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Marginal Discrepancy And Fracture Resistance Of Provisional Restorations Fabricated By Different Fabrication Techniques

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Abstract
Background: *Provisional restoration is a critical stage in the therapy of fixed prostheses. It is utilized from the time the tooth is prepared until the final restoration is delivered. The dental provisional restorations success is detected mainly by 4 factors: biocompatibility, esthetics, fracture resistance and marginal fit.*
Aim of the study: *The study was done for comparing the marginal adaptation and fracture resistance of the provisional crowns manufactured by 3D printing, CAD/CAM & conventional manual techniques.*
Materials and Methods: *Regarding to the sample size estimation, twenty-one crowns in total were constructed & subsequently divided into 3 equal groups, seven samples were produced for every group in accordance with the fabrication method. Group (I): conventional manual technique, group (II): CAD/CAM technique, group (III): 3D printing technique. The provisional crowns were photographed on camera using a USB digital microscope equipped with an integrated camera that was linked to an IBM compatible personal computer. Then, the vertical marginal adaptation was measured between outer cervical margin of every crown & the exterior surface of the finished line. The magnification of the microscope was fixed at 50X. A fracture resistant test was performed on each crown, wherein a compressive force was applied to the middle of their long axis. The testing apparatus utilized a computer controlled universal testing machine, which featured a load cell of five newton (N) and a crosshead speed of 1mm/min. After that, the recording, tabulation and statistical analysis of data were done.*
Results: *Analyses of normally distributed data were conducted post hoc using Tukey's test after one-way ANOVA. A significant variance among variant groups was found in marginal gap (p<0.001). The greatest value was detected in traditional Provisionals (51.53±3.03) (µm), followed by milled Provisionals (42.26±1.70) (µm), while the lowest value was found at 3D printed Provisionals (38.60±1.53) (µm). Also, a significant variance among variant groups was found in fracture resistance (p<0.001). The greatest value was detected in 3D printed Provisionals (1456.13±68.98) (N), followed by milled Provisionals (1334.71±72.87) (N), while the lowest value was found at conventional Provisionals (811.03±92.36) (N). Statistically, every post hoc pairwise comparison was significant (p<0.001).*
Conclusion: *The utilization of 3-D printing for additive manufacturing of provisional crowns may be regarded as a dependable & conservative approach to fabricate stronger provisional restorations as it has the highest marginal adaptation and fracture resistance according to milling and conventional manual techniques.*
Keywords: *Marginal Discrepancy, Fracture Resistance, Provisional Restorations Fabricated, Different Fabrication Techniques*

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I. Introduction

Provisional restoration is a critical stage in the therapy of fixed prostheses. It is utilized from the time the tooth is prepared until the final restoration is delivered. A provisional restoration that is appropriately constructed is critical to the achievement of an indirect restoration. Provisional restoration provides a preview of the final prosthesis regarding esthetics and function. Provisional restoration must fulfill biological, mechanical and esthetic criteria to be considered successful restoration. Additionally, it contributes to pulp protection, the stabilization of occlusal associations, occlusal function, marginal accuracy, & esthetics. Oral rehabilitation cases requiring long-term temporization or bite elevation are critical [1].

There are many fabrication techniques of provisional restorations. Conventional indirect technique of fabrication of provisional restorations was considered the most common manual technique. This technique has several advantages over the direct procedures. At first, materials exhibiting greater strength & durability may be employed in the production of heat-cured acrylic. Additionally, occlusal or aesthetic modifications may be achieved with an articulator. Absolutely, indirect Provisionals have the potential to conserve clinical time, particularly when dealing with several units [2].

CAD / CAM is a process of fabrication of 3D solid object by cutting in a block of material using a milling machine. It is considered subtractive process. The CAD/CAM technique results in good provisional and final prosthesis by using various materials, which satisfy patient's needs. But It's expensive due to waste of material[3].

The 3D printing technique is Fastly growing nowadays using different types of resins. it is considered an additive process. It gives us a prosthesis with minimum material waste. This technique is cheap, fast and it also can produce complex shapes and definite angle[4].The 3D printing technique was firstly used for forming large objects as casts and surgical guides but by technology improvements and introducing newly developed machines. So, it can be used for crowns and provisional restorations. However, it was not clear whether restorations produced by 3D printing show comparable adaptation to those produced via CAD/CAM & traditional methods.

Accurate marginal fit and high fracture resistance increasing durability and longtivity of the restoration. Also increasing patient confidence to the clinician and eliminating complications. It also minimizes the food accumulation risk and facilitates oral hygiene measures which improve oral and periodontal health and esthetics[5].Thus, it was important to assess the adaptation and strength of 3D printing, CAD/CAM and conventional techniques to give us more information on the advantages and limitations of each technique.

