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THE EFFECT OF THE SHAPE OF PREPARATIONS OF THE OCCLUSAL SURFACE OF THE POSTERIOR TEETH ON FRACTURE RESISTANCE OF PFM – ZIRCONIA CROWNS: AN IN-VITRO STUDY

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ABSTRACT:

Background and Objectives: The fracture (chipping) of the ceramic layer covering the metal or zirconia is a frequent clinical problem due to multiple causes. Therefore, we will study the effect of different shapes of preparations of occlusal surface of posterior teeth (flat and anatomical shapes) to resist fracture of the metal-ceramic and zirconia crowns under the effect of different forces.

Methods and Materials: The study sample consisted of 56 first mandibular natural molars with convergent sizes divided into two main groups (28 A / Anatomical /, 28 F/ Flat /). With 'A', the occlusal surface was prepared similarly to the anatomical shape of the tooth while with 'F' it was prepared flatly, (finishing line: 1 mm, axial walls: 1-1,5 mm, the occlusal surface: 1,5-2 mm). Each main group was divided into two subgroups, 14 molars in each one. The cores of the first 14 molars were made of metal (M) and the others' were made of zirconia (Z) with thickness of 0.5 mm for all. Then, each subgroup was subdivided into two mini groups, each including 7 molars so that we have eight mini groups: G1: AM, G2: AZ, G3: FM, G4: FZ, (applied forces at a 45 degree angle), G5: AM, G6: AZ, G7: FM, G8: FZ (applied forces at a 90 degree angle). A silicon guide was made to complete the process of porcelain firing with equal thicknesses. Finally, the samples were preserved in the incubator under 37^0 C until applying the tests using Universal Tests Machine (T114).

Results: No statistically significant difference between anatomical and flat preparations while applying forces at a vertical angle for each of the metal and zirconia and at a 45 degree angle for the metal only was observed. A statistically significant difference between anatomical and flat preparations was observed while applying forces at a 45 degree angle for the zirconia.

Keywords: Fracture resistance – Porcelain Fused To Metal and Zirconia Crowns- Occlusal Forces.

INTRODUCTION:

The tooth does not possess the regenerative ability as found in most organs of the body, therefore, once enamel or dentin is lost as a consequence of caries, trauma, or wear, restorative materials must be used to reestablish the tooth form and function. Teeth require preparations to receive restorations, and these preparations must be based on basic principles from which basic criteria can be developed to help predict the success of prosthodontics treatment. Careful attention to every detail is essential during tooth preparation. The basics of tooth preparation may take into consideration three essential factors, biologic, mechanical and esthetic. A Successful preparation of the tooth and the subsequent restoration depends on integrating all these factors together. Usually, the progression in one area will

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adversely affect another one, however, seeking perfection in one area may lead to failure in another. Since the clinical success of the restorations is the purpose and goal in dental treatments, and to reach this end, it requires the cooperation of the doctor, the laboratory technician and the patient, but the greatest responsibility lies with the doctor to comply with the basic principles of the teeth preparations and material properties that we deal with in addition to the choice of good laboratory technician.[1]

In the last decades, since the development of porcelain-fused to-metal (PFM) procedures in the early sixties, metal–ceramic restorations have represented the “gold standard” for years in prosthetic dentistry, thanks to their good mechanical properties and to somewhat satisfactory esthetic results, along with a clinically acceptable quality of their marginal and internal adaptation.[2]

Recent decades witnessed a continuous and considerable increase in the demand for highly aesthetic and natural-appearing dental restorations. At the same time, development of strong engineering ceramic materials took place. The above trends led to the adoption of sintered ceramics as new load-bearing components used in dental prosthetics. [3]

Yttria (Y2O3) partially stabilized zirconia (ZrO2) (YPSZ) is a ceramic material which has become widely used in the manufacture of dental prostheses due to its high compressive strength, appealing aesthetics, biocompatibility and toughness. In dental prosthetics, zirconia frameworks are veneered with porcelain that is applied as a slurry and then “baked”. This process delivers excellent surface aesthetics, and reduces the surface hardness of the artificial tooth thereby reducing wear on the enamel of opposing natural teeth. Despite the benefits of using porcelain as an outer coating material, clinical trials have identified the primary failure mode associated with this veneering process - near interface chipping of the porcelain.[4]

