



Research Article

Water Sorption and Solubility Behavior of Provisional Restorative Materials Fabricated by Conventional, CAD/CAM, and 3D printing Methods

Hussein Hayder Qasim¹ , Mohammed A. Abdulla² , Hasan Khiraldeen Mohialdeen^{*3} 

¹ First Specialized Dental Center, Kirkuk Health Directorate, Kirkuk, Iraq

² Department of Prosthodontics, College of Dentistry, University of Mosul, Mosul, Iraq

³ PhD Candidate, School of Dentistry, University of Sheffield, UK

* Corresponding author: hasankm2013@uomosul.edu.iq

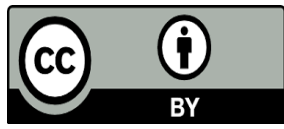
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Abstract

Aims: The present study aimed to assess and compare the levels of water sorption and solubility of provisional restorative materials manufactured by conventional, CAD/CAM, or 3D printing methods.

Materials and Methods: A total of forty-two circular samples of (15mm × 2 mm diameter, thickness respectively) respectively were fabricated and divided into three groups (n= 7 for each sample): Group A: 3D-printed at 0°, 15°, and 45° build angles by using a digital light processing (DLP) printer (Creality LD-006, China) with (FREEPRINT® temp resin, Germany), Group B: CAD/CAM milled at high (5-8m) and low (8-15m) speed by using pre-polymerized PMMA blocks (Dental Direct polyX ML, Germany) using a 5-axis milling machine (Zahndent, China), Group C: Conventional self-curing interim resin IMICRYL® (Imident powder, Turkey). All samples were tested for water sorption and solubility tests. The collected data were statistically analyzed using one-way ANOVA and independent t-tests, with the significance level set at 0.05.

Results: The results of the one-way ANOVA test indicated a statistically significant variation ($P \leq 0.01$) in water sorption values between 3D-printed provisional restorations fabricated with build angles of 0°, 15°, and 45°, but not in water solubility, for which there was no significant difference ($P > 0.05$). However, Independent samples t-tests showed no statistically significant difference ($P > 0.05$), indicating that the variation in milling speeds, low (8-15 m/min) versus high (5-8 m/min) had no detectable effect on water sorption or solubility in the CAD/CAM groups. Comparing all the fabrication processes, ANOVA indicated significant differences ($P \leq 0.05$) in both parameters. Duncan's test showed the highest water sorption in 3D-printed 0° (1.0029 $\mu\text{g}/\text{mm}^3$), followed by 15° (0.878 $\mu\text{g}/\text{mm}^3$) and 45° (0.8177 $\mu\text{g}/\text{mm}^3$). CAD/CAM low-speed milling had 1.1501 $\mu\text{g}/\text{mm}^3$ and high-speed 1.1069 $\mu\text{g}/\text{mm}^3$, while conventional PMMA had 1.0078 $\mu\text{g}/\text{mm}^3$. For water solubility, conventional PMMA had the highest mean value (0.0887 $\mu\text{g}/\text{mm}^3$), and the 3D-printed 0° group had the lowest (0.0183 $\mu\text{g}/\text{mm}^3$).

Conclusion: Results indicate that fabrication method and build orientation influence the water sorption and water solubility of provisional restorative materials. 3D-printed restorations, particularly those printed at a 0° build angle, exhibited the least solubility and good water resistance compared to CAD/CAM and control PMMA groups. The results demonstrate the potential of optimized 3D printing parameters in producing long-lasting, water-resistant provisional restorations.

Keywords: CAD/CAM, 3D printing, Provisional restorations, Water sorption, Water solubility

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INTRODUCTION

Well-fabricated temporary crowns are essential for achieving high-quality definitive restorations, ensuring function, esthetics, and periodontal health (1). Provisional restorations serve multiple purposes, including protecting the prepared teeth, maintaining occlusal relationships, and allowing clinicians to evaluate the esthetics and function before the fabrication of the final prosthesis (2). Provisional restorative materials are required to resist intraoral thermal fluctuations and occlusal forces, particularly when used for extended clinical periods or complex treatments such as full-mouth rehabilitation or implant-supported prostheses (3-6). Thus, their mechanical and physical properties are vital to their clinical success (5).