Finally, the purpose of this research is to define the impact of variant methods for construction on marginal gap & fracture resistance of provisional restoration.

II. Materials And Methods

1-Materials:

Table (1): Commercial names, Types, Chemical composition, manufacturer and lot number of different materials utilized within this research

Commercial name	Type	Chemical composition	Manufacturer company	Lot no.
Next Dent C&B	3D printer liquid resin.	Poly Methyl Methacrylate	Next Dent, Soesterberg, Neitherland.	Xk123No1
DC blank	PMMA CAD/CAM blank.	99.5 wt.% Poly Methyl Methacrylate <1 wt. % Pigments	White peaks dental solutions, Gmbh& co., Germany.	70050120
Charm-temp	Self-cure resin	Bis-GMA, TEGDMA, UDMA & Barium Glass	Dentkist, Republic of korea.	1422014
Zermack elite HD+ putty	Addition silicone Impression material	Vinyl polysiloxane	Zermack, Germany	379716
Zermack elite HD+ light	Addition silicone Impression material	Vinyl polysiloxane	Zermack, Germany	378426
Charm-temp NE cement	Temporary cement	Zinc Oxide non- Eugenol	Dentkist, Republic of Korea.	1420017

2-Methods:

1-Master die preparation:

The typodont model of the maxillary upper first molar was fabricated in accordance with Shillinberg25 in preparation for an all-ceramic crown. The preparation included a 2 mm occlusal decrease, 1.5 mm axial decrease, 1 mm chamfer finish line, & 6°-degree convergence. A proficient prosthodontist performed the preparation by employing a silicone index of an unprepared tooth in order to attain the needed decrease of the tooth.

2- Duplication of master die into epoxy resin die:

The master typodont die was fabricated from duplicating addition silicon material utilized to create the silicon mold. Following the manufacturer's instructions, two equal parts of the base & catalyst of the replicating material were combined with the silicon mixture in the cylindrical Teflon container for five min. The master die was positioned at the center of the container & subsequently extracted once the silicon mold had hardened. Following this, the silicon duplicates were filled with the epoxy resin material mixture while the laboratory vibrator was used for eliminating air bubbles & voids. To ensure thorough setting, epoxy resin dies were left in position for a duration of twenty-four hours.

Digital caliper was used to verify the accuracy of reproduction & to ensure standardized dimensions of all epoxy dies replicas. The replicas were measured occlusso-gingivally, facio-lingually and mesio-distally.

3- Sample Size:

A) Sample Size calculation:

Comparing the marginal discrepancy among the indirect manual method, the CAD/CAM method, & the method of 3D printing was utilized to determine the sample size. The sample size was determined utilizing version

3.0.11 of the PS Power & Sample Size Analyses software for Microsoft Windows (William D. Dupont & Walton D., Vanderbilt University, Nashville, Tennessee, USA).

As reported within previous publication Alharbi, Cuijpers, Osman, Wismeijer.[4] Internal & marginal fit of 3D-printed provisional restoring constructed on various finish line designs are evaluated in all three dimensions. The mean ± standard deviation of the vertical gap in the 3D printing group was nearly 25.6um, whereas in the milling group it was around 40.5um (J Prosthodontic Res. 2018). Based on our calculation, the minimum appropriate sample size for rejecting the null hypothesis with a power of eighty percent at a significance level of 0.05 utilizing the student's t test for independent samples was determined to be seven samples in every group.

B) Samples Grouping:

Samples are divided into 3 groups; each group will have 7 restorations fabricated by a different technique.

4- Scanning procedure (Computer aidded imaging):

Typodont cast with the prepared removable die was attached to lower separate compartment to be fixed to the scanner. The cast was then placed in Dof freedom hd extra oral scanner to be scanned to get 3D virtual cast.

Data collected was summed up from initial cast scanning and scanning of die separately to get final virtual 3D master cast with fine details. Abutment margin and finish line were traced as showed by green line.

5- STL file designing (Computer aided designing)

Once the scanning was completed, STL file designing was started for the provisional restoration on software by choosing full anatomical crown for upper right 1st molar by exocad.

The cement space was set up where cement gap 0.06mm and finish line thickness 1mm. After that, the path of insertion was adjusted.

6- Crowns fabrication:

A) CAD/CAM technique:

D G shape DWX-52D 5 axis milling machine was used. It is a precise 5-axis milling that was used in milling provisional crown from DC PMMA A1 blank. For uninterrupted milling, it is equipped with a 15-station Automatic Tool Changer (ATC) & an Intelligent Tool Changer (ITC). It has enhanced tool management, improved disc handling, & additional enhanced features.