But nonetheless still Clinical practices show many problems, both with PFM and zirconia and foremost cracks (Chipping) and fractures also showed many of the studies. A conducted study by Pjetursson, B.E et.al (2007) survival rate for full crowns (PFM-Ceramics)found that the most frequent failure is the (Chipping) in metal-ceramic crowns.[5] By studying two clinical follow-ups by Sailer et.al (2007) and Raigroski et al (2006) for zirconia bridges and patterns of failure which found that the(chipping) is the most frequent pattern of failure in clinical applications.[6,7]

To overcome these problems, the researcher Jang, G.W et.al (2011) worked out to modify thickness of the zirconia core to increase the resistance of fracture of the zirconia crowns.[8] While the Beuer, F et.al (2012) made a full zirconia crown dispensing ceramic layer covering the core.[9] The researchers Hama Suleiman, S. Vult von Steyern, p (2013) modified the method of making the metal core to increase fracture resistance of metal-ceramic crowns.[10] The researcher Larsson, C et.al (2015) worked on modifying the shape of core (metal ceramic - zirconia) to improve the resistance of fracture.[11]

The appearance of these problems is not related to the doctor alone, but to the technician and materials used. However, before finding problems related to factors other than the doctor, we must start from ourselves and search the problems related to the doctor. Therefore, good materials and a professional technician were selected conduct a comparative study of fracture resistance of the metal-ceramic and zirconia crowns by making two shapes to prepare for occlusal surface of posterior teeth (flat - anatomical) and changing the direction of the forces applied upon them.

Proceeding from reality and the region we live in, the researcher reviewed the group of laboratories that have a long history in teeth industry in the Syrian coast and inquired about the most frequent problems. He also observed the wide range of gypsum examples of teeth preparations which receive a full crown or a bridge especially the posterior teeth where the occlusal surface was mostly prepared flatly which is one of the fastest and easiest preparations for the doctor and the simplest to work for the technician. The researcher, as well, has conducted a questionnaire that was distributed randomly among a group of doctors in the Syrian coast to inquire about the most frequent problems about the fixed compensation and the reasons for these problems, the ways to prepare the teeth, especially the occlusal surface of the posterior teeth, the types of compensation used and so on. It turned out that the metal-ceramic compensation still occupies the largest area in clinical practice, and that the most frequent problems were porcelain cracking (chipping) and breaking either for metal-ceramic compensation or zirconia whereas the preparation method of the occlusal surface varied between the anatomical and flat shape of the tooth.

MATERIALS AND METHODS:

The study sample consisted of 56 first natural mandibular molars with close sizes and free from caries Figure (1), preserved with normal saline and cleaned using Ultra sonic device.

Stages of tooth preparation

Two molars were selected randomly from the sample to be prepared as follows:

First molar: Preparation of this molar was made to be crowned by PFM or zirconia, according to the basic principles of preparation. The finishing line was 1 mm deep, the axial walls were 1- 1.5 mm thick, the converging was 10 degrees until reaching the thickness of 1 , 5-2 mm on the occlusal surface. The occlusal surface was prepared while preserving the anatomical shape of the molar A (Anatomical) which was used to draw a graph Figure (2).

Second molar: This molar was prepared identically to the molar A except for the occlusal surface that was prepared flatly (F/ Flat). Figure (3)

The sample was randomly divided into two main groups:

Group A (Anatomical): included 28 mandibular molars prepared according to the graph Figure (1). This group was also divided into two subgroups. The first included 14 prepared molars ready to be crowned by PFM crowns (all symbolized as AM (Anatomical- Metal)) while the second included 14 prepared molars ready to be crowned by zirconia (all symbolized as AZ (Anatomical- Zirconia)), as shown in Table (1).

Group F (Flat): included 28 mandibular molars prepared according to the graph Figure (2). This group was also divided into two subgroups. The first included 14 prepared molars ready to be crowned by PFM crowns (all symbolized as FM (Flat- Metal) while the second included 14 prepared molars ready to be crowned by zirconia (all symbolized as FZ (Flat- Zirconia), as shown in Table (1).

Stages of laboratory work

After completing tooth preparation according to the above criteria, digital three-dimensional images were taken using the digital imaging device 'Scanner unit' of the CAD/CAM device owned by Cad4dent company of all prepared molars for designing the core using the CAD/CAM device with standardized thicknesses of 0.5 mm and maintaining the core shape in proportion to the preparation of tooth, [12] as shown in Figure (4). After completing cores design, two molars were selected randomly; one prepared flatly and the other prepared anatomically and by using the CAD/CAM device for preparing two full crowns made of wax special to the device and according to the same criteria. An impression of the final crown was made of silicone rubber Siloxane Polyvinyl to be a guide for porcelain firing process onto the metallic and zirconia crowns. According to the stages of porcelain firing process, the manufacturer's recommendations, and the silicone guide, the process of making metallic-ceramic and zirconia crowns was completed, [12] as shown in Figure (5).