Traditionally, provisional materials are categorized into two groups according to their chemical composition: those based on mono-methacrylate-based acrylic resins, such as polymethyl methacrylate (PMMA), polyethyl methacrylate (PEMA), and dimethacrylate-based bis-acryl composite resins, typically formulated from bisphenol A-glycidyl dimethacrylate (Bis-GMA) and urethane dimethacrylate (UDMA) monomers (7,8).

Conventional materials, including PMMA and bis-acryl resins, remain widely used due to their ease of manipulation, low cost, and acceptable esthetics (8,9). However, PMMA materials are prone to polymerization shrinkage, heat generation, and the release of residual monomers, while bis-acryl composites exhibit lower shrinkage and reduced exothermic reactions (10). These differences are largely attributed to their polymerization mechanisms. PMMA undergoes free-radical polymerization that results in higher residual monomers and internal porosities, making it more susceptible to water sorption and solubility. In contrast, bis-acryl resins form a more cross-linked dimethacrylate network, which limits water uptake and enhances dimensional stability (11).

The introduction of computer technologies like computer-aided design/computer-aided manufacturing (CAD/CAM) and three-dimensional (3D) printing technology has significantly improved the fabrication of provisional restorations (12). CAD/CAM

PMMA blocks are industrially polymerized at high temperature and pressure, which results in a higher density and strength, whereas 3D printing offers faster and cheaper additive fabrication(13). In CAD/CAM procedures, milling parameters—particularly spindle speed—play a critical role in the quality of the final restoration. While higher milling speeds can reduce fabrication time, they may also lead to increased surface roughness and marginal discrepancies, as observed in studies evaluating zirconia restorations. These findings highlight the need to balance efficiency with surface quality and marginal fit when selecting milling protocols (14).

Water sorption and solubility are critical factors that influence the stability and biological safety of provisional materials in the oral environment (15-16). Excess sorption can trigger dimensional distortion, while increased solubility may release residual monomers that irritate tissues (17). Therefore, reducing both properties is essential for maintaining the longevity of temporary restorations(16). Sorption reflects the penetration of oral fluids into the material, whereas solubility indicates the loss of soluble components into saliva(12,13,18,19). When elevated, these behaviors weaken the mechanical integrity and overall reliability of the restoration, emphasizing the need to control them for optimal clinical performance(2,17,20).

This research was carried out to investigate and compare the water sorption and solubility behavior of different provisional restorative materials produced by conventional (reflecting a widely practiced conventional method in dentistry), CAD/CAM (to evaluate the impact of milling speed), the milling speed in CAD/CAM systems has little impact on the fundamental properties of fully polymerized blocks, and 3D printing methods (to examine how printing angle influences material characteristics).

MATERIALS AND METHODS

A summary of the materials utilized in the present study is provided in Table 1.

Table (1): Materials used in the study.

Materials	Manufacturer	Composition	Source	Batch No.
3D printed material	DETAX FREEPRINT® temp	*Isopropylidenediphenol PEG-2 dimethacrylate; 1,6-Hexanediol dimethacrylate (HDDMA); 2-Hydroxyethyl methacrylate (HEMA); Hydroxypropyl methacrylate (HPMA); Diphenyl(2,4,6-trimethylbenzoyl) phosphine oxide (TPO); Phenyl-bis(2,4,6-trimethylbenzoyl) phosphine oxide (BAPO).	Germany	04059
CAD-CAM material	Dental Direct poly XML	Polymethylmethacrylate (PMMA) and Color pigments	Germany	BIO 5193
Conventional provisional material	IMICRYL®(Imident powder)	Polymethyl methacrylate powder (cadmium free), methyl methacrylate monomer	Turkey	TS8230

Forty-two specimens of provisional restorative materials were prepared and categorized into three groups (n= 7 for each sample) based on the fabrication method employed:

Group A: 3D printing at build angles of 0°, 15°, and 45°. (N=21) 7 for each group.

Group B: CAD/CAM by milling prefabricated resin blocks under two protocols: a high-speed process (5–8 minutes) and a low-speed process (8–15 minutes). (N=14) 7 for each group.

