 5 Streamer, Cavriago, Italy.
****Programat EP 3010, Ivoclar Vivadent, Schaan/Liechtenstein, Germany.

was 0.7mm cervically and 1.0mm occlusally. Four buildup materials (base dentine, transpa dentine, enamel and glazing layer) of feldspathic glass ceramic Vita Vm9 was used and applied onto the zirconia copings. The first layer (washbake) was then applied by brushes over the ZI core (BZ) to ensure uniform coverage [18].

After firing of the washbake, the base dentine was applied over the whole surface, followed by transpa dentine then an enamel layer was applied to the upper third of the crown. The mix was then condensed and vibrated to eliminate voids. The resulting shapes were then compared to a standardized silicon mold in order to confirm the correct dimensions of the veneering restoration before firing.

Later, another layer of transpa dentine was applied as a corrective layer in order to fill any deficiencies. The restoration was once again compared to the standardized silicon mold. A programat furnace**** was used for firing of the restorations with firing cycles temperatures and rates set according to the manufacturer's instructions.

Post firing:

Restorations dimensions were checked to ensure the following: occlusal thickness of 1.5mm, axial thickness of 1.2mm. After checking the dimensions, a finishing stone was used to finish the crowns. Add one glaze was applied and then a final firing cycle was done to finalize the restoration. Veneering technique of the residual coping was conducted by previously indices and each specimen final thickness was checked using mechanical caliper and index.

Full monolithic crowns (SHT, ST) and cores (BZ) were visually checked for seating on their corresponding dies. Full monolithic crowns (SHT, ST) and bilayered crowns (BZ) before and after veneering were checked under stereomicroscopic* at 50X magnification for marginal integrity and cracks presence. A metallic holder was designed to anchor the restoration to its corresponding die at the time of examination of the marginal gap. The veneered (BZ) and monolithic (SHT, ST) crowns were measured for marginal gaps at each surface at the following three locations: the middle and near both line angles [18)]. Images of marginal gap were captured using digital camera ** connected to a stereomicroscope at 70X magnification. The captured images were analyzed using software***.

Wooden holder was assembled to stereotype the distance (10mm) from the fitting surface of the crowns to the sandblasting nozzle and consists of:

A- Horizontal base of 15cm length, 2cm height and 12cm width.

B- Vertical board of about 9.5cm height and 12cm width containing a hole of 10mm diameter and 23mm thickness for fixation of zirconia crowns.

C- Wooden stick of about 5.5cm length and 10mm width for supporting each Zirconia crown and preventing its movement inside the hole.

D- Vertical board of about 23mm thickness and 12cm width containing a concave upper surface to accommodate the sandblasting nozzle.

Fitting surface of each crown was airborne-particle abraded with 50μm aluminum oxide particles for 10 seconds under 2 bar pressure with sandblasting machine [19]. The internal surface of cores (BZ) were sandblasted before veneering. The crowns (SHT, ST and BZ) were then cleaned for 5 minutes in an ultrasonic bath* with isopropanol alcohol to eliminate blasting particles from the sample surface and then were air dried with oil/water free compressed air [20].

* Technival 2, Caral Zeiss, Oberkochen, Germany.
** Canon pc 1106, Tokyo, Japan.
*** Image J 1.47V, National Institute of Health, USA.

Bonding:

Prior to bonding, the surface of the dies were steam-cleaned and disinfected- PRIME agent was applied as a single thin continuous layer and dried for 3-5 seconds following the manufacturer's guidance. Equal lenghths of RelyX U200 automix were extruded into the internal surface of the crowns which were then placed in its position over the die. A tailored loading device aided to apply a constant load of 5kg parallel to the long axis of each specimen for 5 minutes [21, 22]. The head of metal rod was coated with a Teflon layer in order to avoid direct metal to ceramic contact. The wax state was achieved by tack-curing with excess with light ** at the cervical area for 2-3 seconds during which the specimen was subjected to the load and calibration of the used light was done with its own base charger before curing . A glycerin based gel KLY Jelly*** was then applied at the margins of the crown to prevent the oxygen inhibiting layer. All the surfaces were light cured using LED light cure unit with 1470mW/cm2 intensity for a period of 20 seconds. After cementation, the specimens were kept in distilled water at room temperature (24°C) for one week according to previous studies [18, 23, 24],

Thermocyclying

All specimens were first subjected to 10,000 thermal cycles* between 5±1°C and 55±1°C in one-minute cycles which resembles 1 year of service in the oral cavity [25]. Dwell time was 20 seconds in each bath and 10 seconds for transfer between the baths.