After ensuring that the crown was in the intended location on the blank, the machine holder secured the PMMA blank & transmitted the identical STL file that had been saved. The order was then placed to mill the provisional crown & obtain the final product. Milling procedure took 20-30 min for each provisional crown that was attached to the blank with supports. Following the removal of the supporting structures, the crown was completed & polished to get perfect smooth surface. Then, the crown was checked on its die.

B) Conventional technique:

Charm-temp (Dentkist, Republic of Korea) was utilized to fabricate provisional crowns in group (1). Using silicon (Zhermack, elite HD+, Italy), an impression of a previously constructed CAD/CAM provisional crown was obtained in order to establish a standard for group (1) samples.

Charmtemp was formulated utilizing the self-mixing gun and injected directly into the silicon index. Subsequently, the index was affixed to the die & maintained in position till the amalgamated material formed entirely. All crowns were examined to ensure that there are no any defects then finishing and polishing was done by employing rotary rubber cups (SofLex™ Disc 3M ESPE, Germany) in accordance with the instructions provided by the manufacturer.

C) 3D printing technique:

For construction of 3D printed provisional restoration, polymer material used was Next Dent C&B for the provisional crowns. The resin liquid was then poured in special container & then placed it in Rapid shape D 30 printer. STL file was transferred by flash memory to the printer. The printer took the order to start printing. After finishing the 3D printed crown was attached to upper compartment with 10 supports. It was then placed on the master die to be checked.

After complete printing, the resultant restorations were cured using **Next Dent LC-3D Print Box**, which is a UV light box suitable for curing resin materials after 3D printing and resulted in a quick and uniform curing cycle.

Following curing with ultraviolet light, Next-Dent materials achieved nearly complete polymer conversion; as a result, the amount of residual monomer was minimized, & the materials acquired their maximum mechanical properties. This procedure was a vital step in the production of a biocompatible final product.

Next Dent LC – 3D box is equipped with twelve UV light bulbs positioned in a strategic manner within the box. The post curing cycle last for 30 minutes with blue UV light with 315-400 nm wavelength with total light output 72 watt.

The final end product of 3D printed provisional crown was attached with supporting structures. Following the removal of all these supporting structures, the crown was completed & polished with Jota Arkansas stone 649 to get perfect smooth surface. Ethanol solution was used for cleaning and disinfection of the finished and polished 3D printed provisional restoration. Finally, all provisional crowns were initially evaluated with a dental explorer and magnifying lopes with 3.5X magnification power.

7- Measurements:

A) Vertical marginal gap:

It was possible to determine the vertical marginal adaptation by comparing the outer cervical margin of every crown to the external surface of the constructed finish line. On the epoxy die, provisional crowns were fixed utilizing a specialized holding jig. Next, photographs of the provisional crowns were taken utilizing a USB digital microscope equipped with a camera built in that was linked to an IBM compatible personal computer. The magnification of the microscope was fixed at 50X.

Utilizing Omnimet image analysis software from Buehler USA, a digital image analysis system was employed to quantify & assess the gap width. All parameters that are evaluated sizes, limits, &frames are indicated in pixels. Consequently, in order to convert the pixels to absolute real-world units, system calibration was performed.

All specimens were subjected to four shots of the margins on all surfaces **(Figure 1)**. Then, morphometric evaluations were performed for each shot, utilizing a total of twenty points along the circumference of the crown, with five equidistant landmarks along the circumference for each interface. Every evaluation was performed three times at every point. Following the collection &tabulation of the acquired data, statistical analysis was conducted.

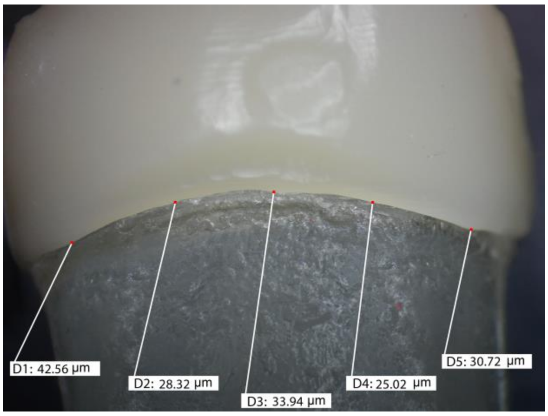

Figure (1): Analysis of microscopic photograph of 3D printed crown on its epoxy die under digital microscope

B) Fracture resistance:

Cementation technique:

In order to adhere the crowns to their respective epoxy resin dies, Charm-temp NE auto-mix cement was utilized. The cement was administered along the axial crown walls. In order to ensure consistent load application during the cementation process of each crown, a loading device of unique design was utilized. This loading device comprises two rigid vertical rods connected by two horizontal plates. A vertical cylindrical steel bar with a flat disc-shaped lower end, designed to support the sample and a flat horizontal upper disc-shaped end, capable of supporting a three kg load throughout the cementation process, passes through the central hole in the upper plate:

Every crown was fixed to its respective epoxy resin die & subsequently attached to the cementation loading device. After lowering the sliding vertical bar of the cementation device until it made contact with the crown, a static load of three kilograms was applied to the upper disc-shaped portion of the instrument for a duration of five min.

