A COMPARATIVE STUDY TO EVALUATE THE EFFECTS OF TWO DIFFERENT MANUFACTURING TECHNIQUES ON THE FRACTURE STRENGTH OF LITHIUM DISILICATE CRYSTALS-REINFORCED GLASS CERAMIC CROWNS (IN VITRO STUDY)

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ABSTRACT

Aim: the aim of the study is to evaluate the effects of manufacturing techniqhes (ips press ,ips cad) on the fracture strength of ceramic crowns made by lithium disilicate crystal_reinforced glass ceramic

Materials and Methods: The research sample consisted of 28 upper first premolar free from caries and fissures, with similar sizes, all of them were preserved with physiological serum at a concentration of 0.9% and at room temperature from the moment of extraction, after being properly cleaned. The sample was randomly divided into two main groups. Each of them has 14 premolar, where the first main group received 14 ceramic crowns made of lithium disilicate crystal-reinforced glass ceramic using the heat press technique (ips press), after preparing the teeth of this group according to the academic protocol adopted in preparation for receiving full ceramic crowns, and the second main group received 14 ceramic crowns made of lithium disilicate crystal-reinforced glass ceramic using the Cad/Cam technique (IPS CAD), after preparing the teeth of this group according to the approved academic protocol adopted in preparation for receiving full ceramic crowns, all the crowns were adhesved to their abutments using resin cement according to the academic protocol adopted in Gluting glass ceramic crowns , then we divided each main group into two sub-groups of 7 crowns each, in order to study the effects of vertical forces (90 degrees) on the fracture strength of the crowns belong to the first sub-group and the inclined forces (45 degrees) on the fracture strength of the crowns belong to the second sub-group and This is done by universal testing machine

Results: there are statistically significant difference in the fracture strength between crowns manufactured using the heat press technique and crowns manufactured using cad\cam technique, where the average fracture strength of the crowns manufactured using the press technique was 1816,71 N ,1154,61 N when applying both vertical forces and oblique forces at an angle of 45 degrees respectively, While the average fracture strength of crowns made using CAD\CAM technology was 1944,17 N, 1243,1N when applying both vertical forces and oblique forces at an angle of 45 degrees respectively

Conclusions: The CAD\CAM technology provided a higher fracture strength than the heat press technique in the manufacture of full ceramic crowns made by lithium disilicate crystal_reinforced glass ceramic , and The fracture strength values were higher when applying vertical forces (90 degrees) compared to the oblique forces (45 degrees).

Key words: lithium disilicate, fracture strength ,ips press , ips cad\cam, manufacturing techniqhes

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Introduction:

- Recent efforts and attempts have focused on developing dental prosthodontics materials that help completely avoid metals, satisfying patient's desires for more aesthetic and biologically compatible restorations with the gum (1).
- These efforts have resulted in the development of numerous metal-free ceramic systems, which have gradually evolved to increase hardness, flexural strength, and ensure a good marginal fit, as well as achieving natural tooth-like aesthetics to the greatest extent possible (1).
- Recently, there has been an orientation towards using advanced types of dental ceramics such as lithium disilicate crystals-reinforced glass ceramics and zirconia for both posterior and anterior teeth due to the improved properties of these ceramics, leading to increased resistance to various masticatory forces within the oral cavity and enhanced cosmetic features (2).
- The IPS Empress 2 system has been developed, which is a lithium disilicate-reinforced glass ceramic characterized by higher flexural strength than the IPS Empress 1 system, reaching up to (400+_40) megapascals (3).
- The indications for the IPS Empress 2 system have expanded to include three-unit anterior bridges, even in the canine area (4). The flexural strength of this type of ceramic has increased by increasing its crystalline content by almost 70% and reducing its size. Despite this high crystalline content, the material remains highly translucent due to the low refractive index of lithium disilicate crystals (5).
- In 2005, the IPS Empress 2 system was further developed into what is called IPS e.max by adding some shading oxides such as aluminum oxide and zirconium oxide to produce varying levels of shade, allowing for the fabrication of restorations for discolored and darkened teeth. This type of ceramic is distinguished by its high mechanical and aesthetic properties (6).
- Prosthodontics can be manufactured using this type of glass ceramic in two techniques:

1. Computer-Aided Design and Computer-Aided Manufacturing (CAD-CAM) Technique : IPS e.max CAD.
2. Heat Press Technique : IPS e.max Press (7)(8).