Mechanical Testing

Mechanical fatigue was performed using a chewing simulator at a cyclic loading the chewing cyclic simulator had four testing chambers. Each specimen was subjected to an occlusal load equal to 49N (5kg) of chewing force which was applied on the crown. Each sample was subjected to 240,000 cycles which is corresponding to 1 year of clinical mouth service [26,27]. After completion of cyclic fatigue, all the specimens were immersed with 10 % methylene blue dye [28] for 24 hours and covered all the margin of restoration with varnish to prevent penetration of the dye) [28]. After cyclic fatigue, each crown was examined for cracks, chips or bulk fractures with a stereomicroscope [29].

Fracture resistance testing

Samples were separately fixed on a computer controlled testing machine* with a load cell of 5kN and data recorded using software**. Fracture test through axial compressive force a with spherical tip (5mm diameter) at cross-head speed 0.5mm/min [21]. Thin foil sheet was applied between the metal sphere and the occlusal surface of the restoration in order to attain homogenous spread of stresses [30]. The load at failure was demonstrated by an noticeable crack and confirmed by a sharp drop at load-deflection curve documented using computer software. The load required to fracture was recorded in Newton.

Statistical analysis

Categorical data was obtained as frequency and percentage values and was analyzed by means of Fisher's exact test. Numerical data was explored for normality by checking the data distribution, calculating the mean and median values and using Shapiro- Wilk tests. Data showing parametric distribution so; were represented by mean and standard deviation (SD) values. One-way ANOVA followed by Tukey's post hoc test was used for intergroup comparison. The significance level will set at $p \leq 0.05$ for all tests. Statistical analysis was performed with IBM SPSS Statistics Version 26 for Windows.

* MCS Ultrasonic Cleaner CD-4830, Codyson, China.
** Elipar DeepCure-L LED curing light, 3M ESPE, Seefeld. Germany.
*** KLY Jelly, Beylikduzu, Istanbul, Turkey.
**** Model 3345, Instron Industrial Products, Norwood, MA, USA.
***** Bluehill Lite Software Instron®, Norwood, MA, USA.

RESULTS

I-Fracture resistance

Descriptive statistics presenting mean values, standard deviations (SD), range (minimum & maximum) and 95% confidence intervals (CI) limits (lower and upper) for fracture resistance load measured in (N) documented for all groups after thermal and mechanical fatigue are presented in (Table 3) and graphically illustrated in (Fig. 1).

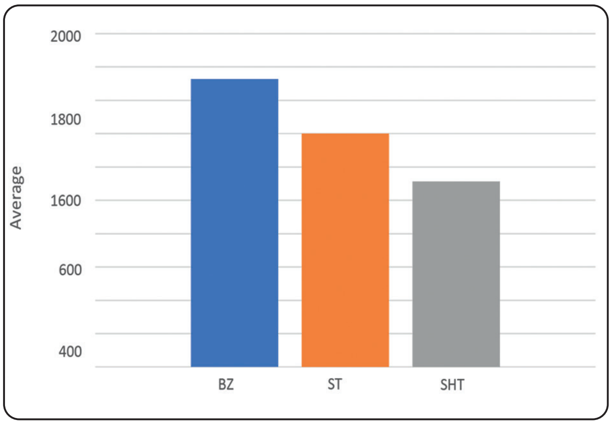

Fig. (1): Bar chart comparing fracture resistance after thermal and mechanical fatigue mean values between all groups.