Fracture resistance test measurements:

Each sample was mounted separately on a universal testing device (Model 3345; Instron Industrial Products, Norwood, MA, USA) that was managed by a computer. By tightening screws, samples were secured to the lower fixed compartment of the testing machine. The fracture test was conducted utilizing an occlusal compressive mode of load applied with a metallic rod having a spherical tip with a diameter of 5.6 mm. It was fixed to the upper mobile compartment of the testing device with a 1mm/min cross-head speed.

The data were acquired utilizing computer software (Bluehill Lite Software Instron Instruments) &a load cell of five kN (**figure 2**). An audible crack indicated the load at failure, which was further validated by a significant decrease in the load-deflection curve captured by computer software. The load necessary to induce fracture was determined in Newtons. The gathered information was tabulated &statistically analyzed.

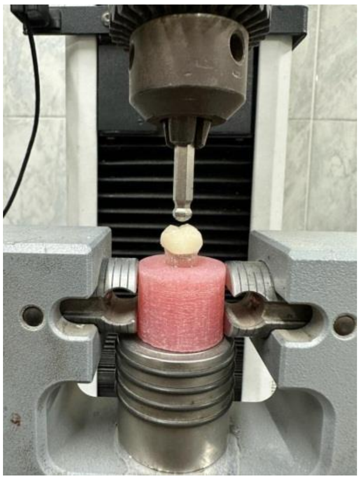

Figure (2): Load applied into samples in the universal testing machine

Mode of fracture of samples:

The fracture patterns of the samples under examination were assessed by employing a magnification lens (X=12) The fracture mode analysis was conducted subsequent to the fracture resistance test, & the results were categorized using Burke's system.[8] as shown in **(table 7**). Each code represents a different mode of fracture to simplify the classification of the tested samples.

Table (2): Burke's classification of mode of fracture:

Classification	Pattern of fracture
Class I	minimal fracture or crack in crown
Class II	less than half of crown lost
Class III	crown fracture through midline; half of crown displaced or lost
Class IV	more than half of crown lost
Class V	severe fracture of tooth and/or crown

Statistical Analysis

Mean with 95% confidence intervals (CI), standard deviation (SD), minimum (min), &maximum (max) values are utilized to present numerical data. The normality of the data was assessed by employing Shapiro-Wilk's test. Analyses of normally distributed data were conducted post hoc using Tukey's test after one-way ANOVA. In all tests, a significance level of $p<0.05$ was established. The statistical analysis was conducted using version 4.3.1 of the R statistical analysis software for Windows.

III. Results

I- Marginal gap

Intergroup comparison:

Marginal gap mean (µm) & standard deviation values are presented in (**table 2**).

Variation among groups was statistically significant ($p<0.001$). The greatest value was detected in conventional provisionals (51.53±3.03) (µm), followed by milled provisionals (42.26±1.70) (µm), while the lowest value was found at 3D printed provisionals (38.60±1.53) (µm). Statistically, every post hoc pairwise comparison was significant ($p<0.001$).

Table (2): Intergroup comparisons, mean & standard deviation values of marginal gap (µm).

Marginal gap (µm) (mean±SD)			p-value
Milled	3D printed	Conventional	
$42.26±1.70^{B}$	$38.60±1.53^{C}$	$51.53±3.03^{A}$	**<0.001***

Values with different superscript letters within the same horizontal row are significantly different *; significant ($p<0.05$) ns; non-significant ($p>0.05$)

II- Fracture strength
Intergroup comparison:

Fracture strength mean & standard deviation values of fracture strength (N) are presented in (**table 3**). There was a significant variance among variant groups (p<0.001). The greatest value was detected in 3D printed provisionals (1456.13±68.98) (N), followed by milled provisionals (1334.71±72.87) (N), while the lowest value was found at conventional provisionals (811.03±92.36) (N). Statistically, every post hoc pairwise comparison was significant (p<0.001).

Table (3): Intergroup comparisons, mean & standard deviation values of fracture strength (N).