Aim of the study

- the aim of the study is to evaluate the effects of manufacturing techniqhes (ips press ,ips cad) on the fracture strength of ceramic crowns made by lithium disilicate crystal_reinforced glass ceramic

Materials and Methods:

Study Design: invitro ,comparative, randomized study

Study sample: The study sample consisted of 28 recently extracted upper first premolar teeth for orthodontic reasons, which were similar in size. The crown length was set at (8.5±0.5) mm, the buccolingual diameter at (8±0.4) mm, and the mesiodistal diameter at (0.4 5.2±) mm, measured using a Digital Caliper (IOS, USA). The sample was randomly divided into two main groups. The first main group included 14 upper first premolars prepared to receive 14 lithium disilicate crystal_reinforced glass ceramic crowns manufactured using the IPS Press technique. The second main group comprised 14 upper first premolars prepared to receive 14 lithium disilicate glass-ceramic crowns manufactured using the IPS CAD/CAM computer-aided design and technique. Each main group was further divided into two subgroups, each consisting of 7 crowns, to study the effect of vertical forces (90 degrees) on the fracture strength of the crowns in the first subgroup and the effect of oblique forces (45 degrees) on the fracture strength of the crowns in the second subgroup.

Inclusion Criteria:

- Teeth should be free from cavities, cracks, and fractures.
- Teeth should be similar in shape and size.
- Teeth should not have undergone previous endodontic treatment.
- Teeth should have been extracted recently (not more than 3 months ago).
- Teeth should have been stored in a physiological solution since the moment of extraction.

Exclusion Criteria:

- Presence of cavities or cracks in the teeth.
- Presence of previous restorations or fillings on the teeth.
- A long period of time has passed since the extraction, and the teeth were not stored in suitable fluids.

Work Stages:

Teeth Preparation

the teeth were prepared in the sample following the approved academic protocol to receive full ceramic crowns. The tooth reduction of the occlusal surface was 2mm, axial walls were prepared by 1.5mm, the finish line was a rounded

shoulder with a thickness of 1mm, convergence of axial walls at an angle of approximately 4 degrees for each wall, functional cusp bevel by 0.5mm, and all sharp angles were rounded off and preparation completed. (9)
The first tooth was prepared according to the previously mentioned method and was used as a reference for preparing the rest of the teeth using the silicone guide
All teeth in the sample were prepared using the aforementioned method, resulting in 28 uniformly prepared teeth.

Crowns Design (Computer-aided design: CAD)
The prepared teeth were randomly divided into two equal main groups, numbered from 1 to 28, and placed within a silicone rubber mold. Then they were sent to the laboratory to begin the procedures of scanning and computer-aided design (CAD) using the CAD/CAM system. We adopted a uniform design for all the crowns using the exocad software with the following thicknesses: 2mm on the occlusal surface, 1.5mm on the axial walls, and 1mm at the cervical finish line.

