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Evaluation of the Effectiveness of Fracture Repairing of the Ceramic-Metal and Zirconia Prostheses by the Direct Method (In Vitro Study)

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KEYWORDS

fracture repairing, zirconia, metal ceramic, direct method, porcelain fused to metal PFM, porcelain fused to zirconium PFZ, Nanohybrid Composite , Clearfil , Universal Ceramic Primer.

ABSTRACT:

Introduction: Metal-ceramic and zirconia restorations are among the most common and widely used in dentistry due to their durability, aesthetics, and other advantages. However, a recurring issue has emerged: the feldspathic porcelain covering these restorations is prone to fracture at very similar rates, as shown in previous research Therefore, it became necessary to seek a solution to this common problem and to develop an effective method that can be relied upon and followed as a standardized protocol for both types of restorations when facing such fractures in dental clinics. Especially since these fracture cases are often urgent and require a quick and direct solution. This is where the idea for the research originated.

Objectives: to compare the effectiveness of the direct method in repairing fractures of porcelain fused to metal (PFM) and porcelain fused to zirconia (PFZ) restorations using nanohybrid composite and universal ceramic primer by studying shear bond strength.

Materials and methods:The research sample consisted of 40 samples in the form of parallelepipeds with dimensions (10x10x3mm). 20 of them were made of metal with a thickness of 1mm, and the other 20 were made of zirconia with a thickness of 1mm. Feldspathic porcelain was applied over all samples with a thickness of 2mm They were then divided into four groups: Group A: 10 fractured metal-ceramic samples with mixed fracture,Group B:10 intact metal-ceramic samples (control group),Group C: 10 fractured zirconia-ceramic samples with mixed fracture, Group D: 10 intact zirconia-ceramic samples (control group) . A standardized method was used for surface treatment of both types of prostheses mentioned above, which is a (mechanical-chemical) method ,then nanohybrid composite resin applied. The samples were then placed in an incubator at 37°C for 48 hours. shear strength test was performed using a Universal Testing Machine.

Results: There were no statistically significant differences between the fractured metal-ceramic samples that were repaired using the direct method group(A) and the fractured zirconia-ceramic samples that were repaired using the direct method group (C), the average shear bond strength for the first group was 36.17MPa, while it was 40.04MPa for the second group .The most common failure pattern in group (A) was cohesive failure, while in group (C) it was adhesive failure.

Conclusions:The direct method of repairing fractured metal-ceramic and zirconia-ceramic prostheses can be considered effective for both types of prostheses.in addition, the technique of mechanical-chemical dual surface conditioning is an ideal method that has achieved a high shear bond strength results in the contex of direct repair , A unified and effective repair strategy or protocol has been developed that can be adopted for both types of restorations , and this is a good thing that saves time, effort, and money.

Introduction

Fixed dental prostheses of various types are used to provide both functional and aesthetic aspects. Many materials have been developed to compensate for lost dental tissues over time [1]. Metal porcelain prostheses are the most commonly used in the field of prosthetic dentistry, despite the development of full ceramic prostheses due to their high mechanical properties, clinically acceptable aesthetics, and low cost. However, some defects and disadvantages have appeared during their use, such as the susceptibility to cracking and breaking in the porcelain mass and the exposure of the interface between the metal and the prosthesis to detachment. These failure cases have been reported in fixed prostheses through studies at a rate of 2.3-8% [2]. Other disadvantages of metal porcelain prostheses have also appeared, such as sensitivity, cyanosis of the gums, and low transparency of these prostheses compared to natural teeth, which made it difficult to simulate the color of natural teeth [3].As a result of these negatives, full ceramic restorations were resorted to, including zirconia restorations, as zirconia has become a preferred material for multiple uses in dentistry at the present time due to its high hardness, resistance to pressure, corrosion, and abrasion, and its biocompatibility and good transparency and aesthetics [4]. But even though it is a solid material , cases of fragmentation and fractures have been observed in its restorations, especially within the covering porcelain layer, as some studies have indicated, and its percentage reached about 6.25% of cases [5]. Fractures of metal and zirconia prostheses can be classified into: simple (involving only the porcelain body), mixed (involving exposure of the porcelain with access to the metal or zirconia structure underneath, leading to its exposure) and complex (involving significant exposure of the metal or zirconia structure) [6,7]. Generally, these fractures occur as a result of exposure of dental materials inside the mouth to many factors such as chewing forces, occlusal trauma, thermal changes in saliva and changes in pH [8]. These fractures vary between what is repairable within the mouth or what is not repairable and it may be desirable to repair the broken fixed restoration rather than removing it which may lead to the complete destruction of the restoration or damage to the supporting teeth. Although some of these fractures do not necessarily mean a significant failure, they remain a disturbing clinical problem for the patient, and the process of replacing these broken prostheses is expensive and takes a long time, causing confusion for both the patient and the dentist [9].

