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FRACTURE RESISTANCE OF INTERIM RESTORATION CONSTRUCTED BY 3D PRINTING VERSUS CAD/CAM TECHNIQUE IN DIFFERENT ORAL MEDIA (IN VITRO STUDY)

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ABSTRACT

Aim: The goal of the research was to assess fracture resistance of temporary restoration materials that will be fabricated with 3D printed technique and CAD/CAM technique in different oral media (artificial saliva, tea, carbonated orange juice).

Methods: According to the sample size calculation, 40-crown-shaped samples were divided into two groups (n=20); group I was manufactured by CAD/CAM, and group II was manufactured by 3D printing technology. Each group was subdivided into four subgroups (n=5). According to the immersion solution, subgroup (A) Artificial saliva, subgroup (B) Tea, subgroup (c) Carbonated orange juice, and subgroup (D) the control (non-immersion). The prepared model was scanned using an extra-oral scanner. Interim crowns were designed using 3Shape software. STL file was Produced and sent to both milling machine and printer. . All samples then were immersed in the different oral media for 7 days. Finally all samples were subjected to fracture resistance testing by using universal testing machine. The data collected, tabulated and statistically analyzed.

Results: Results of the fracture resistance in control group showed higher non-statistically significant difference in cad cam technique (1262.8±580.68) than 3d printing technique (817.98±78.48) ,While after immersion in different oral media the fracture resistance samples of cad cam showed higher statistically significant different (1012.56±363.97) than in 3d printing (594.9 ± 163.1).

Conclusion: The total fracture resistance of milled temporary crowns showed higher fracture resistance than 3D printing technique in different oral media with statistically significant difference.

KEYWORDS: Interim restoration; 3D printing; CAD/ CAM; Oral media.

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INTRODUCTION

The provisional restoration is an important step in fixed prosthetic treatment, and is used routinely in dental office to restore prepared teeth used since the stage of tooth reduction to the stage of finishing cementation. A well-constructed temporary restoration is essential in reaching a successful final restoration [1]. These restorations must be biologically compatible to restore function, esthetics, and have high mechanical properties to resist several forces in the oral cavity [2].

There are three major procedures for constructing temporary restorations: 1. direct temporary designation in the mouth on the prepared teeth; 2. indirect temporary designation; and 3. a combined indirect-direct temporary designation approach [3]. Among the indirect techniques is the usage of a CAD/CAM (Computer-Aided Designing and Computer-Aided manufacture technique (subtractive built-up) and 3D printing technique (additive built-up) [4].

In a digital workflow, the CAM process can be either subtractive or additive in nature. Milling and grinding are subtractive processes that produce restorations from a monolithic block or disc of a definite material. Conversely, the additive process is a built-up technique in which the last product is gained by building up layers of material; for example, in 3D printing, a focused light beam is used to attract and solidify the material on a platform, resulting in a procedure called rapid prototyping (RP) [5].

Physical, mechanical, and handling characteristics must be addressed when selecting a material for interim restorations, the selected material should meet the specific requirements of each clinical situation[6]. Another crucial consideration to examine is a material's biocompatibility with soft tissues, as well as its bio tolerance, as some materials trigger exothermic reactions that might be detrimental[7]. Polymethylmethacrylate (PMMA), composite or polyether ether ketone (PEEK) are the most commonly used materials for temporary crown [8].

The mechanical properties of temporary restorations can be affected by saliva, food ingredients, drinks, and interfaces between these materials in the oral environment [9]. Consequently, throughout the course of therapy, their integrity must be maintained. In the current study, tea and orange juice were chosen as the immersion solutions because they are considered common beverages.

Multiple researches have demonstrated that the most common reason of failure is fracture of provisional restorations, leading to discomfort and pain. Therefore, fracture resistance is important and must be considered while selecting the material for these uses[10]. So the aim of our research is to investigate fracture resistance of provisional restoration constructed by 3d printing technique compared to cad/cam technique in different oral media.

Hypothesis

The hypothesis of this study proposed that 3D printed provisional crown would have higher fracture resistance than CAD/CAM provisional crowns after immersion in different oral media.

MATERIAL AND METHOD

Sample size calculation:

According to study conducted by **Alharbi et al. (2017)** [11]. Given a statistical power of 90% and a significance threshold of 5%, a sample size is 5 crowns in each group was sufficient to detect the effect size, same number of crowns was used for the other technique, and total number of crowns was 40 crowns. The G power program was utilized to ascertain the sample size.