Fracture strength (N) (mean±SD)			p-value
Milled	**3D printed**	**Conventional**	
$1334.71±72.87^{B}$	$1456.13±68.98^{A}$	$811.03±92.36^{C}$	**<0.001***

The results of the fracture mode analysis:

In this study; fracture mode analysis was done using magnifying lens (X= 12). Fractured and cracked samples were analyzed in the three groups: conventional, milled & 3D printed. The samples' fracture modes were described in accordance with Burke's classification [11].

Table (4): Fracture mode analysis

Burke's classification	Conventional N=7	CAD-Cam N=7	3D printing N=7
Class I minimal fracture or crack in crown	3	1	1
Class II less than half of crown lost	2	1	2
Class III crown fracture through midline; half of crown displaced or lost	2	3	2
Class IV more than half of crown lost	0	1	1
Class V severe fracture of tooth and/or crown	0	1	1

Figure (3): (Class I) crack started from point of load application propagates up to mesial surface until reach margin.

Figure (4): (Class II) with two fracture lines: one fracture line propagated from occlusal surface to palatal surface until reach the margin and the other propagated to mesio-palatal line angle.

Figure (5): (Class III) fracture path propagated from occlusal surface in mesio-distal direction, results in splitting of the specimen into two equal parts.

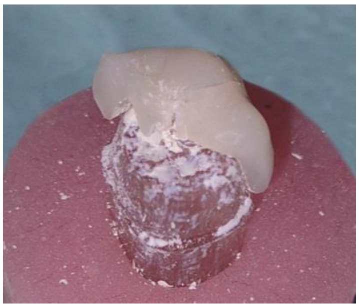

Figure (6): (Class IV) more than half of crown was fractured with lost fragments

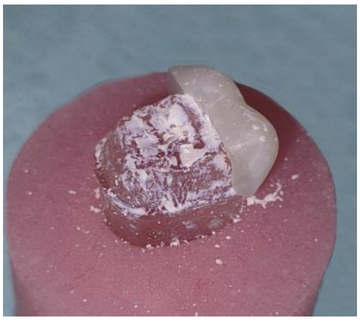

Figure (7): (Class V) A severe crown fracture into small fragments that were displaced or lost

IV. Discussion

Provisional restoration plays a very important role in the treatment plan success on which functional, occlusal and esthetic adjustments which lead to final restoration and overall treatment plan success[9,10]. The more the proposed treatment's level of complexity, the more importance of provisional restoration and its requirements to meet all situations. In rehabilitation cases that need long term provisionalization, they must function for long time (may reach 6 months) while adjunctive treatment is done. Until now, an ideal provisional material that is applicable to every clinical condition didn't exist. So, the need for biocompatible materials that have higher esthetics, less fabrication time, low cost and more accurate has led to increased development in fabrication techniques[11].

Marginal gap and fracture resistance are essential factors contributing to the lifelong success of the provisional restoring. The marginal discrepancies in the restoration presence leads to luting agent exposure to the oral environment, increasing cement dissolution rate as well as bacterial plaque retention and other irritants that represent a potential risk to the vital pulp[12,13].

Utilizing digital technology, the conventional chair-side method, or working casts in the laboratory, it is now possible to fabricate the provisional restoration. The direct conventional technique is associated with several drawbacks, including the generation of exothermic heat, a significant amount of residual monomer, & increased shrinkage that leads to discrepancies in dimensions. Additionally, the mechanical properties & fit of the prosthesis are impacted[7].

CAD/CAM fabricated provisional restoration was The prevalent advanced technique utilized in the production of provisional crowns has shown clinical efficacy as a result of developments in CAD/CAM systems, materials, &machines [14]. However, it has been documented that there are certain deficiencies to this technique, including marginal discrepancies, lots of material wastage, cracks introduced during milling and long time for fabrication. **Wright RP (2009)**[15], said that Polymethyl methacrylate (PMMA-resin CAD/CAM) is the most frequently material utilized with milling technique was as it has good esthetics, accuracy and color stability However, it has a fracture susceptibility which need some improvements as crosslinking in order to increase its mechanical properties.

Recently, technologies like 3D printing have been broadly utilized in manufacturing models with complex freeform surfaces. The 3D printing technology can fabricate models which can be easily customized its geometric shape. It has numerous benefits over the subtractive milling method: unlike subtractive milling, which is restricted to the size of blocks, it is capable of printing anything from very small objects to enormous structures. It is also a faster manufacturing technique, so it is called rapid prototyping. within the 3D printing processes, the final 3D shape is produced by deposition of the material layer by layer, which leads to less material waste, less expenses, improve mechanical properties (no cracks) and produce a cheaper provisional restorations[16,17].