Group C: Conventional self-curing (auto polymerizing) PMMA, fabricated using the traditional flasking procedure. (N=7)

Specimen Preparation

3D-Printed Specimens

The 3D-printed specimens (Figure 1) were produced utilizing a digital light processing (DLP) printer, Creality LD-006 (Shenzhen Creality 3D Technology Co., Ltd., Shenzhen, China), with FREEPRINT® Temp resin (detax GmbH, Germany). STL designs (Figure 1) were processed in HalotBox slicer software and printed at build

angles of 0°, 15°, and 45° with a layer thickness of 100 µm. After printing, the specimens were cleaned in 99% isopropyl alcohol for four minutes and subsequently post-cured under 405 nm ultraviolet light for thirty minutes in a Creality curing unit (21).

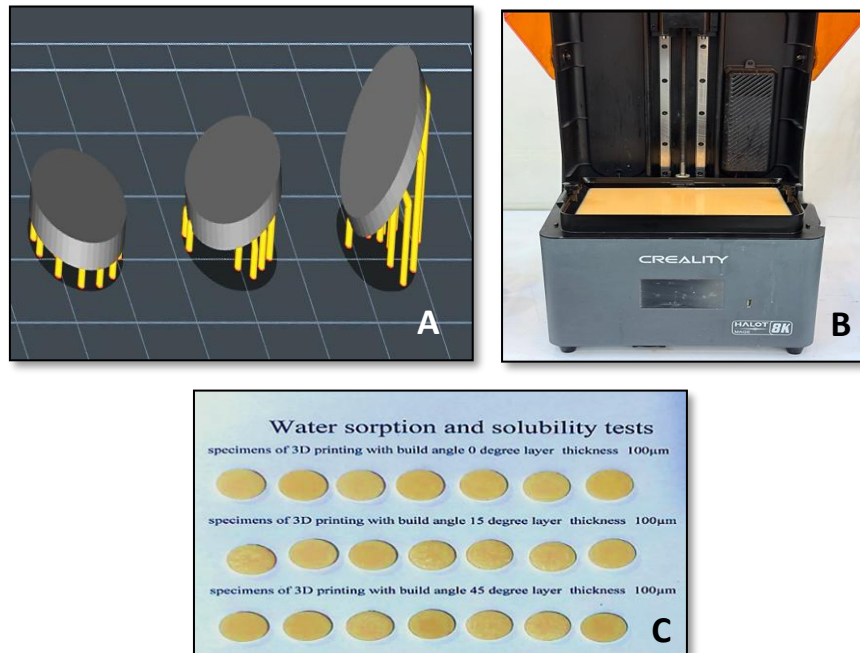


Figure 1. A) Samples for 3D-printed restoration resin were digitally designed at different build orientations (0°, 15°, and 45°) with the corresponding printing support structures. B) Digital printer. C) Printed samples

CAD/CAM Specimens

The CAD/CAM specimens (Figure 2) were fabricated by milling pre-polymerized PMMA blocks (Dental Direct polyX ML) using a 5-axis milling machine (Zahndent, China). Virtual models were designed in GO2 dental CAM software, exported as STL files, and milled with burs of 2.5, 1.0, and 0.5 mm diameter (3,22).

The milling speed was controlled by setting two specific protocols in the CAM software:

- High-speed protocol: Milling time 5–8 minutes per specimen
- Low-speed protocol: Milling time 8–15 minutes per specimen

By adjusting the feed rate, spindle speed, and step-over parameters in the software, the machine maintained consistent cutting conditions for each speed group. This

allowed us to systematically evaluate the effect of milling speed on the specimens while keeping other factors (tool type, bur size, and cooling) constant.