Therefore, it was considered to use different techniques to repair these prostheses as an alternative to re-making them in possible cases or removing them to try to repair them outside the mouth and what may result from that.Hence, it was necessary to choose the direct intraoral repair technique and test its effectiveness to determine its efficiency and the feasibility of using it and relying on it as an effective solution that can be resorted to in the event of facing this problem,Intraoral repair systems for fracture repair depend on the use of composites with suitable color and high mechanical and aesthetic properties. Nanohybrid composite is the most common and widely used in repairing these Ceramic fractures, due to its previous properties and low material cost compared to removing the prosthesis and repairing it outside the mouth in the laboratory or remaking a new prosthesis [10] . Previously, resin materials relied on microscopic mechanical fixation for their bonding with alloys and metallic oxides. This was achieved by the penetration of adhesives into micro-retentive grooves created by etching or any method of mechanical surface roughening. Subsequently, surface primers emerged, which contain monomers capable of forming a chemical bond with the surfaces of different metal composites.

These monomers were called adhesive monomers, and some refer to them as functional monomers [11]. Adhesive (functional) monomers either contain a sulfur group that chemically bonds with precious alloys

,Or contain an acidic group that chemically bonds with non-precious alloys, as well as chemically bonds with zirconia, various types of ceramics, and dental tissues. An example is 10-Methacryloxydecyl dihydrogen phosphate (10-MDP) & 4- methacryloxy ethoxycarbonyl phthalic anhydride(4-META).

Currently, new types of metal primers contain both types of functional monomers in one package. Studies have shown that the combination of sulfur-containing monomers and acidic monomers in a single metal primer allows resin cement and composite resin to bond more effectively with both precious and non-precious metal alloys at the same time [12,13]. Thus the same metal conditioner can be used for different types of precious and non-precious metal alloys, and is called a dual-function primer [14] . As for what is called the multi-purpose primer, Single-bottle, also known as the universal primer, it is a primer that contains a triple combination of a silane coupling agent, an acidic adhesive monomers, and a sulfur-containing monomers [15]. Clearfil ceramic primer plus system has recently been introduced as a universal primer to ensure a strong bond between composite resin and various types of dental prostheses in the context of direct repair of intraoral fractures. However, studies on its effectiveness and role in this context are still limited, hence the importance of the current study .

Materials and Methods

Research Desig

A comparative laboratory study to evaluate the effectiveness of repairing fractures in two types of dental restorations (metal-ceramic and zirconia-ceramic) using the direct method after standardizing the mechanical and chemical treatment of the surface of those restorations using nanohybrid composite resin for the repair.The study was conducted in the Department of Fixed Prosthodontics at the Faculty of Dentistry, Tishreen University, with the assistance of the Faculty of Mechanical and Electrical Engineering and the Faculty of Sciences at Tishreen University.

Research sample:

The research sample consisted of 40 samples in the form of parallelepipeds with dimensions (10x10x3mm). 20 of them were made of metal with a thickness of 1mm, and the other 20 were made of zirconia with a thickness of 1mm. Feldspathic porcelain was applied over all samples with a thickness of 2mm They were then distributed into four groups as follows:

Group A: Included 10 metal samples with porcelain applied to only half of their surface and considered as fractured metal-ceramic samples with mixed fracture.