In the present study, stereolithography technique (SLA) was chosen for additive manufacturing (AM) technology as it is fast and high resolution technique[18,19]. The SLA has higher accuracy according to other 3D printing methods, & it could print complex geometries in fine details. It can achieve a resolution of five µm in the X-/Y-axis & ten µm in the Z-axis. **Xiangjia et al (2018)** and other studies[20-22], used SLA to print provisional restorations with photo-curable dental resin. The liquid resin used in the present study was NextDent C&B (biocompatible class II a material) which increases the possibility to use as long-term restorations intraoraly[23].

Since the standardization is not easily achieved with extracted natural molars due to the variation in mineralization, sizes, age of natural molars and its mechanical features. That's why in the current study; the artificial upper right 1st molar in a typodont model was used for the aim of standardization[24].

Thus, the purpose of the recent study was to assess the reliability of 3D printing technique in the production of provisional restorations with clinically accepted marginal gap & fracture resistance compared to CAD/CAM & conventional techniques.

Before beginning this study, a pilot study was performed where typodont preparation was done as in **Wilson E. L.** (2012)[25]. using porcelain fused to metal crowns preparation criteria as it is the material most frequently utilized in constructing of complete coverage[26]. The model was prepared using depth grooves with 2mm occlusal reduction following occlusal anatomy ensuring the exact reproducibility of placement of the crown samples over their dies, with 6° convergence angle to improve crown retention. In theory, the greater parallel the walls of tooth preparation, the greater the retention & more conservative tooth preparation, and with 1 mm chamfer finish line improves esthetics and fracture resistance. Roundation of all sharp line angles to avoid stress concentration[27].

The master die was duplicated using **REPLISIL 22 N** as it can record fine details due to its low viscosity. It also has high mechanical features with great ultimate tensile strength & offers a very high accuracy in dimensions and design in the duplicating form[29].

Selection of epoxy resin material is due to its elasticity is similar to that of dentin (12.9GPa). It was found that the CAD/CAM crowns constructed on dentin dies has fracture resistance values similar to that of CAD/CAM crowns constructed on epoxy resin dies. Also, we use the epoxy resin material in this study because of its high dimensional accuracy, surface detail reproduction, strength & high abrasion resistance[30].

The indirect conventional techniques using Charmtemp was utilized for constructed provisional crowns. As indirect technique crowns have superior properties compared to the other conventional technqiues[31].

The DC PMMA disc was used in the current study; it is a cross-linked PMMA resin-based disc for the construction of long-lasting temporaries (over a year) by means of the CAD/CAM procedure. It was reported that this type of blocks has improved material properties as a outcome of a homogeneous & greatly crosslinked structure. Also, it's polymerization process conducted under optimized high pressure & temperature conditions. In addition to the lack of porosity and voids[32,33].

In the present study, Stereolithography technique (SLA) was selected for additive manufacturing technology as it was fast with high resolution technique. The accuracy of SLA was superior to other 3D printing techniques, & it could print complex geometries with fine details [29,34,35]. The liquid resin used in present study was NextDent C&B biocompatible class II a material for fabrication of long-term 3D printed provisional restoration[36].

Marginal adaptation:

Choosing the evaluation of vertical marginal gap as it is one of the most clinical significant outcomes. Since, any marginal discrepancy will result in wider cement exposure zone which leads to cement dissolution, crown retention loss, high plaque retention, sub gingival micro-flora composition changes, gingival and periodontal disease[37].

The provisional crowns are seated on the typodont using holding jig to hold the crown on its die with standardized force. No cementation was done to exclude the cementation technique variations effect.

Based on literature review, the clinically accepted vertical marginal gap ranges from 10 to 160 µm. **Rudolph H (2006)**[38]**,** found that 100 µm is considered good marginal misfit and 200 to 300 µm is considered acceptable misfit. Recently. Most investigators recommend conclusion stated by **Liu PR** that the maximum clinically accepted gap should be 90 µm[39].

In the present study, it was detected the marginal gap mean value documented for the conventional group was (51.53±3.03 µm), milled group was (42.26±1.70 µm) while the 3D printed group mean value was (38.60±1.53 µm) which is within clinically accepted range. The 3D printed provisional crowns showed higher marginal adaptation & lower marginal discrepancy than milling and conventional crowns.

This outcome agreed with several studies, **Park et al (2016)**[40], stated that marginal discrepancy value of implant provisional restorations within the 3D printed group was higher than that within the subtractive milling technique (CAM). He attributed positive or negative error to milling bur diameter that should be considered. While the 3D printing was highly accurate and fast to produce an equal molded layer with a uniform face. The 3D printing method uses digital processing light. This technique laminates the resin, by passing light onto a liquid photopolymer resin while exhibiting the desired mold shape. For the purpose of hardening, the laminated form is subsequently re-exposed to light within an integrated UV light polymerization station.