Pairwise comparisons:

A-(BZ) and (ST) groups:

Mean and standard deviation (SD) values for maximum load values (N) for (BZ) and (ST) groups were documented in (Table 4) and. Post hoc pairwise comparisons utilizing Tukey's post hoc test showed that (BZ) group had a significantly higher value than (ST) group (p=0.036).

B-(BZ) and (SHT) groups:

Mean and standard deviation (SD) values for maximum load values (N) for (BZ) and (SHT) groups were documented in (Table 5). Post hoc pairwise comparisons utilizing Tukey's post hoc test displayed that (BZ) group had a significantly higher value than (SHT) group (p<0.001).

C-(ST) and (SHT) groups:

Mean and standard deviation (SD) values for maximum load values (N) for (ST) and (SHT) groups were documented in (Table 6). Post hoc pairwise comparisons utilizing Tukey's post hoc test disclosed that there was no significant different between both groups (p=0.069).

TABLE (3) Descriptive statistics of fracture resistance results in Newton's (Mean values ±SD) for all groups after thermal and mechanical fatigue

Groups	Maximum load (mean±SD)	Min.	Max.	95%CI		p-value
				Lower	Upper	
BZ	1727.19±311.75	1423.62	2378.28	1438.87	2015.50	**<0.001***
ST	1399.75±130.08	1198.46	1558.83	1279.45	1520.05	
SHT	1112.70±195.20	841.91	1363.04	932.17	1293.23	

; significant (p ≤ 0.05) ns; non-significant (p>0.05)

TABLE (4) Mean and standard deviation (SD) values for maximum load values (N) for (BZ) and (ST) groups

Maximum load (mean±SD)		Mean difference	95%CI		p-value
BZ	**ST**		**Lower**	**Upper**	
1727.19±311.75	1399.75±130.08	327.44	20.16	634.72	**0.036***

; significant (p ≤ 0.05) ns; non-significant (p>0.05)

TABLE (5) Mean and standard deviation (SD) values for maximum load values (N) for (BZ) and (SHT) groups

Maximum load (mean±SD)		Mean difference	95%CI		p-value
BZ	SHT		Lower	Upper	
1727.19±311.75	1112.70±195.20	614.49	307.21	921.77	**<0.001***

; significant (p ≤ 0.05) ns; non-significant (p>0.05)

Table (6): Mean and standard deviation (SD) values for maximum load values (N) for (ST) and (SHT) groups

Maximum load (mean±SD)		Mean difference	95%CI		p-value
ST	SHT		Lower	Upper	
1399.75±130.08	1112.70±195.20	287.05	-20.23	594.33	**0.069**

; significant (p ≤ 0.05) ns; non-significant (p>0.05)

TABLE (7) Mean and standard deviation (SD) values for maximum load values (N) for bilayered vs monolithic groups

Maximum load (mean±SD)		Mean difference	95%CI		p-value
Bilayered	Monolithic		Lower	Upper	
1727.19±311.75	1256.22±218.13	470.96	227.31	714.62	**0.001***

; significant (p ≤ 0.05) ns; non-significant (p>0.05

D-Bilayered and monolithic groups:

Mean and standard deviation (SD) values for maximum load values (N) for bilayered vs monolithic groups were documented in (Table 7). Results of independent t-test indicated that bilayered group had a significantly higher value than monolithic groups (p=0.001).

DISCUSSION

Monolithic zirconia restorations have been used as an alternative treatment option attempting to overcome the bilayered zirconia complications as chipping and delamination as well as providing higher flexure strength and fracture toughness [(13)]. The main disadvantage of 3Y-TZP monolithic zirconia is its unsatisfactory esthetic performance. Recent innovations in structure and composition led to monolithic zirconia of superior translucency but with reduction of strength. Super translucent or super high translucent monolithic zirconia formulations contain 4-5mol% which results in materials with different structure, mechanical and optical properties. These materials requires additional studies and investigations to explore their properties compared to one gold standard material [(32)].