Group B: Included 10 metal samples with porcelain applied to their entire surface and considered as intact metal-ceramic samples (control group).

Group C: Included 10 zirconia samples with porcelain applied to only half of their surface and considered as fractured zirconia-ceramic samples with mixed fracture.

Group D: Included 10 zirconia samples with porcelain applied to their entire surface and considered as intact zirconia-ceramic samples (control group).

(Note: Mixed fractures refer to fractures that occur within the feldspathic porcelain layer, reaching the underlying metal or zirconia structure, leading to its exposure.)

Sample Design:

First: The Intact samples (control groups):

a. Intact metal-ceramic samples : The samples were designed in the form of metal parallelepipeds with dimensions (10x10x3mm). 10 samples were made using a nickel-chromium alloy through Metal Laser Sintering with a thickness of 1mm. The surface was then treated with aluminum oxide sandblasting and covered with an opaque layer of VITA VMK Master OPAQUE from Germany. Feldspathic porcelain with a thickness of 2mm of EX-3 Super Porcelain from Kuraray Noritake Japan was then applied over the entire surface, resulting in a total thickness of the metal-ceramic sample of 3mm.

b. Intact zirconia-ceramic samples : The samples were designed in the form of zirconia parallelepipeds with dimensions (10x10x3mm). 10 samples were made of HT PLUS zirconia from Bloomden, designed using CAD/CAM with a thickness of 1mm. The surface was then treated with aluminum oxide sandblasting and feldspathic porcelain with a thickness of 2mm of CERABIEN ZR Ceramic from Kuraray Noritake Japan was applied over the entire surface, resulting in a total thickness of the zirconia-ceramic sample of 3mm.

Second: Fractured samples (experimental groups)

(The fracture pattern in the research samples was standardized by imitating the mixed fracture shape, as it is the most common and frequently encountered in clinical cases.)

c. Fractured metal-ceramic samples: The samples were designed in the form of metal parallelepipeds with dimensions (10x10x3mm). 10 samples were made using a nickel-chromium alloy through Metal Laser Sintering with a thickness of 1mm, their surface was

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treated with aluminum oxide sandblasting, and feldspathic porcelain was then applied over it according to the previous procedure, covering only half of the sample's surface. This represents the mixed fracture shape of the porcelain, with the metal exposed underneath it, to be repaired using nanohybrid composite as will be described later.

D. Fractured Zirconia Ceramic Samples:

The samples were designed in the shape of a zirconia rectangular parallelepiped with dimensions of (10x10x3mm) and consisted of 10 samples using the HT PLUS type of ultra-translucent zirconia from Bloomden. The design was executed using CAD/CAM technology with a thickness of (1mm), its surface was treated with sandblasting using aluminum oxide grains. The feldspathic ceramic was then applied over it as previously described, covering only half of the sample surface to represent a mixed fracture of the porcelain , with the zirconia exposed underneath to be repaired using nanohybrid composite as mentioned later.

Steps and Procedures:

First: The groups of Intact Samples:

After designing and manufacturing the intact ceramic-metallic and ceramic-zirconia samples in the laboratory, they were placed in a thermal incubator at 37°C for 48 hours. They were then cast into acrylic bases, trimmed, and numbered for each sample in the four groups from 1 to 10. See Figures (1) and (2).

Figure (1) The intact ceramic-metal samples after being cast in acrylic bases, trimmed, and numbered .

Figure (2) The intact zirconia ceramic samples after being cast in acrylic bases, trimmed, and numbered .