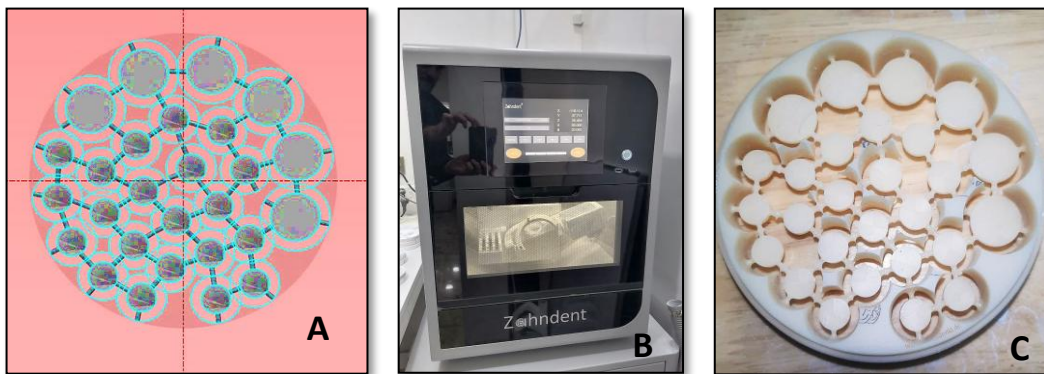


Figure (2): A) Sample design with GO2dental Cam software to be prepared for milling. B) CAD CAM Milling Machine (Zahndent). C) Samples after milling.

Conventional Specimens

The conventionally fabricated specimens were produced using a self-curing PMMA resin (IMICRYL®, Imident powder) according to the traditional flasking technique. Resin patterns were invested in a two-part brass flask using die stone and a separating medium (Zhermack®, Italy). The acrylic resin was mixed according to the manufacturer's recommended powder-to-liquid ratio, packed into the mold, and processed in an Alvomet unit (DIKAN 105) under controlled pressure and mild heat. Although the resin is chemically classified as a self-curing PMMA, the specimens were subjected to a standardized post-packing cycle consisting of 70°C for 5 minutes under controlled pressure. Applying this combination of moderate heat and pressure is widely recommended to improve the polymer network of auto-polymerizing PMMA by reducing porosity, enhancing monomer-polymer conversion, and decreasing the amount of residual monomer, without converting the material into a heat-cured system. Such protocol is consistent with previous findings demonstrating that short-term exposure of autopolymerizing PMMA to temperatures between 60–80°C significantly lowers residual monomer content and improves the physical properties of the material (23). Following polymerization, the flask was allowed to bench-cool

before deflasking, and all specimens were subsequently finished and polished before testing.

Water sorption and Water solubility

Water sorption and solubility were assessed according to the procedure outlined by Shin *et al.*(16). In total, forty-two disk-shaped specimens, each measuring 15 mm in diameter and 2 mm in thickness, were produced using the fabrication techniques previously described. The specimens were divided into six subgroups: three 3D-printed groups fabricated at build orientations of 0°, 15°, and 45°, two CAD/CAM groups (high-speed and low-speed milling), and one conventional self-cured PMMA group.

Following fabrication, all specimens were stored in a desiccator containing silica gel and maintained at 37 °C until a stable mass was achieved, which was confirmed through successive measurements. The mass of each specimen was determined using a Joanlab analytical balance (Figure 3) with a precision of (±0.1 mg). Weights were recorded in milligrams (mg), and the final stable value obtained after multiple readings was noted as (m¹). Next, the specimens were submerged in distilled water and stored at 37 °C for a period of 7 days. Following immersion, surface moisture was removed by air-drying for 15 seconds, and the specimens were weighed again after 1 minute to determine (m²). Afterward, the specimens were placed back in the desiccator and maintained at 37 °C for reconditioning with silica gel until a stable weight was achieved, which was recorded as (m³). The values of water sorption (WSP) and water solubility (WSL) were determined according to the following formulas.

$$\text{WSP (\%)} = \frac{m_2 - m_1}{m_1} \times 100 \quad (1)$$

$$\text{WSL (\%)} = \frac{m_1 - m_3}{m_1} \times 100 \quad (2)$$



Figure (3): A digital balance for weighing the specimens for water sorption and solubility.

Statistical Analysis

Statistical analysis of the obtained data was carried out using SPSS software (version 23; Statistical Package for the Social Sciences). The statistical procedures included descriptive statistics, the Shapiro–Wilk test for normality, the independent-samples t-test, one-way ANOVA, and Duncan’s multiple range test. A level of significance of $p < 0.05$ was considered statistically significant.