Upper first premolar typodont was selected in the current study due to the high fracture rate in premolars than others combined with the unique morphology of upper premolar teeth having cusp steepness which make them more prone to fracture under occlusal loads [(18,33,34)]. An artificial maxillary first premolar was designed and prepared for the three experimental groups.

To simulate the clinical conditions, fully anatomical restorations were used to reproduce the stress state of crowns in clinical service instead of discs or bars [35]. Internal space was set to 50µm following the manufacturer's recomendations. CAD/CAM technique was used for restorations fabrication, as it allows more systematic approach and to ensure similar geometries for the restorations and cores within the groups. Milling machine used has a 5-axis milling, the number of axes is one of the crucial parameters; the more axes, the more detailed restoration morphology. Pre-sintered zirconia blocks offered faster and easier milling procedure, while the milling procedure of fully sintered blocks is more time consuming and can generate flaws and cracks resulting from their high hardness [36].

The hand-layering technique was used as a control group in this study, which had recorded the highest fracture resistance values. The BZ group cores internal and external surfaces were sandblasted, and subjected to heat treatment for 15 min at 950ºC in accordance to **Passos et al.,**[37]. It was found that 3Y- TZP contained 6.1% of monoclinic phase after sandblasting with 50µm of Al2O3, reverse transformation from monoclinic to tetragonal phase was confirmed after heat treatment[37]. Sandblasting induces phase transformation from tetragonal to monoclinic phase which affects the bonding between the core and veneering porcelain[38]. Monoclinic phase coefficient of thermal expansion of is $7.5x10^{-6}/^{o}C$ and tetragonal phase is $10.8x10^{-6}/^{o}C$, increasing the difference in coefficient of thermal expansion between zirconia core and veneering ceramic led to decrease in bond strength[38,39]. Coefficient of thermal expansion and contraction of ceramic block (Ceramill Zolid ZI) value is $10.5x10^{-6}/^{o}C$. Which matches the CTE value of Vita Zhanfabrik veneering glass ceramic $9\text{-}9.5x10^{-6}/^{o}C$ [34]. In our study, one experienced technician performed the veneering for bilayered restoration to avoid operator variations. The layering veneering protocol was according to manufacturer's instructions [34]. To stereotype the layering veneering specimens, silicon index was fabricated from a finalized full contoured specimen which was split [16, 17]. All the restorations of three experimental groups were glazed to mimic clinical conditions, using glaze layer placed on surface in a compressive state to reduce the width and depth of the surface flaws that can affect ceramics brittleness' [40].

Cementation protocol was standardized for all specimens, using self-adhesive resin cement. The sandblasting procedure was performed following the manufacturer's guidlines, and carried out in accordance with **Mehari et al.**[19]. It was found that sandblasting with same parameters increased the bond strength to all three zirconia types (3Y, 4Y, and 5Y). Sandblasting process removes surface contamination, increase surface energy and surface roughness to maximize the bonding action[41]. The load application was standardized with a loading device to avoid the variation of finger pressure and ensure complete seating of restoration before curing[42]. Priming agent (Z-Prime plus) was used before cementation which improves bond strength by acting as wetting agent and allowed easier penetration of the resin cement [43]. (Rely X) resin cement exhibit high mechanical properties as well as the presence of MDP increases the bonding action, which resulted in increased fracture resistance of zirconia restorations when compared to other cements[38,44]. In the current study, dual-curing resin cement was used because of higher degree of conversion ability when compared to self-curing alone[45].

All samples were stored for a period of seven days after completion of cementation then thermo cycling process was done.[45], the temperature alteration was set between the 5º and 55ºC with 1-minute cycle time according to an ISO standard as an appropriate aging procedure[45].

Thermal-fatigue process affects physical, chemical and mechanical properties of restorative materials such as water sorption leading to component hydrolysis, in addition, hot-cold passages lead to expansion-shrinkage. Zirconia is more susceptible to low temperature degradation in presence of water [(46)].