Secondly: The group of broken ceramic-metal samples which has been repaired by the direct method : The following steps were followed in the repair process:

The sample was rinsed with running water for a full minute and then dried with oil-free dry air for two minutes. The fracture site of both the exposed metal and the feldspathic porcelain-covered surface involved in the fracture was sandblasted using an intraoral sandblaster with 50-micron aluminum oxide particles under a pressure of 4 bar for 15 seconds, with the distance between the sandblaster tip and the fracture surface being 3 mm. Then, the residues of sandblasting were rinsed off the sample surface with running water for 30 seconds. The surface was then cleaned using ultrasonic waves for two minutes and then dried with dry air for a full minute. A 37% phosphoric acid etching agent was applied to the fracture site on both the metal and the porcelain involved in the fracture for only 5 seconds to remove contaminants, followed by thorough rinsing and drying of the sample for a minute. A first layer of the ceramic primer Clearfil Ceramic Primer Plus was applied to both the exposed metal surface and the fracture line within the porcelain layer using a brush, and then the sample surface was dried with oil-free dry air. A second layer was applied, followed by a third layer of the ceramic primer Clearfil Ceramic Primer Plus, according to the study by(Klisiri A & Maneenacarith et al. 2022), using the same method A layer of light-curing opaque Empress Direct Opaque was applied to cover the color of the metal with a thickness of 0.5 mm and then cured with a light-curing device for 40 seconds. A first layer of Tetric N-Ceram Nanohybrid Composite Color B2 Dentin was

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applied with a thickness of 0.5 mm and cured with a light-curing device for 40 seconds. A second layer of Tetric N-ceram Nanohybrid Composite Color A1 was applied with a thickness of 0.5 mm, cured for 40 seconds, and then a third and final layer, also with a thickness of 0.5 mm, was applied and cured for 40 seconds. Thus, the total thickness of the applied composite is 2 mm, equal to the thickness of the adjacent porcelain covering layer. Then, the repair composite was finished and polished using appropriate burs and tools.

Figure(3) shows the materials used in the direct repair in our research

Thirdly: The group of broken zirconia ceramic samples which has been repaired by the direct method :

The same steps were followed as previously mentioned, but without applying the light-cure opaque, Because zirconium is white in color and does not need to be covered as is t he case with dull metal restorations, the Opaque layer was replaced with a layer of nanohybrid composite to achieve a total thickness of 2 mm, as previously mentioned,

After that, all the samples repaired with nanohybrid composite were placed in a thermal incubator at 37°C for 48 hours, then cast in acrylic bases for shear testing.

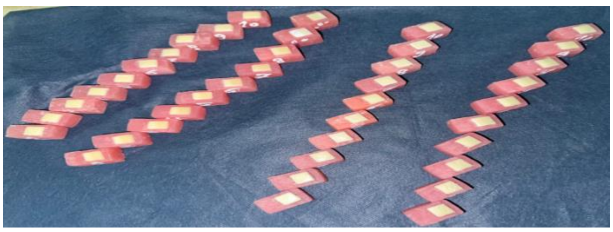

Figure (4) shows the four research sample groups after being cast in acrylic bases for shear testing .

Mechanical Experiments

All samples were subjected to shear strength testing using the Universal Testing Machine (UTM) available at the Faculty of Mechanical and Electrical Engineering at Tishreen University. The tests were conducted using a wedge-shaped head (knife edge) with a thickness of 1 mm and a width of 8 mm made of steel. The force was applied parallel to the bonding surface in all samples at a speed of 0.5 mm/min. The force application continued until failure, which was identified by a fracture on the surface of the sample. The device was then stopped, and the digital value of shear strength in megapascals was recorded, calculated using the following equation: **Shear Bond Strength (SBS) = Applied Force (N) / Surface Area (mm²)**

Figure (5): Application of Shear Force Parallel to the Interface Surface.

Examination of Failure Patterns under the Microscope:-

After conducting the shear test on all intact samples and repaired broken samples, each sample was examined individually at the College of Science, Tishreen University, using the Euromex Stereomicroscope HOLLAND with X20 magnification to determine the failure pattern, which can be classified into three types:**(A) Cohesive Failure:** This refers to breakage or fragmentation within the repair composite layer or within the covering porcelain layer without exposure of the underlying surface, it occurs within a single surface.**(B) Adhesive Failure:** This refers to the breakage or separation of the repair composite or the covering porcelain from the underlying surface, leading to its exposure, it occurs between two surfaces **(C) Mixed Failure:** This involves both cohesive and adhesive failures within the same sample.