After manufacturing ceramic-metallic and zirconia crowns, acrylic templates (Vertex Italian type) were made as a base (height 25 mm - and diameter 21 mm) for the teeth to be planted on according to the longitudinal axis and 2 mm before the cementoenamal junction as shown in figure (6). Figure (7) shows all specimens.

- Crowns were cemented with glassy ionic cement (from Ivoclar Vivadent company) according to the manufacturer's instructions where crowns were tested, teeth were washed with running water and dried with smooth airflow. The liquid was mixed with the powder then the inner surface of the crown was painted with a sufficient quantity of cement. Then, the crown was put on the tooth, a strong pressure was applied by finger, a5 kg force was applied for 10 minutes above the teeth and the excrescent cement was removed. [13]

- The samples were preserved in physiological serum and placed in the incubator at the temperature of 37 degrees for at least 24 hours then samples were ready for mechanical testing.

Method of conducting mechanical testing

Tests of resisting fracture forces were conducted using the mechanical testing machine (Universal test machine Test 114) at Damascus University - Faculty of Electrical and Mechanical Engineering after preparing extensions especially designed to fit the sample with a 0.5 mm / min speed. The utilized device was connected to a computer with a special order to draw diagrams of the forces of the fracture. These forces are usually manifested through the collapse of the graph whenever there is a chipping or cracking. In this case, the value of the force falls back so the device is turned off and the numeric value of the refractive force is recorded in Newton. However, the forces were applied on the sample in parallel and lateral to the longitudinal axis of the tooth (vertically at a 90 degree angle- lateral 45 degree angle) Figure (8).

RESULTS:

After obtaining the test results for the studied sample, and to fulfill the study objectives, the researcher used the Statistical Package For Social Sciences (SPSS) program, as well as Excel 2007, to analyze and achieve the goals of the study. The following statistical methods were used:

- Kolmogorov-Smirnov test for testing the normal distribution of data.
- The standard deviations and arithmetic means.
- The independent samples test for independent samples to compare sample means.

The study of the comparison between different types of preparation (anatomical-flat) of the posterior teeth's occlusal surface:

The results of the comparison between the two types of preparation are shown in table (3), through which we observe that:

- there are no significant differences of statistical indication between the two fracture strength means (G1AM- G3FM), (AM G5- FM G7) at an importance level of 5% , noting that the fracture resistance strength mean of the group prepared in flatly is higher than the fracture resistance strength mean of the group prepared anatomically.

- there are significant differences of statistical indication between fracture strength means (G2AZ - G4FZ) at an importance level of 5%, noting that the fracture resistance strength mean of the group prepared flatly is significantly higher than the fracture resistance strength mean of the group prepared anatomically.

- there are no significant differences of statistical indication between the two fracture strength means (AZ G6- FZ G8) at an importance level of 5 %, noting that the fracture resistance strength mean of the group prepared flatly is higher than the fracture resistance strength mean of the group prepared anatomically, Figure(9).

DISCUSSION:

Despite the wide spread of the zirconia restoration as a substitute for full ceramic restorations, due to its good cosmetic and excellent mechanical properties, the metal-ceramic restorations are still the most popular in our region, due to their cheap prices and good properties, as the survey conducted prior to the study indicates.

Despite that the medical literature recommends basic principles for teeth preparations, we notice no commitments by many dentists in clinical practices which in turn causes several problems.