RESULTS

The Shapiro-Wilk test was initially applied to assess the normality of the main study data for water sorption and water solubility across all groups, indicating that the data were parametric and followed a normal distribution.

The mean \pm standard deviation (SD) values for water sorption and water solubility for the tested provisional materials are summarized in (Table 2). One-way ANOVA (Table 3) revealed a significant difference ($P \leq 0.01$) in the mean water sorption values, whereas no significant difference was observed in the mean water solubility among the 3D-printed provisional restoration groups at build angles of 0° , 15° , and 45° .

The results of the independent-samples t-test for equality of means (Table 4) revealed that the difference in water sorption and water solubility between the two CAD/CAM groups produced at different milling speeds (low and high) was not statistically significant.

One-way (ANOVA) in (Table 5) indicated a statistically significant difference ($P \leq 0.05$) in the mean value of the water sorption and water solubility for the 3D-printed

specimens fabricated at 0°, 15°, and 45°, the CAD/CAM subgroups processed at low and high milling speeds, and the conventionally produced group.

Table (2): Mean, Standard Deviation of the water sorption and water solubility for the Tested Materials:

	Water sorption Mean ± SD	Water solubility Mean ± SD
3D Printed (0)	1.00 ± 0.06	0.01 ± 0.01
3D Printed (15)	0.87 ± 0.07	0.02 ± 0.01
3D Printed (45)	0.81 ± 0.05	0.02 ± 0.01
CAD-CAM Low(8-15m)	1.15 ± 0.02	0.07 ± 0.01
CAD-CAM High(5-8m)	1.10 ± 0.08	0.05 ± 0.00
Conventional	1.07 ± 0.07	0.08 ± 0.01

SD= Standard deviation

Table (3): One-way analysis of variance for Water sorption and Water solubility test of the 3D printed provisional restoration groups fabricated with different orientations (0, 15, 45).

Water sorption ANOVA					
SOV	SS	DF	MS	F-value	P-value
Between Groups	.125	2	.062	14.418	.000*
Within Groups	.078	18	.004		
Total	.203	20			
Water solubility ANOVA					
Between Groups	.000	2	.000	.322	.729
Within Groups	.004	18	.000		
Total	.004	20			

SOV: the source of variance; SS: Sum of Squares; DF: the degree of freedom; MS: mean square. *Statistically significant at p < 0.01.

Table (4): Independent Samples t-test of water sorption and water solubility test between CAD-CAM groups.

Tests	Groups	N	Mean ±SD	T value	Sig.
Water sorption	CAD-CAM Low (8-15)	7	1.1501 ± 0.0239	1.235	.240
	CAD-CAM High (5-8)	7	1.1069 ± 0.0894		
Water solubility	CAD-CAM Low (8-15)	7	0.0719 ± 0.0194	1.725	.110
	CAD-CAM High (5-8)	7	0.0591 ± 0.0030		

Table (5): One-way analysis of variance for Water sorption and Water solubility test of the 3D printed, CAD-CAM, and the conventional provisional restoration groups.

Water sorption ANOVA					
SOV	SS	DF	MS	F-value	P-value
Between Groups	.616	5	.123	27.850	.000*
Within Groups	.159	36	.004		
Total	.775	41			

Water solubility ANOVA					
SOV	SS	DF	MS	F-value	P-value
Between Groups	.031	5	.006	29.904	.000*
Within Groups	.008	36	.000		
Total	.039	41			

SOV: the source of variance; SS: Sum of Squares; DF: the degree of freedom; MS: mean square. *Statistically significant at $p < 0.01$.

According to (Figure 4), Duncan’s test revealed that water sorption was greatest in the CAD/CAM group milled at low speed, followed by the conventional PMMA group, with the 3D-printed groups exhibiting progressively lower values as the build angle increased.

According to (Figure 5), Duncan’s test revealed that water solubility was highest in the conventional PMMA group, followed by the CAD/CAM material milled at low speed, then the CAD/CAM material milled at high speed, while the 3D-printed group fabricated at a 0° build angle showed the lowest solubility values.