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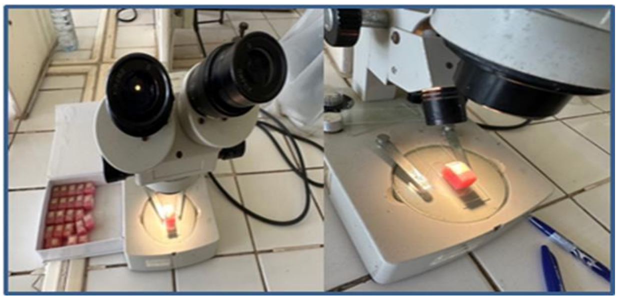

Figure (6): Examination of Failure Patterns for All Samples Using Euromex Stereomicroscope HOLLAND

Statistical Analysis:

The Statistical Study of the Research Samples:

Description of the Sample:

The research sample consisted of 40 ceramic samples in the shape of rectangular parallelepipeds with dimensions of 10 × 10 × 3 mm. They were divided into four equal groups according to the type of ceramic and fracture repair (A: 10 metal-ceramic samples repaired by the direct method, B: 10 intact metal-ceramic samples, C: 10 zirconia-ceramic samples repaired by the direct method, D: 10 intact zirconia-ceramic samples)

:Studying the amount of shear bond strength (in Megapascals) in the research sample 1-

❖ Studying the effect of the type of sample on the amount of shear bond strength in the research sample: A one-way Analysis of Variance (ANOVA) test was conducted to study the significance of differences in the mean shear bond strength (SBS) (in megapascals) between the four studied porcelain types in the research sample as follows in table No.(1) :

Table (1)

The variable being studied = The value of shear bond strength in(MPA)				
Type of the samples	**The number of samples**	**Arithmetic mean**	**minimum**	**maximum**
Fractured Metal-ceramic samples repaired using the direct method.	10	36.17	25.6	45.5
Intact metal-ceramic samples	10	51.16	43.9	67.9
Fractured Zirconia ceramic samples repaired using the direct method.	10	40.04	32.2	52.7
Intact zirconia ceramic samples	10	55.47	45.7	68.5

Results of the One-Way Analysis of Variance (ANOVA) Test:

The results of the one-way ANOVA test to study the significance of differences in the mean shear bond strength (in megapascals) between the four studied porcelain types in the research sample show that at a 95% confidence level, there are statistically significant differences in the mean shear bond strength (in MPA) between at least two of the four studied groups. To determine which of the groups differ significantly from the others in the values of shear bond strength (in MPA), a pairwise comparison was conducted using the Bonferroni method for pairwise comparison of shear force resistance values between the studied porcelain groups in the research sample. From the Bonferroni pairwise comparison, we found that at the 95% confidence level, there are statistically significant pairwise differences in the values of shear bond

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strength (in Megapascals) between the studied porcelain groups mentioned in the research sample. By studying the algebraic sign of the differences between the means, we conclude that:

1- The values of shear bond strength (in Mpa) in both the group of metal- ceramic samples repaired by the direct method and the group of zirconia- ceramic samples repaired by the direct method were smaller than those in both the group of intact metal ceramic samples and the group of intact zirconia ceramic samples separately.
2-There were no statistically significant pairwise differences in the values of shear bond strength (in Mpa) between the group of metal- ceramic samples repaired by the direct method and the group of zirconia- ceramic samples repaired by the direct method.
3- There were no statistically significant pairwise differences in the values of shear bond strength (in Mpa) between the group of intact metal ceramic samples and the group of intact zirconia ceramic samples in the research sample.