The chipping in the ceramic layer covering the metal or zirconia structure is considered the most recurring problem in fixed restorations, which puts the dentist in an embarrassing position and causes loss of the patient's trust. To overcome this problem, several studies have been conducted that modified the shape of the core structure and manufacturing method, dispensing the outer ceramic layer and even modifying the preparation. [8,9,10,11]

Based on these ideas, the study has been conducted starting with the primary stage of manufacturing the fixed restoration which is the preparation, where mandibular natural molars of convergent sizes were prepared in two occlusal surface shapes (the flat shape- the anatomical shape) following the basic principles of preparation (the metal-ceramic and zirconia crowns) and according to a unified shape for the two preparations, to unify the standards and simulate the clinical setting, keeping a unified core thickness of 0.5 mm and following a unified method of constructing the ceramic according to the silicone guide to obtain equal thicknesses and using the same ceramic commercial brand. Vertical and lateral forces were applied simulating the internal oral forces. [12,13]

The mechanical test results show that there are no differences of statistical significance between the flat and the anatomical preparations of the metal-ceramic crowns with the flat preparation having higher fracture resistance average respectively (951-944 N) by lateral forces and (1591-1274 N) by vertical forces. These results converge with the results of the study conducted by Hama Suleiman, S. and Vult von Steyern, P., 2013, where the fracture value of the metal-fired ceramics of a 0.5 mm thickness and flat shape, with a ceramic cover layer of a 1.2-1.5 mm thickness is 1560 N,[10] whereas in this study it is 1591 N, which corresponds with the physical laws where the force moves from the ceramics to the (metal-zirconia) core, and from there to the surface of the tooth (the flat shape allows the equal and horizontal diffusion of force, whereas in the curving shape, the force breaks down into lateral and tangential components and causes an increase in pressure until fracture.)

The mechanical test results show that there are no differences of statistical significance between the flat and the anatomical preparations of the zirconia crowns with the flat preparation having higher fracture resistance average respectively (1922-1556 N) by vertical forces.

The results of this study corresponds with the results of the study conducted by Krishnan, G.A., 2010, where the fracture strengths up until failure were 1300 N for crowns prepared anatomically (whereas in this study it is 1676 N) and 1572 N for crowns prepared flatly (whereas in this study it is 1922 N) where there were no differences of statistical indication, with the crowns prepared flatly.[14]

The results of this study converge with the results of the study conducted by Sawada T., et al (2016), where the zirconia core's shape was modified to increase the fracture resistance of zirconia crowns. In the sample similar to our study, which was prepared anatomically, with a 0.3 mm thickness, and covered with ceramics, the crowns' fracture resistance was 2049 N, with the forces applied vertically on the center of central fossa, whereas in this study it is 1676 N where forces applied vertically on the top of distobuccal cusp.[15]

The results of this study differ from the results of the study conducted by Larsson, C et al., 2015) according to fracture resistance of metal-ceramic crowns where fracture resistance average was 2155 N preserving the anatomical shape of preparation while in this study it was 1274 N. The results are converged for the zirconia crowns (1505 N) whereas in this study (1676 N).[11]

The results of these tests also showed that there are differences of statistical significances between the flat and the anatomical preparations of the zirconia core, with lateral forces applied, regarding the fracture resistance strength average of the group prepared flatly (1556 Newton) which was much higher than the fracture resistance strength average of the group prepared anatomically (1556-882 N).

CONCLUSION

- There are no impacts to the differences in preparing the grinding surface of back teeth (flat-anatomical) on the fracture resistance of the ceramic-metallic and zirconia full crowns when applying vertical forces.

- There are no impacts to the differences in preparing the occlusal surface of back teeth (flat-anatomical) on the fracture resistance of the ceramic-metallic full crowns when applying lateral forces (at a 45 degree angle.)

- There are impacts to the differences in preparing the occlusal surface of back teeth (flat anatomical) on the fracture resistance of the zirconia full crowns when applying lateral forces (at a 45 degree angle.)

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TABLES AND FIGURES:

Figure 1 some natural mandibular molars with close sizes

Figure 2 Molar was prepared Anatomicaly

Figure 3 Molar was prepared Flatly

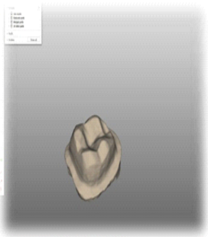
 Digital three-dimensional image of a molar A	 Core design anatomically A	 metallic core A	 zirconia core A
 Digital three-dimensional image of a molar F	 core design flatly F	 Metal core F	 zirconia core F

Figure 4 illustrates the stages of the design and manufacture of metallic-zirconia cores (for flat and anatomical) with a thickness of 0.5 mm via the CAD / CAM device.

 The production of the final wax designed through CAD / CAM	 Impression of the crown by the additional silicon rubber	 Guide cut in mesial distal direction
 applying silicon guide on the tooth	 Applying the silicon guide after putting the core	 The use of silicon guide through the stages of porcelain firing

Figure 5 shows the production of the silicon guide of the final crown and its usage in the stages of firing procelain.