In the current study, mechanical cycling of specimens were performed to simulate repetitive stresses during mastication in a moist environment [(47)]. After mechanical cycling, the crowns were stained then examined using stereomicroscope for detection of the methylene blue dye penetration through the cracks [(29)]. After examination no samples showed any cracks or fractures, only superficial wear, this was in harmony with **Baladhandayutham et al.,** [(29)] and **Spitznagel et al.,** [(48)].

Failure of the specimens was evaluated using a universal testing machine. The null hypothesis of this study was partially rejected because results revealed significant difference in fracture resistance between bilayered and different types of translucent zirconia. On the other hand, the other section of the null hypothesis was accepted as there were no significant difference in fracture resistance between different types of translucent zirconia.

Fracture resistance values all of the tested groups were (1727.19±311.75 N, 1399.75±130.08 N, 1112.70±195.20 N) exceeded the average maximum force in the premolar region (220- 450 N) [(27)]**;** this could result from the high mechanical properties of zirconia, especially [(49)].

The majority of bi-layered zirconia restorations showed lower fracture resistance values after exposing the restorations to different aging methods. However, the bi-layered zirconia restorations (control group) used in the current study after thermomechanical fatigue, showed higher fracture resistance values (1727.19±311.75 N) than the super translucent monolithic zirconia **(ST)** (1399.75±130.08 N) and super high translucent monolithic zirconia **(SHT)** group (1112.70±195.20 N) (intervention groups); the possible explanation might be due to the protected core of the bi-layered zirconia by the veneering porcelain material however monolithic zirconia shows high tendency to low temperature degradation (LTD) which is mainly originated in humid setting [(50)]. The low temperature degradation reduces the mechanical properties of the material and puts zirconia frameworks at the threat of spontaneous catastrophic failures. Such phenomenon is speeded up by a number of factors, as moist, temperature, grain size, surface defects, type of stabilizing oxides, and processing techniques. It might be intimidating specifically if it took place at the margins of the restorations this was in accordance with **Sorrentino et al.,** [(26)].

Similarly **Kolakarnprasert et al.,**[(51)] **and Abdulmajeed et al.,**[(52)] showed that after water aging at 120°C for 12h, greater monoclinic content was found in Multi-layered zirconia ML: 3Y-PSZ, while Ultra Translucent Multi-layered zirconia (UTML):5Y-PSZ , Super Translucent Multi-layered zirconia STML: 4Y-PSZ did not display noticeable monoclinic phase.

Moreover **Sorrentino et al.,** [(26)] they explained the effect of existence of stabilizers, during the handing out of zirconia frameworks or monolithic crowns on the phase content and in return on the mechanical properties of the restoration, zirconia polycrystals continue in the tetragonal polymorphic phase (TZP), metastably retained when the temperature declines. This metastable tetragonal phase gives an attention-grabbing performance that makes it mechanically more resistant than the monoclinic one: when a crack is initiated at the tetragonal -zirconia surface, the tensile stress concentration persuades the transformation of the grains proximate the crack from metastable t-ZrO_2 to m-ZrO_2, the monoclinic crystals being outsized the tetragonal ones. The energy dissipation mechanism defines a 3%–5% volume rise of the crystals, guarded by the neighboring crystals, consequential in a advantageous compressive stress that acts as a crack restrainer. This stress-induced t–m phase transformation of zirconia crystals when subjected to load is identified as "phase transformation toughening" (PTT) and escalates the fracture toughness as well as the flexural strength of the material. At room temperature, the transformation from tetragonal to monoclinic is a one-way process, which defines that following the t–m transformation, zirconia can no more display the phase transformation toughening and its crack-hindering influence.

Our results disagreed with **Holman et al.,**[53], **Kayali and Kahramanoglu** [49], **Rosentritt et al .,** [30] **Vidotti et al.,** [54] since the researchers observed that the fracture strength of monolithic restorations showed excellent performance over the veneered one; it was claimed that the decreased fracture resistance values of bilayered zirconia restorations was because of different methodologies engaged, as type of restoration examined (crown or FPD), type of die used, cycles number and force exerted throughout thermomechanical loading. Also, this may be attributed to the exclusion of the interface between the core and the veneer which is supposed to be the delicate link in the bilayer systems. Moreover, fabrications of CAD/CAM restorations digitally comprise high quality material with least flaw and residual thermal stresses compared to the manual veneering process.