Manufacturing of Crowns:
The prepared teeth numbered from 1 to 14 were selected to receive 14 lithium disilicate crystal_reinforced glass ceramic crowns manufactured using the IPS Press technique. First, 14 wax crowns with uniform dimensions matching the previously mentioned design were created using a CAD/CAM wax milling machine. Then, the investment crucible ring was positioned, and the investment powder (IPS Press VEST, Ivoclar Vivadent) was applied. The crucible was put in a heating furnace at 850 degrees Celsius for 30 minutes. Afterward, the ingot (e.max ingot from Ivoclar Vivadent) and the aluminum press were placed in the crucible, and the entire assembly was put into the ceramic press furnace (Programat EP 3010, Ivoclar Vivadent) to complete the injection process according to the manufacturer's instructions.
The investment crucible was left to cool down to room temperature, and the ceramic crowns were separated from the investment powder using a separating disk and then sandblasted with aluminum oxide particles at 4 bars of pressure. After removing the excess material at 2 bars of pressure, the ceramic crowns were immersed in a low-concentration hydrofluoric acid solution (IPS e.max Press Invex Liquid, Ivoclar Vivadent) for a duration of 10-30 minutes. Finally, the crowns were washed with water and air stream.
The rest prepared teeth numbered from 14 to 28, were selected to receive 14 lithium disilicate crystal_reinforced glass ceramic crowns manufactured using the IPS CAD/CAM technique. After the design process, they were milled using a dedicated wet milling machine for e.max blocks (E.max block Ivoclar Vivadent, Liechtenstein) with an Arum 5x-400 lathe (ARUM, South Korea). Once the milling was complete, the crowns were fixed onto a custom tray using IPS Object Fix Putty (Ivoclar Vivadent, Liechtenstein) and then hardened using a ceramic furnace (Programat® P300, Ivoclar Vivadent, Liechtenstein) in two stages without an interval. The first stage was set at 820 degrees Celsius for 2 minutes, followed by 840 degrees Celsius for 7 minutes. Afterward, the crowns were left to cool down to room temperature.
After obtaining crowns manufactured by both techniques, all the sample teeth were poured with cold acrylic above the cementoenamel junction(CEJ) by 2mm.

cementation
All crowns were tested before cementation to verify their internal and marginal fit using a silicone putty material, and no significant adjustments were needed.
All crowns were cemented using dual-cure resin cement, Variolink N (Lot V03436, Ivoclar Vivadent, Liechtenstein).

According to the following steps:
First: Treatment of the inner surfaces of the crowns
1. Initially, the crowns were cleaned and disinfected using alcohol, then rinsed with a water and air stream, followed by air-drying.
2. The inner surface of each crown was then etched with 10% hydrofluoric acid (Ultradent Porcelain Etch, 9%, South Jordan, UT, USA) for 90 seconds. Afterward, the crowns were rinsed with running water for 30 seconds and air-dried for another 30 seconds.
3. Two layers of silane coupling agent (Silane, Ultradent Products, BDJZH, South Jordan, UT, USA) were applied and left for one minute until dry.

Second: Treatment of the prepared abutment surfaces
1. The prepared abutment surfaces were cleaned using fluoride-free prophy paste (Prophylaxis Paste, SS White) and then rinsed with a water and air stream.
2. The abutment surfaces were then etched with 37% phosphoric acid ((Eco-Etch 37%, Ivoclar Vivadent, Liechtenstein) for 15 seconds. Afterward, the abutments were rinsed with

running water for 20 seconds and air-dried for another 20 seconds.

3. A dental bonding agent (Tetric N-Bond Universal, W08416, Ivoclar Vivadent, Liechtenstein) was applied to the prepared surfaces, and a gentle air stream was used to ensure its complete spread on the surface. It was then light-cured for 20 seconds.
4. All crowns were then cemented using dual-cure resin cement (Variolink N, Ivoclar Vivadent, Liechtenstein). The base and catalyst were mixed in a 1:1 ratio, and the cement was applied to the inner surfaces of the crowns. The crowns were then placed on the prepared abutments, and light pressure was applied using finger. Excess cement was removed before curing, and the cement was light-cured using an LED curing light (Hemao Medical, China) from all four sides (buccal, lingual, mesial, and distal) for 45 seconds each side

A picture showing the complete sample after the crowns have been cemented

fracture strength tests

- **Method of Conducting Fracture Strength Tests:**

Fracture strength tests were conducted using a Universal Test Machine located at Tishreen University (Faculty of Electrical and Mechanical Engineering). Special fixtures were prepared to fit the samples, and the tests were performed at a speed of 0.5 mm/min. The machine was connected to a computer to graphically plot the fracture forces. The graphical representation showed the collapse of the plotted line when cracking or fracturing occurred, and the force value decreased. At this point, the machine was stopped, and the digital value of the fracture force in Newtons was recorded.