Figure 6 Final crown

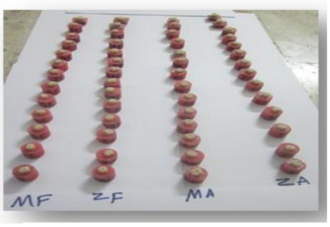


Figure 7 All

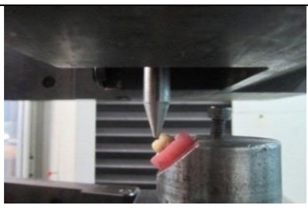
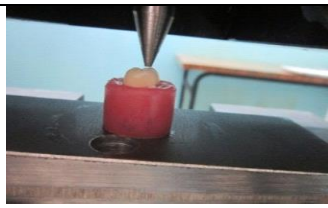
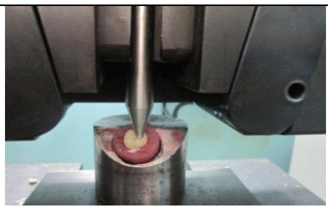
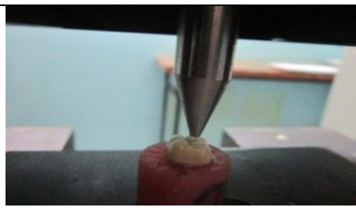
	
 The application of force on Inclined distobuccal cusp with a 45 degree angle	 The application of force parallel to the longitudinal axis of the tooth on the top of distobuccal cusp

Figure 8 shows the Mechanical Tests Device utilized during the application of forces (lateral and vertical) on the samples with its supplement .

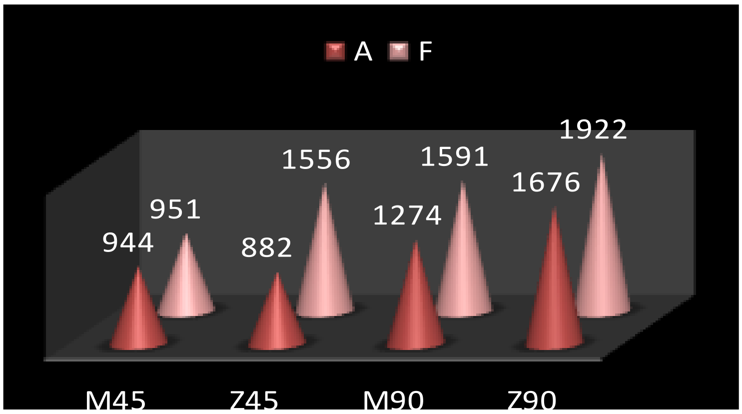


Figure 9 shows the results of the comparative between tow shapes of preparation(A-Anatomical. F- Flatly)

Table 1 illustrates the sample division according to the preparation of the occlusal surface and the type of the crown

The total number	The sample division according to the preparation of the occlusal surface	The sample division according to the type of the crown
56 Molars	**28 A (Anatomical)**	**14 AM (Anatomical- Metal)**
		14 AZ (Anatomical- Zirconia)
	28 F (Flat)	**14 FM (Flat- Metal)**
		14 FZ(Flat- Zirconia)

Table 2 shows the distribution of the sample and place, speed and direction of force application

Position of force application	Crowns and preparation type	Groups	Speed of force application	Angle of force application
Inclined distobuccal cusp	AM	G1(1-7)	0,5mm/min	45^0
	AZ	G2(8-14)		
	FM	G3(15-21)		
	FZ	G4(22-28)		
The top of distobuccal cusp	AM	G5(29-35)		90^0
	AZ	G6(36-42)		
	FM	G7(43-49)		
	FZ	G8(50-56)		

Table (3) shows the results of comparison between anatomical and flat preparation with mean difference, t test results and P value

	Mean	SD	Mean difference	t-test	p-value
G1 AM 45	944.43	±274.97	6.57	0.052	0.959
G3 FM 45	951	±190.71			
G2 AZ 45	882.86	±210.69	674	4.82	0*
G4 FZ 45	1556.86	±303.78			
G5 AM 90	1274	±224.55	317.71	2.13	0.055n.s
G 7 FM 90	1591.71	±325.27			
G6 AZ 90	1676.14	±279.76	246.57	1.79	0.099n.s
G8 FZ 90	1922.71	±233.53			