Sample grouping:

40-crown-shaped samples were divided into two groups (n=20); group I was manufactured by CAD/CAM, and group II was manufactured by 3D printing technology. Each group was subdivided into four subgroups (n=5). According to the immersion solution, subgroup (A) Artificial saliva, subgroup (B) Tea, subgroup (c) Carbonated orange juice, and subgroup (D) the control (non-immersion).

Sample preparation

Typodont replicas of the maxillary first molar with 2 mm occlusal reduction, 1.5 mm axial reduction, 1 mm deep chamfer finish line, and 6-degree convergence were prepared to obtain an all ceramic crown corresponding to **Shilinberg et al.** [12]. To standardize the occlusal and axial reduction, the preparation was done utilizing a silicon index of an unprepared tooth .then replication of the master die into epoxy resin was performed .Silicon mold for the master typodont die was created using duplicating addition silicon material (Reprisil 22 dent-econ e.k, lonsee, german). The master die was positioned in the middle of the container, two equal amounts of the base and catalyst of the duplicating material were mixed for 5 minutes according to manufacture instruction. And it was later removed after addition the silicon material had been set.

The epoxy resin material (CMB, chemical modern building, Egypt) mixture was poured into the silicon molds, then voids and air bubbles removed by using the laboratory vibrator (laboratory vibrator (Model DV34)). 40 Epoxy resin dies were placed for a day to guarantee complete setting.

Scanning the preparation

An extra-oral scanner (3Shape D850 extra-oral scanner, ivoclar, vivadent, USA) was utilized to create a 3D virtual version of the die. The master cast was placed on the lower separate compartment part to be fixed to the scanner. The entire scanning procedure took about a minute. Then data collected to get the final virtual 3D master cast with fine details.

Restoration designing

The upper right sixth molar, tooth number 16, was picked. The 3Shape program (3Shape Dental System software, 2018) created a virtual model **Figure (1)** from scanned images ready to identify the finish line. An automatic margin finder was used for margin detection, and the tooth anatomy that matched the anatomy of tooth 16 was chosen from dental databases libraries.

Milling process

Dry milling process of PMMA disc (Telio CAD temp Disc) to create interim crowns, a specific type and disc size were chosen. , the chosen disc was put into the spindle of the milling chamber of the IDC shape milling machine (ROLAND DWX-52Dci milling machine,DG shape,USA). It is a milling machine with five axes. It has an intelligent tool changer (ITC) and a 15-station automatic tool changer (ATC) for uninterrupted milling. It has improved tool management, better disc handling, and other features.

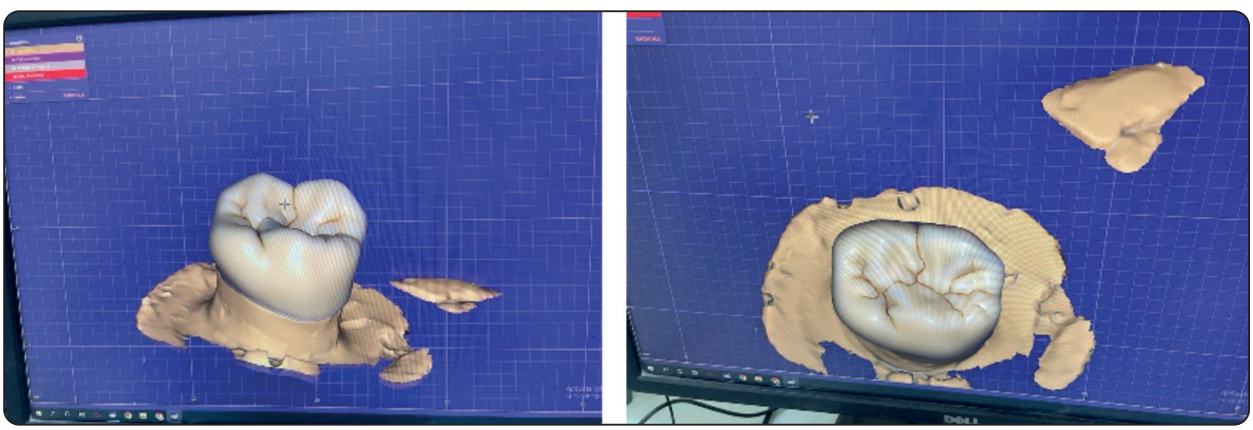

Fig. (1) Designing the final virtual restoration

3D Printing process:

The anycubic photon SE printer was used to print the STL file after selecting the appropriate design. After adjusting the printing parameters, the building process could start. Next, dent C&B resin was utilised and poured into a container that was made to precisely fitting inside the anycubic printer.

