The Effect of Different Cement Space on the Fracture Strength of Two Different Types Zirconium CAD/CAM Crowns

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Abstract

Objectives: Evaluate and compare the effect of three different cement space (50um, 70um and 90um) on the fracture strength of (vita zirconia crowns and Ips e-max Zir/cad zirconia crowns).

Materials and Methods: An ideal prepared plastic dentoform model of a left maxillary first molar with deep chamfer finish line design was used as a pattern for fabrication master metal die. The model was scanned and the master metal die was milled by CAD/CAM system. Sixty crowns made from two different types of zirconium were fabricated on a metal die and were divided into two major groups (A and B)(30 crowns for each group) according to the two different types of zirconium being used: Group A: fabricated with vita zirconium crowns ; Group B: fabricated with IPS e-maxZir/CAD crowns. Each group further subdivided into three subgroups (10 crowns constructed with 50 um cement space crowns) , (10 crowns constructed with 70 um cement space crowns) and (10 crowns constructed with 90um cement space crowns).

Results: The results of this study presented that the highest mean value of fracture strength is recorded via Group A1 (3.767 ± 0.242), followed by GroupA2 (3.266 ± 0.116), Group A3 (2.883 ± 0.085), Group B1 (2.505 ± 0.155), Group B2 (2 ± 0.141) and Group B3(1.508 ± 0.151) respectively. The data were statistically analyzed using one-way ANOVA and HSD testes which revealed highly significant differences ($p<0.01$) among groups . independent sample t-test result revealed a statistically highly significant difference between subgroups. **Conclusion:** Vita zirconium crowns is more resistance to fracture than IPS e-max Zir/CAD. (50um cement space) have higher fracture strength than the others.

Keywords: *Cement space, Zirconia, CAD/CAM, Fracture strength.*

Introduction

Cement space can be define is the vertical distance between the surface of the die and the inner surface of the restoration [1]. Advantage of using the die spacers permit increased space for the cement between the internal surface of the casting and the tooth surface, decreasing stress areas formed during cementation and thus resulting in better fit to the final restoration [2]. With the CAD/CAM system digital die spacer is very consistent in thickness regardless to the shape of the die [(3, 4)].

The overview of the technology of new CAD/CAM milling and new zirconia materials are ready possibilities for manufacture the monolithic zirconia crown [5, 6]. The monolithic crown zirconia is the restoration of a full-contour crown zirconia designed without the addition of porcelain, which was industrialized to overcome the main complications problems of zirconia-based restoration is the veneer cracks [7, 8].

Zirconia has attracted maximum attention because it has the highest flexural strength and fracture toughness of all the existing ceramics. Natural phase transformation occurs internally in zirconia when an external stress is applied, which prevents crack propagation and tightens the crack tip, resulting in increase in the flexural strength and fracture toughness [10, 11].

The Fracture strength of all-ceramic restorations is strongly dependent on the support materials. In addition, cement type, cement thickness and preparation design can be influential factors. The film thickness of the cement affects directly the long-term clinical success. While determining film thickness of the cement, rate, mixing technique and heat are as much important as the clinician's experience of the material. As a result, in real clinical situations, the actual cement thickness depends on the material used and the experience of the clinician [13].

Materials and Method

Standardize die

An ideal prepared plastic maxillary left first molar tooth (Nissin Dental Products, Kyoto Japan) with deep chamfer finishing line of (2 mm) occlusal reduction and axial reduction of (1.5 mm) was used to construction the master metal die.

Several CAD/CAM studies have used master metal dies [(14,15,16)]. Then a metal die was fabricated by using CAD / CAM system to simulate the shape of ideal prepared plastic tooth to receive the zirconium crowns [17, 18].

The plastic prepared die was scanned using white light scanner (DOF, full HD, 2 M pixel /, Korea) with stable scan stage method, then the digital model of the die sent to the milling machine (VHF S1, K5 impression machine, Germany) which was loaded with cobalt chromium disc 14mm (Interdent , Travagliato (BS) Italy) to start dry milling process.

The metal base was flat and cubic in shape with length , width of (20 mm) and height of about (15mm) fabricated by using Computer Numerically controlled machine (CNC) [19] figure (1).

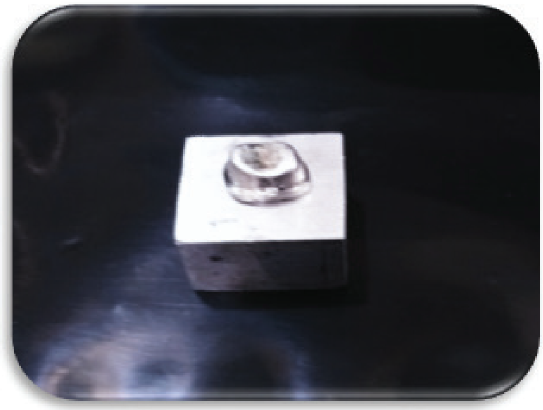

Figure (1): The metal die with metal bas

Sampling grouping

Sixty crowns were introduced in this study which is divided into two groups according to the two types of zirconium and three different cement space as follows:

Group A: 30 crowns were constructed from (VITA Zahnfabrik Zirconia crowns).