❖ **Study on the Failure Pattern in the Research Sample:**

Results of the investigation of the failure pattern in the research sample according to the studied samples type: Table No. (2) shows the results of the investigation of the failure pattern in the research sample according to the studied samples type

Table (2):

Type of samples studied	Number of the samples				percentage			
	Cohesive Failure	**Adhesive Failure**	**Mixed Failure**	**Total**	**Cohesive Failure**	**Adhesive Failure**	**Mixed Failure**	**Total**
Fractured Metal-ceramic samples repaired using the direct method	9	1	0	10	90%	10%	0%	100
Intact metal-ceramic samples	7	1	2	10	70%	10%	20%	100
Fractured Zirconia ceramic samples repaired using the direct method	3	6	1	10	30%	60%	10%	100
Intact zirconia ceramic samples.	7	1	2	10	70%	10%	20%	100
Full research sample	26	9	5	10	65%	22.5%	12.5%	100

❖ Study on the Effect of the Studied sample Type on the Frequencies of the Failure Pattern in the Research Sample:

A Chi-square test was conducted to study the significance of pairwise differences in the frequencies of the failure pattern between the four studied samples groups in the research sample.it was found that: At the 95% confidence level, there were statistically significant pairwise differences in the frequencies of the failure pattern between the group of fractured metal ceramic samples repaired by the direct method and the group of fractured zirconia ceramic samples repaired by the direct method in the research sample . By studying the table of frequencies and percentages, it was found that the rate of the samples that experienced Cohesive failure in the group of fractured metal ceramic samples repaired by the direct method was higher than that in the group of fractured zirconia ceramic samples repaired by the direct method .Also the rate of the samples that experienced Adhesive failure in the group of fractured zirconia ceramic samples repaired by the direct method was higher than that in the group of fractured metal ceramic samples repaired by the direct method in the research sample .

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❖ Study on the Relationship Between the Failure Pattern and Shear bond strength Values (in MPA) in the Research Sample:

A one-way Analysis of Variance (ANOVA) test was conducted to study the significance of differences in the mean shear bond strength (in Mpa) between the three studied failure pattern groups: (cohesive failure, Adhesive failure, and mixed failure) in the research sample as follows in table no.3 :

Table (3):

The variable being studied = The value of shear bond strength in (MPA)				
Failure pattern	**number of ceramic samples**	**Arithmetic mean**	**minimum**	**maximum**
Cohesive failure	26	46.15	25.6	68.5
Adhesive failure	9	41.38	34.5	54.7
mixed failure	5	51.20	43.9	67.9

The results of the one-way Analysis of Variance (ANOVA) test indicate that at the 95% confidence level, there were no statistically significant differences in the mean shear bond strength (in megapascals) between the three studied failure pattern groups (cohesive failure, Adhesive failure, mixed failure) in the research sample .

Discussion:

Despite the recent developments in dental prosthetics, fractures of ceramic prosthetics, especially metal ceramic and zirconia ceramic , are among the most common problems facing dentists, despite the development in the techniques and materials used and the resulting functional, aesthetic and health problems that affect patients [7]. These cases pose a challenge to the dentist because the process of removing and replacing the prosthesis is not easy, in addition to the time and potential financial cost, and the possibility of the fracture and fragmentation extending within the prosthesis during the attempt to remove it or causing damage to the supporting teeth. Also, the deformation of the porcelain resulting from repeated baking makes the option of repair outside the mouth undesirable [16]. The direct repair of broken ceramic prostheses aims to re-establish the function and aesthetics of the prosthesis using various intraoral repair systems. In order for the repair to cope with and withstand the required functional loads, the bond between the repair material and the remaining restoration must be strong and durable. The refraction rate of metal-ceramic and zirconium-ceramic prostheses according to previous studies was (2.3-8%) and (6.25%) respectively [2][5]. Most previous studies have examined the repair of each of these prostheses separately by testing different surface treatments, bonding materials, primers, and composite resins of various types and compositions, and comparing these strategies for the repair of a single type of prosthesis. Therefore, this research was conceived differently from previous studies, by comparing both the most common types of broken metal-ceramic and zirconia-ceramic prostheses. This research used a unified repair strategy, treating the surfaces of these prostheses mechanically and chemically by sanding with aluminum oxide granules and using bonding agents and newly marketed universal ceramic primers. These primers are suitable for all types of dental prostheses with various compositions, while also using the same repair material, nanohybrid composite resin, due to its superior mechanical and esthetic properties and its ability to replace the missing ceramic component in