Cementation of temporary crowns:

For the cementation of crowns on their corresponding epoxy resin dies, automix dual-cure self-adhesive resin cement (Breeze, Pentron Clinical Technologies, USA) was used. The cement was applied to the axial walls of the crown during cementation by light curing for 20 second then complete setting by chemical curing. To standardize the cementation, all samples were cemented using the same method by using a specially constructed cementing device **Figure (2).**

Immersion of temporary crown in different storage media:

The first immersion media was Artificial Saliva, which was produced at Cairo University's Faculty of Pharmacy in Egypt, Tea and Ready-made carbonated orange juice (Miranda) was used. The production of various oral media for each group as part of the intervention was done based on research by **Radwan et al.** [13] and **Zortuk et al.** [14]. Each sample group was put into a container that was completely sealed before being stored in the immersion medium .In order to prevent contamination from bacteria or yeast, the solutions were changed daily.

Fracture Resistance measurements:

All samples were individually placed on a computer-controlled INSTRON universal testing machine. A load cell of 5 kN and data were recorded using computer software. The samples were attached to the testing equipment's lowest fixed compartment using screws that needed to be tightened. To obtain uniform stress distribution and prevent contact damage with the steel indenter, the fracture resistance measurement was conducted in the compressive mode of load application using a metal rod with a spherical tip (5.6 mm diameter) at a cross-head speed of 1 mm/min with tin foil piece in between to attain equal distribution of stress and to prevent contact damage with steel indenter. The fracture load was calculated. The information was collected, processed, and statistically examined.

Mode of Fracture of samples:

An electron microscope (JSM-IT 200, JEOL, USA) was used to evaluate the broken pattern of the examined temporary crowns, and it will provide a report. After the fracture resistance test, all samples in the test groups were examined under digital microscope at a magnification of x100

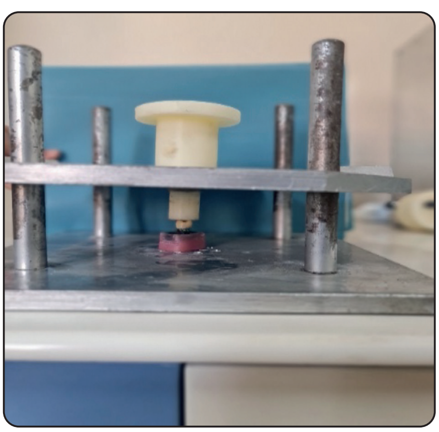

Fig. (2) cementing device

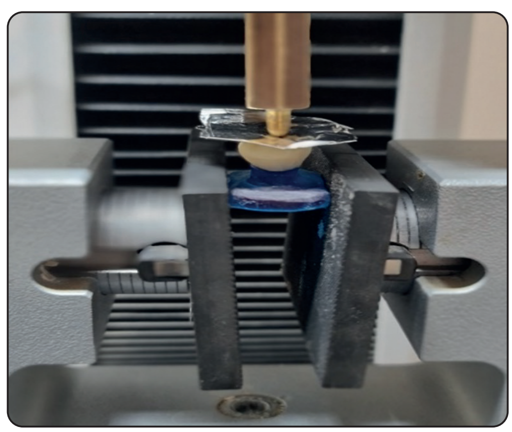

Fig. (3) measurement of fracture resistance of the sample

Statistical method

The data were analyzed by Statistical Package of Social Science (SPSS), version 22. Quantitative data were presented by mean and standard deviation. A nonparametric "Mann-Whitney" test was used to compare means between the two groups. ANOVA test was used to compare means between more than two groups. Post hoc test "LSD" was used to show significance within groups after the ANOVA test. The probability of less than (0.05) was used as a cutoff point for all significant tests. Figures were done in Excel Office 2010.

RESULTS

(A) Comparison of fracture resistance of samples in 3D printed technique and CAD/CAM techniques in different sub groups.