The forces were applied to the samples parallel to the longitudinal axis of the tooth at a 90-degree angle on the internal slope of the palatal cusp of the upper first premolar, in the middle of the distance between the cusp tip and the central groove. Additionally, the oblique forces were applied at 45-degree angle until the collapse of the plotted line on the computer screen, indicating the moment of cracking or fracturing, and the force value was recorded in Newtons for all individual samples.

Statistical analysis was conducted using the Kolmogorov-Smirnov test, and based on the results, the samples were divided as follows:

The tests were conducted according to the previously mentioned division of the sample:

Group 7-1: Lithium Disilicate Glass-Ceramic crowns manufactured using the heat-pressing technique. Vertical forces were applied to them until fracture occurred.

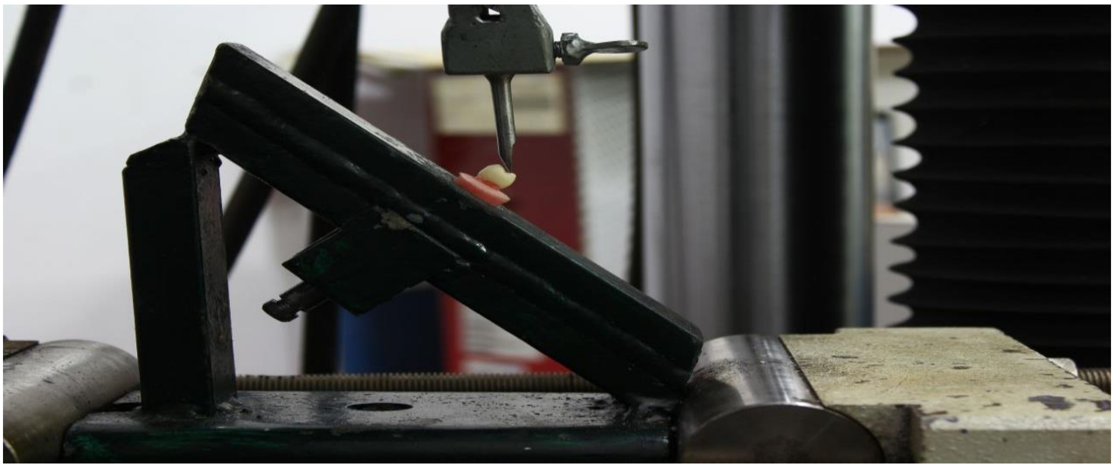
Group 14-8: Lithium Disilicate Glass-Ceramic crowns manufactured using the heat-press technique. Inclined forces at 45-degree angle were applied to them until fracture occurred.

Group 21-15: Lithium Disilicate Glass-Ceramic crowns manufactured using (CAD/CAM) technique. Vertical forces were applied to them until fracture occurred.