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these prostheses. The success of this strategy will make it easier and faster for the clinician to repair and manage this problem, rather than having to use different strategies and materials for each type of prosthesis separately. Shear strength testing was performed on both broken ceramic-metal and zirconia ceramic specimens, and the results were compared within and between specimens to evaluate the effectiveness of this standardized repair strategy. The failure mode of the specimens was also examined to evaluate the bond quality.

Two surface preparation methods were used for both types of restorations: mechanical and chemical preparation combined to improve the bond quality of the restoration material to the fractured surface. Mechanical preparation was performed by air-sandblasting 50 micron aluminum oxide particles using an intraoral sandblaster to roughen the surfaces of the metal, zirconia, and overlying porcelain under 4 bar pressure for 15 seconds to form microscopic depressions suitable for mechanical bonding. This method is suitable for both types of restorations used in this study, especially since the metal and zirconia are resistant to etching by hydrofluoric acid . Chemical preparation of the surfaces of the research samples was done using KLEARFIL CERAMIC PRIMER PLUS as a surface preparation material for the metal, zirconia and the feldspatic porcelain covering them at the fracture line . In previous studies, a metal primer (ALLOY PRIMER) was used for chemical preparation of metals and a ceramic primer (CERAMIC PRIMER) for ceramics. In this research, a single primer was used in a single package that is suitable for all types of restorations regardless of their type and composition, which saves time and cost for both the doctor and the patient, and eliminates the need to use hydrofluoric acid (HF) to treat the surface of glass-based porcelain such as the feldspar porcelain covering