Abdullah et al. (2016) and other studies[41-43], stated that the fewer marginal fit observed in crowns manufactured using traditional techniques can be attributable to polymerization shrinkage. This phenomenon is non-existent in resin blocks employed in CAD-CAM technology, as they undergo full pre-polymerization prior to milling.

Lee et al (2017)[44], stated that gap values at margin area with the curved surface in the 3D printing technique are small values. It was due to the limitation of CAM equipment in the reproduction of margin accurately with the cutting device diameter used. It was reported also, it is more difficult to produce the sharp edge, protruded part & undercut part in the milling technique.

Elfar et al (2018)[45], compared marginal fit of crowns constructed via 3D printed & subtractive CAD/CAM wax patterns. It was found that the lowest value was detected in 3D printed group (40.33 ± 0.77) while the highest mean marginal gap value was found in CAD/C group (42.18 ± 1.44). He stated that the 3D printing technique produce the most accurate marginal fit as series of cross-sectional slices were created. After that, the 3D object is constructed with minimal marginal variation by printing each slice on top of the other.

Alharbi et al (2018)[4], stated that in comparison to milled restorations, the marginal gap values of 3D printed restorations are considerably reduced. Errors arising from the tolerance of milling burs may contribute to the inadequate marginal fit of milled restorations; in particular, surface details smaller than the diameter of the milling bur will be excessively milled, leading to inadequate marginal fit of the restoration.

In a study conducted by **Chaturverdi et al. (2020)**[46], it was observed that provisional crowns manufactured using 3D printing exhibited superior fit quality in comparison to pressure molding. **Peng et al. (2020)**47 documented that the marginal fit of crowns manufactured using CAD-CAM technology &3D printing was found to be superior when compared to crowns manufactured via the direct technique utilizing auto-polymerizing resin.

Contradicting results were reported by **Alshalan et al (2019)**[5]**,** concluded that the software design of CAD/CAM system whether it was subtractive or additive had an impact on the marginal adaptation of prosthesis. They stated that despite the advantages of additive technique, it has less marginal fit compared to the subtractive technique. This additive technique discrepancy is due to the shrinkage during building, post-curing, and minimal thickness of the layers.

Wu et al. (2021)[48], documented Conventionally constructed provisional crowns have an internal & marginal fit that is superior to those constructed using CAD-CAM technique & 3D printing. The observed variance in outcomes could potentially be attributed to the conventional construction of provisional crowns utilizing bis-acrylic composite, which potentially exhibits enhanced clinical performance in comparison to PMMA.

Actually, composite resins exhibit reduced polymerization shrinkage in comparison to materials like methyl methacrylate, which comprises mono-methacrylate, owing to the monomers' lower molecular weight[49-50].

Fracture resistance:

It has been reported that conventional technique has a greater impact on fracture strength than milled restoration machining. Furthermore, information regarding the fracture resistance of 3D printed provisional restorations is limited in comparison to other methods.

In order to evaluate the fracture resistance of provisional restorations constructed using conventional, 3D printing, & CAD/CAM methods, the current study was conducted.

The present investigation was guided by the hypothesis that the fracture resistance of provisional crowns constructed using conventional, CAD/CAM, &3D printing methods would not differ. In contrast, the findings indicated that 3D printed provisional crowns exhibited superior fracture resistance in comparison to milled crowns &conventional techniques crowns, leading to the rejection of the null hypothesis.

In the present study, all provisional crowns were cemented to their epoxy dies before fracture resistance measurement. ZONE cement was preferred to be used rather than ZNO cements. As the residual eugenol in ZOE cements alters the polymerization of some resins and may also cause sensitivity to some patients. The ZONE cements can solve this problem and increase retention than ZOE[51].

A special cementation loading device was used in current study during cementation of provisional crowns on epoxy resin dies instead of finger pressure. Using a constant value of pressure is very important at the time of cement setting to ensure a uniform thickness of cement under all [crowns52].

Upon analysis of the fracture resistance results, the mean ± standard deviation (SD) values for the milled group (1334.71±72.87 N) & the conventional group (811.03±92.36 N) were determined to be fracture resistance values. In contrast, the printed group exhibited a mean ± SD value of (1456.13±68.98 N). The results indicated that the printed group exhibited a significantly greater mean fracture resistance value compared to both the milled group &the conventional group ($P \leq 0.01$).

The values observed in both the printed & milled groups exceed the clinically accepted normal masticatory forces, varying from 360 to 900 N [53-54] at the molar region. Consequently, it falls within the acceptable range for clinical use.