The intercomparison difference between super translucent monolithic zirconia **(ST)** (1399.75±130.08 N) and super high translucent monolithic zirconia **(SHT)** group (1112.70±195.20 N) showed that there is no significant difference in fracture resistance values between both of them. This could be explained by the very close sintering temperature of both materials 1550^{0}C and 1450^{0}C respectively according to the manufacturer instructions. Sintering temperature is considered to be one of the most important factors controlling the mechanical properties of the material together with the yttria content, as the higher the sintering temperature and yttria content is, the greater the cubic content, the grain size and the lesser the monoclinic content which means reduction in tetragonal phase, decreased transformation toughening and lower fracture resistance values. Hence there is no significant difference in sintering temperatures of both, despite having different yttria content as claimed by the manufactures; there is no significant difference in fracture resistance values.

Our results agreed with **Kolakarnprasert et al.,** [51] who conveyed that both high cubic-containing UTML and STML did not show any transformation toughening after 12 h aging and equal monoclinic content % by weight after 100 hours (<1), despite of their different yttria and cubic phase content: Ultra Translucent Multi-layered zirconia (UTML): 5Y-PSZ (5mol% yttria-partially-stabilized zirconia) with 7.5wt% cubic content and a 4.05 (±0.85) um average grain size, Super Translucent Multi-layered zirconia STML: 4Y-PSZ with 6.5wt% cubic content and a 2.81 (±0.17) um average grain size. Which means that it is considered to be slight difference in cubic phase and yttria content not to the extent of affecting fracture resistance values of both.

However, results were in contrast with **Holman et al.,** [53] they stated that 5Y-PSZ Lava Esthetic group showed a higher flexural fatigue strength than 4Y-PSZ Katana STML group. That was claimed to be related to difference in material chemical composition and sintering process between companies. These proprietary formulas and fabrication methods have been shown to affect the material properties of zirconia. On the other hand **Spitznagel et al.,** [48] they stated that Z-XT: 5Y-TZP monolithic- zirconia (Vita-YZ-XT) showed lower failure loads than Z-ST: 4Y-TZP monolithic-zirconia (Vita-YZ-ST). This was claimed to be related to using higher content of yttria with increased contents of cubic phase for increasing translucency that was accompanied by decreased tetragonal phase and transformation toughening. Consequently, the improvement of optical properties directed to a decrease in strength and toughness.

Also, **Rosentritt et al.** [30], they suggested that 5Y-TZP must be notable from other Y-TZP materials. Manufacturer permitted suggestions for 5Y-TZP tell that these materials are equivalent to strong glass-ceramic materials than to "conventional" 3Y-TZP, 4Y-TZP zirconia, as both showed increased force fracture after TCML (thermal cycling and mechanical loading) while 5Y-TZP didn't show any increase in force fracture, that was credited to the minor percentage of contained tetragonal phase zirconia headed for a high ratio of stabilized cubic phase crystals. As a conclusion; these materials have increased volume that enriched the optical properties nevertheless lowered mechanical ones.

Limitations:

An in-vitro study where not all in-vivo simulation conditions were implemented such as; pH changes and existence of saliva and bacteria. Epoxy die has different modulus of elasticity than dentine which may affect the result. Absence of periodontal imitation is thought to lessen the fracture strength of the prosthesis. Considering with long term thermomechanical fatigue duration could be essential to attain better assessment of in-vitro studies.

CONCLUSION

It can be concluded that; all the crowns tested obtained high fracture resistance (above 1000 N) and could n successfully withstand the average clinical masticatory force in the premolar region. The group of bilayered crowns recorded higher fracture resistance mean value than the two groups of translucent monolithic crowns. Increasing yttria percent from 4mol% to 5mol% in monolithic zirconia does not affect the fracture resistance value.

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