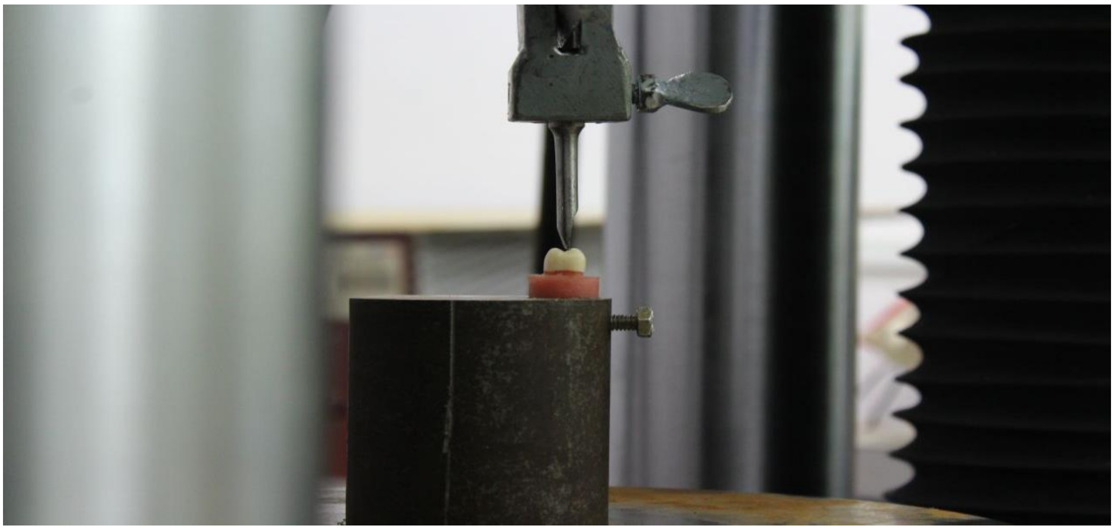
Group 28-22: Lithium Disilicate Glass-Ceramic crowns manufactured using (CAD/CAM) technique. Inclined forces at a 45-degree angle were applied to them until fracture occurred.

Point of Force Application:

the internal slope of the palatal cusp of the upper first premolar, in the middle of the distance between the cusp tip and the central groove.



A picture illustrating the application of inclined forces at a 45-degree angle on a sample using the Universal Test Machine.



A picture illustrating the application of vertical forces at a 90-degree angle on a sample using the Universal Test Machine

Results:
The fracture strength (in Newtons) of each crown among the studied ceramic crowns in the research sample was measured. Then, the effect of the manufacturing technique and the type of applied force on the fracture strength values (in Newtons) was measured. The results of the analysis are as follows:

- ***Study of the effect of the manufacturing technique on the fracture strength in the vertical force application group of the research sample:***

Students T-test conducted on Independent Samples to study the significant differences in fracture strength values (in Newtons) between the group manufactured using the heat press technique (IPS Press) and the group manufactured using IPS CAD technique in the vertical force application group of the research sample as follows:

- ***Descriptive Statistics:***

Table number (1) shows the arithmetic mean, standard deviation, standard error, minimum, and maximum values of the fracture strength (in Newtons) in the vertical force application group of the research sample according to the manufacturing technique used.

The studied variable = Fracture resistance value (in Newtons)							
Type of applied force	The manufacturing technique used	Number of ceramic crowns	arthemetic mean	Standard Deviation	Margin of Error	Minimum	Maximum
Vertical force	(IPS Press)	7	1816.71	47.17	17.83	1748.9	1902.2
	(IPS CAD)	7	1944.17	65.83	24.88	1852.1	2022.2

- **Students T-test for Independent Samples Results:**

Table (2) shows the results of Student T-test conducted on the Independent Samples to study the significant differences in the values of fracture strength (in Newtons) between the IPS Press technique group and the IPS CAD group in the vertical force application group from the research sample.

The studied variable = Fracture strength value (in Newtons)				
Type of applied force	The difference between the .means	The calculated .t-value	The significance .level value	The significance of .the differences
Vertical force	-127.307	-4.164	0.001	There are significant differences

The above table indicates that the significance level is less than 0.05, which means that at a confidence level of 95%, there are statistically significant differences in the values of fracture strength (in Newtons) between the two manufacturing techniques in favor of IPS(CAD/CAM) group in the vertical force application of the research sample.

Study of the effect of the manufacturing technique on the fracture strength values in the group of inclined force application at a 45-degree angle from the research sample:

Student T-test conducted on the Independent Samples to examine the significant differences in the values of fracture strength (in Newtons) between the group using the IPS Press technique and the group using IPS CAD technique in the group of inclined force application at a 45-degree angle from the research sample as follows:

Descriptive statistics

*Table number (3) represents the arithmetic mean of the **fracture strength** value (in Newtons) in a set of inclined force application in a 45-degree angle from the research sample, according to the utilized manufacturing technique.*

The studied variable = Fracture strength value (in Newtons)							
Type of applied force	The manufacturing technique used	Number of ceramic crowns	arithmetic mean	Standard Deviation	Margin of Error	Minimum	Maximum
Oblique force at a 45-degree angle.	IPS Press	7	1154.61	44.62	16.87	1093.3	1203.1
	IPS CAD	7	1243.10	38.86	14.69	1193	1298.4

- **Student's T-test results for independent samples:**

Table number (4) shows the results of the Student's T-test conducted on independent samples to study the significant differences in the values of fracture strength (in Newtons) between the IPS Press technique group and the IPS CAD technique group in the inclined force application at a 45-degree angle from the research sample.