Due to the layered structure of the 3D-printed object, the printed group may have a higher fracture resistance than other groups [55]. Possible cause of the comparatively high strength: chemical bonding among layers.

The large values of the printed group fracture resistance may also be attributed to the vertical orientation of the 3D printed provisional crowns utilized in the present investigation. The outcome is consistent with the findings of **Alharbi et al. (2017)**[6], who reported that the fracture resistance of horizontally printed crowns with parallel layers to the load direction is lower than that of vertically printed crowns with perpendicular layers to the load direction.

The higher fracture resistance of the printed group may also be attributed to the thin printed layer utilized in the current research, which had a construction thickness of approximately 50 µm. These results correlate with the findings of **Tahayeri et al. (2018)**[23], who discovered that the mechanical properties of samples may be significantly influenced by the thickness of the layers. Their research demonstrated that a reduction in layer thickness results in a rise in the number of interfaces between layers, which ultimately enhances the degree of polymerization within each layer & yields superior mechanical properties.

Furthermore, the outcomes of the present investigation may be attributable to the post-curing procedure implemented in a specialized Next dent curing unit for the 3D-printed crowns. These results are consistent with those of **Tahayeri et al. (2018)**[23], who reported that the post-curing process of 3D printed crowns can result in an elevated rate of conversion &a reduction in the presence of residual monomers, thereby increasing fracture resistance.

Conversely, the diminished fracture resistance values observed in CAD/CAM crowns constructed using alternative methods may be attributable to the presence of parallel lines & fine grooves on the milled crown surfaces. This may be due to the nature of the milling process; prolonged use of these lines could result in a defect or [fracture56].

In their study, **Suralik et al. (2020)**[57] showed that provisional crowns constructed using 3D printing exhibited a significantly greater fracture resistance in comparison to crowns constructed using CAD-CAM technology & conventional techniques.

Significantly greater fracture resistance was observed in the subtractive group of FDPs compared to those produced via the direct method utilizing auto-polymerized PMMA. The observed outcome may be attributed to the thorough pre-polymerization of blocks utilized in the CAD-CAM fabrication procedure prior to milling, which led to the development of a polymer network with an increased load-bearing [capacity57].

In contrast, **Sadid-Zadeh et al. (2021)**[58] discovered no statistically significant difference between conventional method & CAD-CAM technology-fabricated provisional crowns with regard to this aspect. It is important to note that the indirect-direct method was utilized in the production of provisional crowns. Additionally, bis-acryl composite resin was employed in the direct manufacturing of provisional crowns.

Conversely, the outcomes of the current investigation differed from those reported by **Hazeveld et al. (2014)**[59], which indicated that milling technique obtained provisional crowns with greater fracture resistance than 3D printing technology. This occurs as a result of the crowns contracting during construction & after curing. Additionally, conversions & manipulations of data during formatting to an STL format may result in modifications.

Furthermore, the results obtained in this study were inconsistent with those reported by **Digholkar et al. (2016)**[7] who conducted a comparative analysis of the mean flexural strength values of provisional crowns manufactured using three distinct techniques. The flexural strength of the 3D printed crowns was the lowest (79.54 MPa) comparing to the conventional group's crowns (95.58 MPa). The CAD/CAM group exhibited the greatest flexural strength (104.20 MPa).

V. Conclusions:

Within the study's limitations, the following conclusions may be drawn as follows compared to traditional and CAD/CAM techniques, the marginal adaptation of provisional restoration constructed with 3D printing process proved to be more precise. The CAD/CAM fabricated provisional restoration was shown to have the second-highest fracture resistance, behind 3D printing. whereas the least fracture resistance was demonstrated by the traditional method. The utilization of 3-D printing for additive manufacturing of provisional crowns may be regarded as a dependable and conservative approach to construct stronger provisional restorations.

VI. Recommendations:

3D printing technique is preferred in long-term temporization as it has good marginal adaptation and high fracture resistance. Based on the present outcomes of the recent research further investigation are needed to done about the other physical and mechanical properties of the material. Further in vitro studies should be carried out on natural teeth with a larger sample size utilizing different 3d printing systems which allow for optimization of printing parameters which in turn leads to extend the application of 3D printing to provisional crowns. Clinical trials must be under oral conditions with variant tooth preparations, scanners and machines are needed to verify the present results, testing material durability and longevity.

VII. Limitations Of The Study:

In vitro studies cannot completely simulate the oral environment such as the saliva or blood presence, restricted mouth opening which can limit the digital scanner accuracy, fluctuation in PH and the presence of parafunctional habits.

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