Group B: 30 crowns were constructed from (IPS e-max Zir CAD Zirconia crowns).

Each group then subdivided into three subgroups of (10 crowns constructed with 50 um cement space crowns) ,(10 crowns constructed with 70 um cement space crowns) and (10 crowns constructed with 90um cement space crowns).

Fabrication of crowns

All manufacturing procedures containing model scanning, milling and sintering protocols. All procedures have been carried out in accordance with the manufacturer's instructions for the zirconia and the CAD-CAM system used.

Exocad software (GmbH, Germany) were used to design the crown , the same design is programmed for both types of zirconium CAD/CAM crowns.

In this study three different cement gap thickness of 50 um (0.05mm) , 70 um (0.07mm) and 90 um (0.09 mm), and an adhesive space of 1000um (1mm) from the finish line is used, Proximal contact :0 , Minimum occlusal thickness: 2000 um (2mm), Minimum circular thickness: 1500um (1.5mm), and 1000um (1mm) Margin thickness.

fracture strength testing procedure

Single load to failure test was used in the current study to measure the fracture strength of the crowns fabricated with the (vita zirconia crowns and Ips e-max Zir/cad crowns).

A (1 mm) thick piece of rubber was placed between the crown and the occluding rod to prevent peak load pressure on the crown surface and distribute the applied force over a larger area , i.e., homogenous stress distribution [20, 21] figure (2).

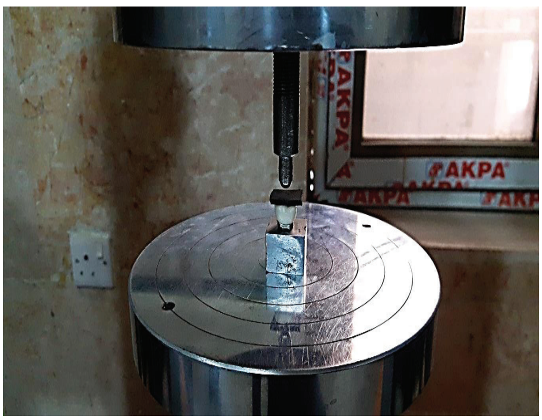

Figure (2): The sample with metal base stable to the testing machine.

All samples were loaded until fracture and the maximum breaking load of each sample was recorded automatically in kilo Newton (KN) through a computer linked to the loading machine.

The mode of the fracture in this study divided into three types as follow:

Type one : Partial fracture of crowns from margin towards occlusal surface

Type two: Complete fracture of crowns through midline (half of crown displaced or lost (catastrophic failure))

Type three: Chipping at the finishing line.

Statistical Analyses

The data was statistically analyzed using SPSS (statistical package for social science) version 24. One-way ANOVA and Tukey HSD tests for comparing fracture strength among different cement spaces in each group. Independent samples t-test to test any statistically significant difference in the fracture strength between the two groups for each cement space.

Result

Table (1): Descriptive statistics of fractural strength (KN) with different groups

Groups	Subgroups	N	Mean	S.D.	Min.	Max.
VITA Zirconia	A1	10	3.767	0.242	3.52	4.12
	A2	10	3.266	0.116	3.11	3.45
	A3	10	2.883	0.085	2.77	3.01
IPS e-max Zir/CAD	B1	10	2.505	0.155	2.3	2.69
	B2	10	2	0.141	1.78	2.15
	B3	10	1.508	0.151	1.31	1.7

Table (2): Comparison of fracture strength among different subgroups in each main group

Groups	ANOVA	Sum of Squares	d.f.	Mean Square	F-test	p-value
VITA Zirconia	Between Groups	3.930	2	1.965	74.268	0.000 (HS)
	Within Groups	0.714	27	0.026		
	Total	4.645	29			
IPS e-max Zir/CAD	Between Groups	4.970	2	2.485	111.905	0.000 (HS)
	Within Groups	0.600	27	0.022		
	Total	5.570	29			

Table 3: Multiple comparisons between each two types of subgroups in each main group

Groups	Subgroups		Mean Difference	p-value
VITA Zirconia	A1	A2	0.501	0.000 (HS)
		A3	0.884	0.000 (HS)
	A2	A3	0.383	0.000 (HS)
IPS e-max Zir/CAD	B1	B2	0.505	0.000 (HS)
		B3	0.997	0.000 (HS)
	B2	B3	0.492	0.000 (HS)

Table 4: Descriptive statistics and subgroup difference regarding the fracture strength

Subgroups	Descriptive statistics				Comparison (d.f.=18)	
	VITA Zirconia		IPS e-max Zir/CAD			
	Mean	S.D.	Mean	S.D.	t-test	p-value
A1-B1	3.767	0.242	2.505	0.155	13.881	0.000 (HS)
A2-B2	3.266	0.116	2	0.141	21.890	0.000 (HS)
A3-B3	2.883	0.085	1.508	0.151	25.143	0.000 (HS)

Discussion

The Computer aided design/ Computer aided manufacturing system are used in the manipulation of ceramics, such as zirconia or glass ceramics , as well as, this technology have the ability to produce an accurate fit and individual design, simple handling characteristics, and time consuming production processes; in addition to that, the CAD/CAM system demonstrated a variety from the options during scanning, design and during production of restoration. This system also permit the thickness of restoration and simulated die spacer (cement space) to be specified to the wanted thickness [11].