The results of fracture resistance between 3d printing and cad cam techniques in control media showed that; the (mean ±SD) fracture resistance of samples of CAD/CAM technique (**1262.8±580.68)** was higher than that of 3D printing technique (**817.98±78.48).** This difference was no statistically significant **table (1).**

Regarding saliva and control media, the cad cam technique showed higher mean fracture resistance than those in 3d printing technique, the difference between those two techniques was not statically significance. As regards tea media, , the cad cam technique showed higher mean fracture resistance than those in 3d printing technique, the difference between those two techniques was statically significance (P=0.03). Regarding orange media, the cad cam technique showed higher mean fracture resistance than those in 3d printing technique, the difference between those two techniques was statically significance (P=0.03) **Table (1).**

TABLE (1) Fracture resistance of mean ± SD of samples in 3D printed technique in comparison to CAD/CAM techniques in different sub groups

	3D Printing technique (N=20)	**CAD CAM technique (N=20)**	**Significance**
Control Media			P=0.25
Mean	**817.98**	**1262.8**	
SD	78.48	580.68	
Median	776.43	1044.34	
Range	(769.01-908.49)	(848.88-2113.65)	
Tea Media			P=0.03*
Means	**547.74**	**1012.39**	
SD	124.18	250.58	
Median	545.01	1075.78	
Range	(399.52-701.43)	(736.2-1225.18)	
Orange Media			P=0.03*
Means±	**500.31**	**941.38**	
SD	102.9	233.43	
Median	536.93	944.67	
Range	(384.1-579.89)	(653.47-1222.69)	
Saliva Media			P=0.08
Means±	**545.7**	**833.65**	
SD	154.16	227.48	
Median	513.33	909.09	
Range	(408.8-748.07)	(506.86-1006.54)	

The result showed that the total mean of resistance fracture in all media, (Means±SD) of the 3D printing technique was (594.9 ± 163.1) compared to (1012.56±363.97) for the CAD CAM technique. The CAD CAM technique had significantly higher mean value than the 3D printing technique when the P=0.001 **Table (2).**

Results of mode of failure by using scanning electron microscope (SEM):

The horizontal orientation shape was observed in 3d printed samples with fine grooves which could be related to the nature of 3D printing technique**,** these lines and grooves may lead to defect or fracture with longer use. While Parallel lines were observed on the surface of the cad cam samples which could be related to the nature of technique.

(B) Total fracture resistance in all media

TABLE (2) Total mean ±SD of fracture resistance in all media

	3D Printing technique (N=20)	CAD CAM technique (N=20)	Significance
Total mean of fracture resistance of all media			P=0.001*
Mean	594.9	1012.56	
SD	163.1	363.97	
Median	571.49	971.33	
Range	(384.1-908.49)	(509.86-2113.65)	

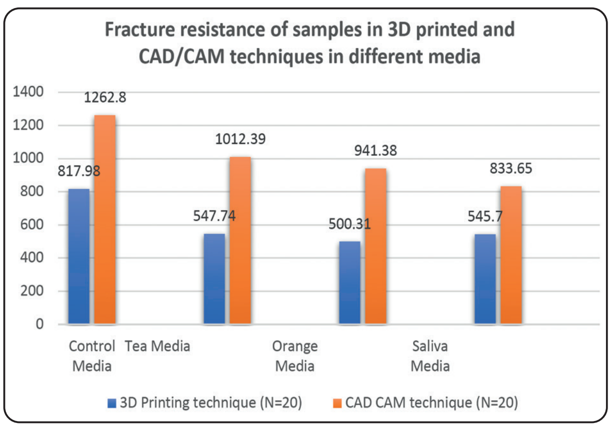

Fig. (4) Comparison of fracture resistance of samples in 3D printed technique and CAD/CAM techniques in different sub groups

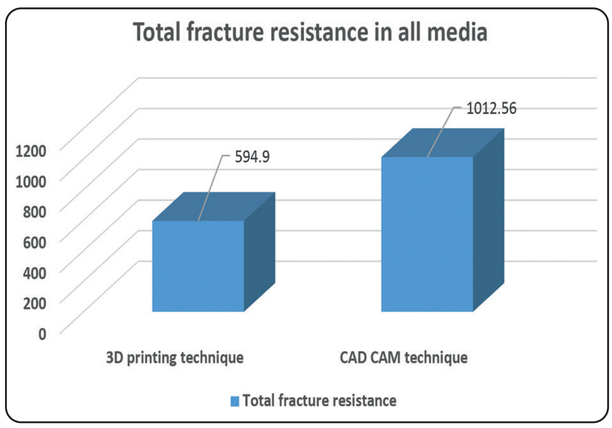

Figure (5) Total fracture resistance in all media

DISCUSSION

CAD/CAM and 3D printing have become widely used in dentistry during the last several decades, thanks to technological developments like digital impressions and the designing and milling processes that go along with them.