The studied variable = Fracture Strength value (in Newtons)				
Type of applied force	The difference between the .means	The calculated .t-value	The significance .level value	The significance of .the differences
Oblique force at a 45-degree angle	-88.486	-3.956	0.002	There are significant differences

The above table indicates that the significance level is less than 0.05, meaning that at a 95% confidence level, there are statistically significant differences in the values of refractive resistance (in Newtons) between the IPS CAD technique and the IPS Press technique in the inclined force application at a 45-degree angle from the research sample.

Study on the impact of applied force type on the fracture strength in the IPS Press technique group from the research sample:
A Student's T-test was conducted on independent samples to study the significant differences in the values of fracture strength (in Newtons) between the vertical force application group and the inclined force application at a 45-degree angle group in the IPS Press technique from the research sample, as follows:

- **Descriptive Statistics:**

Table number (5) presents the arithmetic mean, standard deviation, standard error, minimum, and maximum values of the fracture strength (in Newtons) in the IPS Press technique group from the research sample, according to the applied force type.

The studied variable = Fracture Strength value (in Newtons)							
The manufacturing technique used	Types of applied force	Number of ceramic crowns	arithmetic mean	Standard Deviation	Margin of Error	Minimum	Maximum
IPS Press	Vertical force	7	1816.71	47.17	17.83	1748.9	1902.2
	Oblique force at a 45-degree angle.	7	1154.61	44.62	16.87	1093.3	1203.1

Results of the Student T-test conducted on the independent samples:
Table number (6) shows the results of the Student T-test that was conducted on the independent samples to study the significant differences in the values of fracture strength (in Newtons) between the vertical force application group and the inclined force application at a 45-degree angle group in the IPS Press Technique from the research sample.

The studied variable = Fracture Strength value (in Newtons)				
The manufacturing technique used	The difference between the means.	The calculated t-value.	The significance level value.	The significance of the differences.
IPS Press	662.100	26.977	0.000	There are significant differences

The above table indicates that the significance level is less than 0.05, meaning that at a 95% confidence level, there are statistically significant differences in the values of refractive resistance (in Newtons) between the two force application groups, favoring the vertical force application group, for the sample manufactured using the IPS Press technique.

Study on the impact of applied force type on the refractive resistance in the IPS CAD Technique group from the research sample:
A Student's T-test was conducted on independent samples to study the significant differences in the values of refractive resistance (in Newtons) between the vertical force application group and the inclined force application at a 45-degree angle group in the IPS CAD technique group from the research sample, as follows:

- **Descriptive Statistics:**

Table number (7) shows the arithmetic mean, standard deviation, standard error, minimum, and maximum values of the refractive fracture strength (in Newtons) in the IPS CAD Technique group from the sample.

The studied variable = Fracture Strength value (in Newtons)							
The manufacturing technique used	Types of applied force	Number of ceramic crowns	arithmetic mean	Standard Deviation	Margin of Error	Minimum	Maximum
IPS Cad	Vertical force	7	1944.17	65.83	24.88	1852.1	2022.2
	Oblique force at a 45-degree angle	7	1243.10	38.86	14.69	1193	1298.4

Results of the independent samples t-test:

Table number (8) presents the results of Student's T-test that was conducted on independent samples to study the significant differences in the values of refractive resistance (in Newtons) between the vertical force application group and the inclined force application at a 45-degree angle group in the IPS CAD technique group from the research

The manufacturing technique used	The difference between the means.	The calculated t-value.	The significance level value.	The significance of the differences.
IPS CAD	701.071	24.264	0.000	There are significant differences

The above table indicates that the significance level is less than 0.05, meaning that at a 95% confidence level, there are statistically significant differences in the values of fracture strength (in Newtons) between the two force application groups, favoring the vertical force application group, for the sample manufactured using the IPS CAD technique.