Zirconia fractures do not appear to be a common problem, although ceramics counting zirconia, this referred to as fragile materials [12] , if monolithic zirconia crowns look to have adequate fracture resistance, the importance of cement should not be underestimated [5] , It has been proven that the supporting materials, like cement and abutment material, will affect the fracture strength of all ceramic crowns [10] .

Methodology

Using the Master die

In the current study, an ideal prepared plastic tooth #28 is used for the construction of a master metal die, [18]).

The master die of Deep chamfer finishing line was selected because it improved the biomechanical performance of posterior single zirconia crown, which might be attributed to greater thickness and more rounded internal angles between the axial wall and gingival seat [16] **.**

Then a metal die was fabricated by using CAD/ CAM to simulate the shape of an ideal prepared plastic tooth to receive the two types of zirconium crowns [17] .

The advantages of using metal die include standardized preparation, better resistance to scratching, destruction or wear under repeated crown seating during fracture strength measuring procedure([14] .

Construction of metal base for the metal die.

In the present study, the base used for the metal die is made from (cobalt chromium alloy) to allow proper position of the metal die during the test to prevent the fracture of the base [14] .

The metal base was fabricated by using Computer Numerically controlled machine (CNC) [19] **.**

Using the single load.

The single load to failure test was used to test the fracture strength of the crowns, because this test provides helpful data for comparing between the tested materials without the contribution of confounding variables brought from fatigue testing [21] .

Results

In this study, Vita zirconium crowns fabricated with (50 um) cement space (Group A_1) showed a mean fracture strength of (3.767± 0.242 KN), while Vita zirconium crowns fabricated with (70 um) cement space (Group A_2) showed a mean fracture strength of (3.266± 0.116 KN) and Vita zirconium crowns fabricated with (90 um) cement space (Group A_3) showed a mean fracture strength of (2.883± 0.085 KN). IPS e-max Zir/CAD crowns fabricated with (50 um) cement space (Group B_1) showed a mean fracture strength of (2.505± 0.155 KN), while IPS e-max Zir/CAD crowns fabricated with (70 um) cement space (Group B_2) showed a mean fracture strength of (2 ±0.141 KN) and IPS e-max Zir/CAD crowns fabricated with (90 um) cement space (Group B_3) showed a mean fracture strength of (1.508±0.151 KN).

Effect of cement space on the fracture strength .

In this study, the result revealed that the decreased cement space causes increased fracture strength for all the groups (vita zirconia crowns (Group A) and Ips e-max Zir/CAD zirconia crowns (Group B)). This may be attribute to, that increase cement space measurement causes the crown thinner, because the strength required to fracture any crown is straight proportional with thickness of the material. Thus, thicker crowns will required more force to fracture than the thin crown. Therefor (90 um cement space) needed less force to break the crown compared with (50 um and 70 um cement space) . In addition, the increase cement space result in more space between the die and the crown, did not improve crown seating [3, 21].

These results came in agreement with [3] and [4] who found that the increased cement space causes decreased fracture strength.

The effect of two types zirconium crowns on the fracture strength.

The result of the current study about the fracture strength measurements of two types zirconium CAD/CAM crowns (Vita and Ips e-max Zir /CAD) fabricated by three different cement space showed that the differences between the cement space was highly significant .

This coincide with [8] who conclude that the sintering time influenced the density and mechanical properties, they stated that the great sintering temperature and extended sintering period increased the grain size and thus result in a material with decreased mechanical properties.

In this study, restoration of the full-contour zirconia crowns with no ceramics overlay from all groups (A and B) is used to provide the crowns with adequate mechanical strength in order to resist occlusal forces while preserving biocompatible properties and excellent esthetics, Because of multilayered zirconium crown structures having loading capacity and distributions different from stress when compared to the monolithic restorations. Therefore, differences in fracture and mechanical behavior can be expected. In addition, the monolithic zirconia crowns, due to single composition of the anatomical blanks of zirconium material can be milled directly to full anatomical crown without the need for a ceramic veneer, and therefore not subject to an additional firing cycle compared to that of zirconia core materials [6] .

Conclusions

Within the limitations of this study, the following conclusions can be derived:

1. The highest fracture strength mean value is recorded by crowns fabricated with (50um cement space) whereas the lowest mean value of

fracture strength is recorded by fabricated crowns with (90um cement space).

2. Differences were present in the fracture strength between two types of zirconium crowns; that show Vita zirconium crowns is more resistance to fracture than IPS e-max Zir/CAD.

3. The result of this study about the fracture strength measurements of two types zirconium CAD/CAM crowns (Vita and Ips e-max Zir / CAD) fabricated by three different cement space showed that the differences between the cement space was highly significant.

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Conflict of Interest: None to declare.

Ethical Clearance: All experimental protocols were approved under the Collage of Health and Medical Technology, Iraq and all experiments were carried out in accordance with approved guidelines.

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