The 3D printing technology has increased support for interim construction to address some of the drawbacks of CAD/CAM, such as excessive waste material [15]. According to several researchers, the bond strength between layers is related to the more excellent mechanical qualities of restoration, as demonstrated by a 3D-printed restoration that can resist cracks and has a high level of building of restoration.

Due to differences in mineralization, dimensions, age, and mechanical properties of natural molars, standardization with extracted molars is difficult to achieve. Because of this, the artificial upper right first molar from a typodont model was used in this research with the aim of standardization [16].

An additional silicon material was used to duplicate each master die because it has the best mechanical properties with a high ultimate tensile strength and gives a very high degree of accuracy in dimensions and design of the duplicating form [17].

The die was prepared of epoxy resin because its elasticity (12.9MPa) is comparable to that of dentin. The fracture resistance of CAD/CAM crowns made on dentin dies and epoxy resin dies was discovered to have the same fracture resistance values. Due to its superiority in dimensional precision, surface detail reproduction, strength, and improved abrasion resistance, the epoxy resin material was utilized in the current investigation [18].

The current study used resin cement for cementation rather than conventional cement. For maximum cementation, low-solubility factors, suitable working and setting times to prevent cementation failure in the storage media until fracture resistance test [19].

A special cementation loading device was used instead of finger pressure during cementation and seating of interim crowns on epoxy resin dies. To make sure that all specimens have the same cement thickness, it is essential for using a constant pressure when the cement is set [20].

Result of this study showed that the CAD/CAM group had higher fracture resistance than 3D printed group. This can be attributed to the shrinkage of the sample during building and after curing in 3d printing technique [21]. Also, building direction is one of the most essential step in 3D printing technique. Materials printed vertically with the load perpendicular to the layer orientation show higher compressive strength than materials printed horizontally [22]. In the current research, the crowns were horizontally printed causing decrease in fracture resistance.

These results agreed with those of **Sakr et al., 2022** [22], where it was found that the fracture resistance of CAD/CAM provisional crowns, showed the statistically significant highest mean value, followed by 3D Printing provisional crowns ,while the least value was noted for Conventional provisional crowns .

In contrast, **Ibrahim et al., 2020** [23] and **Suralik et al., 2020** [24] documented that the group of 3d printing interim restorations recorded a mean value of the fracture resistance much higher than the group of cad/cam interim restorations.

The findings showed that the various storage media had a statistically significant difference on the fracture resistance of the 3D printing technique at a significance level of P=0.03. However, there was no statistically significant difference on the fracture resistance of the CAD CAM technology, with a significance level of P=0.43. This can be explained by that the oral media had affected the 3d printing than cad cam due to the 3D-printed materials are built in layers, and water can pass in these layers, leading to movement in the polymer chains, which can lead to dimensional changes. Additionally, although 3D printing resins undergo post-curing processes after printing, but the presence of free monomers in 3D printing materials due to the low polymerization degree increases the water sorption. In the other hand, the milling PMMA materials are created by polymerizing in a high-temperature and high-pressure environment. Consequently, these materials have compact structures and high polymerization rates [25].

This results in accordance with **Mohammed and Mahmood, 2021** [26] who found that the immersion of Cad Cam PMMA temporary crown in 3% hydrogen peroxide solution had no significant effect on the mechanical properties of the material. In contrast **Ribera et al., 2023** [27] found that the different oral media had statistically significant effect on strength and time to fracture of Cad Cam PMMA interim crowns.

The surface topography of the cad cam and 3d printing samples was measured by using a scanning electron microscope. The reduced fracture resistance of the 3D group may be attributed to the presence of horizontal lines and tiny grooves showed on the surface of the 3D samples. This phenomenon can be attributed to the inherent characteristics of the three-dimensional process, as showed in the scanning electron microscope (SEM) image .These lines and grooves have the capacity to make defects or fractures over long periods of usage.

From the above discussion the current study hypothesis was rejected and demonstrated that CAD/CAM temporary crowns had higher fracture resistance than those made by 3D printing after immersion in different solution.

Some Limitation of the study that is an in vitro study cannot completely simulate the oral environment such as the presence of saliva, fluctuation in PH and the presence of parafunctional habits but they are considered a reliable testing method for comparison among tested groups and give an indication about the behavior of the material under different testing conditions.

CONCLUSION

The total fracture resistance of milled temporary crowns showed higher fracture resistance than 3D printing technique in different oral media with statistically significant difference, while in control group was no statically significance.

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