Discussion:

Methodological Research Discussion:

- In this study, natural human extracted teeth were used instead of artificial teeth models made of metal to simulate the clinical reality. The anatomical and morphological characteristics of natural teeth differ from artificial models. Additionally, the enamel and dentin surfaces are scratchable and bondable, making the bonding process more accurate and clinically realistic compared to using artificial models.
- Full crowns made of lithium disilicate-reinforced glass ceramic were selected for the study due to the various common failure patterns observed in this type of crowns, such as fractures. The effect of the manufacturing technique on their fracture strength was studied after confirming several studies that indicated a relationship between ceramic manufacturing techniques and their mechanical properties and fracture strength (9)(10)(11).
- The upper first premolars were selected as abutments in this study because they are more susceptible to fractures. Salis and colleagues found that 49% of tooth fractures in the upper jaw occur in the first premolars, and more than half of these fractures were fractures in the support cusp (12). Also, crowning the upper first premolars is considered an indication for lithium disilicate-reinforced glass ceramic crowns.
- Teeth were selected to be similar in shape and size, and their preparation standards were standardized to eliminate the influence of these differences on the study results and to reduce possible variations and errors.
- The teeth were extracted and cleaned, then preserved in a saline solution (0.9% sodium chloride) at room temperature until the sample collection was completed. That is because sodium chloride provides a resinous bond to extracted teeth similar to that of non-extracted teeth (13).
- The premolars were fixed in acrylic bases because the elastic modulus of acrylic is similar to the elastic modulus of alveolar bone. The bases were designed to allow fixation on the mechanical testing machine base.
- A tooth-simulating material, such as soft rubber, was not used in this study, and the teeth were directly fixed within the acrylic bases. The decision not to use this material can be justified as some studies did not show differences in results between samples designed with or without a simulated periodontal ligament (14)(15). Additionally, Chia found that the simulated periodontal ligament made of soft rubber around abutment roots exhibited greater

thicknesses than those in clinical reality. Moreover, uneven thicknesses of the simulated rubber ligament can cause uncontrolled movement of the abutments and lead to more errors (16).

- The universal testing machine (IBMU4 series) was used to study the fracture strength of the crowns. Inclined forces at a 45-degree angle were applied to the internal slope of the support cusp (the palatal cusp) until fracture occurred, and vertical forces at a 90-degree angle were also applied to the same area until fracture occurred. This method of applying force was adopted because it is commonly used in many previous studies (17)(18).

As for choosing the 45-degree angle, the reason behind this choice is that applying force at a 45-degree angle is considered less favorable during masticatory function, as this type of force induces the worst stresses on the teeth (19)(20).

Results Discussion:

Discussion of the study's results on the effect of the manufacturing technique used (IPS Press and IPS CAD/CAM) on the fracture resistance in two groups: vertically applied forces and obliquely applied forces.

- The results of this study showed that the forces responsible for failure in both manufacturing techniques (IPS Press and IPS CAD/CAM) were higher than the physiological forces that occur in the oral cavity. The natural masticatory forces in the premolar region range from 222 to 445 Newtons, indicating that both manufacturing techniques can be safely used in patients without parafunctional habits.
- The superior performance of IPS CAD/CAM over IPS Press technique in fracture strength may be attributed to the increased laboratory errors and mechanical properties affected by multiple laboratory procedures involved in IPS Press technique, such as waxing, investing, burnout, casting, and heat pressing, along with the possibility of various errors occurring (e.g., surface roughness due to improper powder mixing or slightly excessive heating during the casting process, fusion-related defects like gas porosities and bubbles, powder inclusions, and voids formed during solidification).