A pilot study was conducted on the sidelines of the research to determine the necessity of using the bond or not with the repair system used in this research. The results of the study showed that there were no statistically significant differences between its use or not with the repair system used in this research. This saves time, effort and errors committed with multiple work stages and the resulting negative impact on the work in many cases. Thus, the survey study confirmed the manufacturer's claims [17] . Three coats of comprehensive primer were applied instead of one coat to both types of samples in this study, based on the study by Klisiri A & Maneenacarith et al. [18] ,The results of this study showed that applying three coats of primer containing MDP significantly increased the bond strength of the composite to the zirconia compared to applying one coat. Therefore, this result was utilized and used in the current study . Tetric Nceram NanoHybrid Composite resin has been used in direct fracture repair due to its mechanical and cosmetic properties. It has excellent softness, aesthetics, excellent finish, and the ability to maintain anatomical details and a smooth, glossy surface for a long period of time. It has been widely used on anterior teeth. In contrast, its good mechanical properties and high wear resistance make it also suitable for use on posterior teeth, whether as a restorative filling or repairing broken ceramic prostheses [19] . The samples were placed and stored in water at a temperature of 37°C in a thermal incubator in an attempt to cope with the presence of the prosthesis inside the mouth and its exposure to moisture and the resulting effect on the properties and resistance to shear forces. Then, these samples were placed in acrylic bases with dimensions of (1.7 X 2.5 cm) to fit the metal base on which the samples will be fixed on the general mechanical testing device to conduct the shear force resistance test. After conducting a shear strength test using a Universal mechanical testing machine and applying force to the bonding surface of the samples using a wedge head (knife-edge shape), it was observed that there were no statistically significant differences between the two groups of broken ceramic-metal and zirconia samples that were repaired by the direct method in their resistance to shear forces. The average shear strength in the first group was 36.17 MPA and in the second group was 40.04 MPA, recording a slightly higher value, meaning that the direct method was effective and gave good values for both types of restorations. The comprehensive ceramic primer used, which contained the adhesive monomer 10-MDP and the silane bonding agent simultaneously, contributed to enhancing the bonding strength of the resin with both ceramic-metal and zirconia restorations in a good and similar manner. These results are consistent with the results of the studies of Tang L et al. & Yadav J et al [20] , where they found that the direct method of repairing ceramic-metal samples was effective with different types of fractures (simple , mixed , and complex) and was stronger and more capable of repairing mixed fractures by observing the shear strength values in those samples. This study also agreed with Mahdi R et al [21], who found that the simultaneous use of mechanical and chemical methods to prepare the surface of ceramic-metal samples and the use of chemical primers containing functional monomers significantly increased the bond strength and Akrami S et al [22] , who found that the method of air roughening with aluminum oxide granules on the surface of zirconium samples before repair is a suitable and effective method as it gave high shear strength values . Higher shear strength values were observed for the broken zirconia ceramic specimens repaired by the direct method. This may be due to the comprehensive ceramic primer containing the functionalized 10-MDP monomer, where the phosphate group at one end contributes to chemical bonding with the zirconia and the polymerizable methacrylate group at the other end contributes to bonding with the resin [23]. When this was coupled with sanding with aluminum oxide particles, the zirconia oxide layer and surface wettability were increased, resulting in the ability of the phosphate monomer to form chemical bonds with the oxide on the zirconia surface[24,25]. Comparing the shear strength values of the samples repaired directly with similar studies, the values in this study ranged between 36-40 MPA, which is significantly higher than the values in other studies, which ranged between 25-30 MPA [20]. This is most likely due to the application of three layers of primer instead of one layer, as it provided a higher bond strength than previous studies. Based on the research of Klisiri A & Maneenacarith et al, they demonstrated that applying three layers of primer containing 10-MDP significantly increased the bond strength of composite to zirconia compared to applying one layer, two layers, four layers and five layers as well [18]. No significant differences were observed in the shear strength values of the intact metal-ceramic and intact zirconia-ceramic control samples, indicating the strong bonding of the ceramic used with both the metal and zirconia structures. Thus, the results of this study are consistent with those of Abrisham SM et al & Jalalian E et al [26,27] , who studied the shear bond strength values (SBS) between intact metal-ceramic and zirconia-ceramic restorations and found no significant differences between them. As for the failure pattern in the research samples, whether the broken ceramic-metal samples that were repaired by the direct method, as well as the intact ceramic-metal samples (the control group), the most common pattern was cohesive failure, meaning that the failure occurred within only one surface, which is the ceramic surface in the intact samples and the composite surface in the broken samples that were repaired without exposing the metal underneath, which indicates the strength of the composite's bond to the surface underneath, and that the surface preparation method (mechanical-chemical) used in this study increased the bond strength to the prosthetic surface and was similar to the failure pattern in the intact samples. In the fractured zirconia ceramic samples that were repaired by the direct method, the most common failure pattern was adhesive failure. In the intact zirconia ceramic samples (control group), the most common pattern was cohesive failure. That is, in the majority of the fractured zirconia ceramic samples, failure occurred between two surfaces: the composite surface and the zirconia surface underneath, which means that there is some form of incompatibility or incomplete integration between the repair composite and the zirconia surface. This type of adhesive failure may be due to the difficulty of roughening the zirconia surface and creating ideal microscopic grooves due to the high hardness of the zirconia surface .

Conclusions:

- The use of Tetric N Ceram Nanohybrid Composite and the universal ceramic primer Clearfil Ceramic Primer Plus contributed to the effective and acceptable direct repair of fractures in metal-ceramic and zirconia restorations.

- The dual surface preparation technique, both mechanical (sandblasting with 50-micron aluminum oxide particles) and chemical (application of a universal ceramic primer) is an ideal method that achieved satisfactory bond strength results for metal – ceramic and zirconia restorations .

- The most common failure pattern in the group of fractured metal -ceramic specimens repaired by the direct method was cohesive failure, and in the group of

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fractured zirconia-ceramic specimens repaired by the direct method, it was adhesive failure.

- A unified and effective repair strategy or protocol has been developed that can be adopted for both types of prostheses in the context of direct repair. This is a good thing that saves time, effort and money for both the doctor and the patient .

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