In contrast, the dimensions and overall process in IPS CAD/CAM are controlled and governed by computers, making it simpler, less complex, and less prone to laboratory-related errors.

- Additionally, the glass particles are affected and become rougher during the heat-pressing process, impacting their resistance and mechanical properties. This could result from the challenging precise calibration of the powder-to-liquid ratio during mixing or slightly excessive heating of the casting crucible, leading to microcracks in the glass-ceramic powder.
- Our findings are consistent with a study conducted by Chang_Halim et al. in 2019, which compared the fracture strength of various types of crowns, including lithium disilicate crowns manufactured using IPS Press and IPS CAD/CAM techniques. The study showed that the average fracture strength for lithium disilicate crowns manufactured using IPS Press was 1656.2 N, while the average fracture strength for crowns manufactured using IPS CAD/CAM was 1822 N, indicating that IPS CAD/CAM yielded higher fracture Strength than IPS Press technique. The slight numerical difference in results can be attributed to differences in the force application method between the two studies.
- Our results also agree with a previous study by Albrecht T et al. in 2011, comparing the fracture strength of zirconia crowns with lithium disilicate crowns manufactured using IPS CAD/CAM. The study showed that the average fracture strength for lithium disilicate crowns manufactured using IPS CAD/CAM was 1850 N when vertical forces at a 90-degree angle were applied to the crowns bonded to extracted maxillary first premolars. These results were in close agreement with our study's results (1852.1 N) for the group of vertically applied forces, given the similarities in force application method and studied samples between the two studies.
- However, our findings differed from a study by Zhao K and Pan Y et al. in 2012, where they compared the fracture strength of lithium disilicate crowns manufactured using IPS Press technique with two types: full anatomic and bi-layer (glazed). The study showed that the average fracture strength for lithium disilicate crowns (IPS e.max Press Full Anatomic) was 2665.4 N, which differed from our study's results (1816.71 N).

The difference in results between our study and this study may be attributed to the following reasons:

Firstly, the difference in the studied sample. This study used 40 extracted lower first molars, while our study applied to 28 extracted upper first premolars. The larger size of the abutments and crowns in this study may play a role in increasing fracture strength compared to our study.

Secondly, the difference in the force application method. This study used a 6mm diameter sphere to apply forces on the central groove of lower first molars, with a tin foil separating the sphere from the crown to distribute the forces evenly. In contrast, in our study, we applied forces using a custom-designed head directly on the internal incline of the palatal cusp of the upper first premolar, midway between the cusp tip and the central groove.

Our results also differed from a study by Gresnigt MM and Ozcan M et al. in 2016, where they compared the fracture strength of endo crowns made of lithium disilicate using IPS CAD/CAM and composite materials. Their study showed that the average fracture strength for IPS CAD/CAM lithium disilicate endo crowns was 2428 N for vertical forces and 1118 N for oblique forces at a 45-degree angle. This differs from our study's results of 1944.17 N for vertical forces and 1243.10 N for oblique forces at a 45-degree angle. The primary reason for the difference in results between our study and theirs is mainly due to differences in the type of prosthodontics design (full crowns in our study versus endo crowns in their study) and the studied sample (upper first premolars in our study versus lower first molars in their study).

Results Discussion: The Effect of Applied Force Type (Vertical and Oblique) on Fracture Strength in the Two Manufacturing Techniques Used:

The explanation for the increase in crown fracture strength when applying vertical forces significantly compared to the fracture strength when applying oblique forces lies in the difference in force composition. Vertical forces consist of a single compound applied on the vertical Y-axis, while oblique forces decompose into two compounds X and Y that contribute to crown fracture more easily.

Conclusions:

Within the limits of this study, we found that:

- IPS CAD/CAM manufacturing technique yielded higher fracture strength than the IPS Press technique for full crowns made of lithium disilicate crystal _ reinforced glass ceramic.
- The fracture strength values in Newtons were higher in the group of vertically applied forces than in the group of obliquely applied forces for both manufacturing techniques.

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