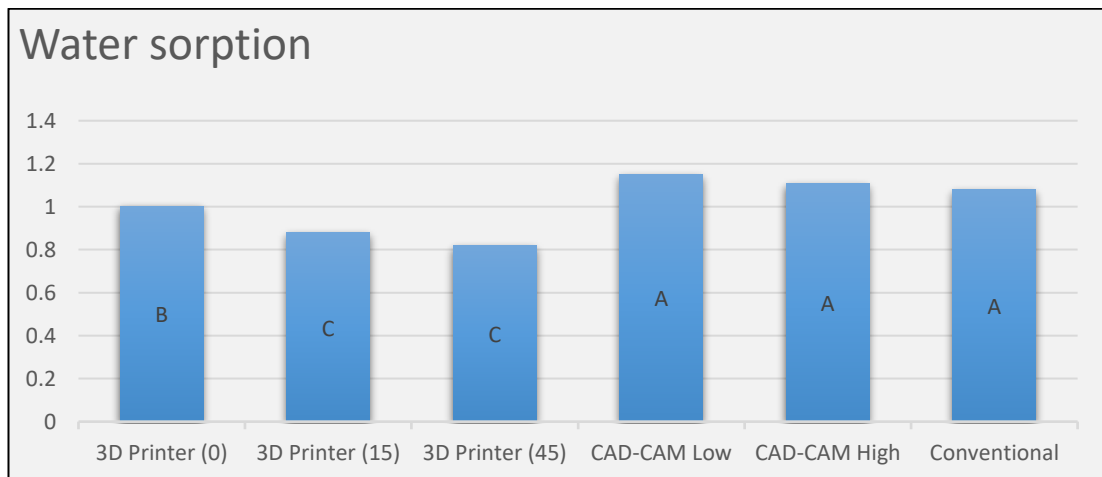


Figure (4): Duncan's multiple range test, mean, and standard deviation for the water sorption test of (0, 15, and 45) 3D printed, (high and low) CAD-CAM, and conventional groups. Bars labeled with the same letters represent non-significant differences ($P > 0.05$), whereas bars with different letters indicate significant differences ($P \leq 0.05$).

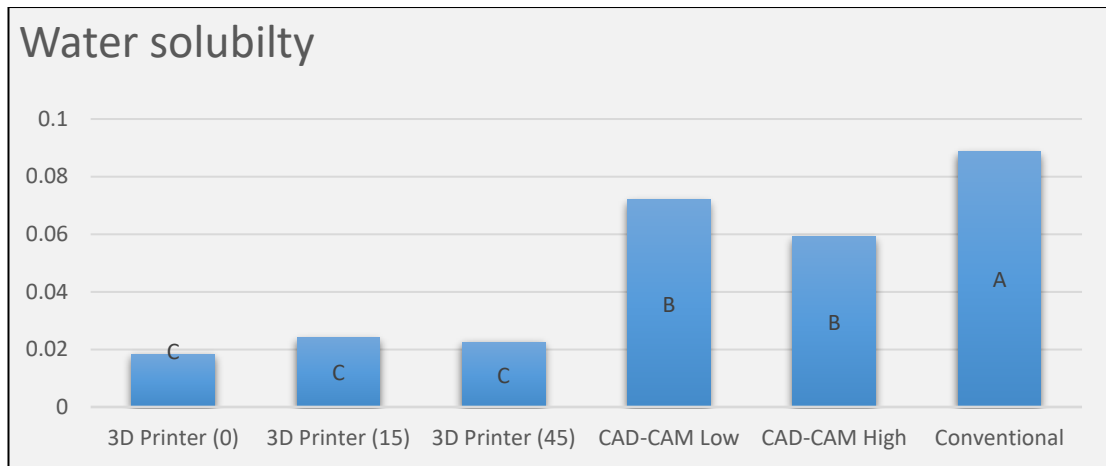


Figure (5): Duncan's multiple range test, mean, and standard deviation for the water solubility test of (0, 15, and 45) 3D printed, (high and low) CAD-CAM, and conventional groups. Bars labeled with the same letters represent non-significant differences ($P > 0.05$), whereas bars with different letters indicate significant differences ($P \leq 0.05$).

DISCUSSION

The purpose of this study was to evaluate and compare the water sorption and water solubility of provisional restorative materials fabricated through 3D printing, CAD/CAM, and conventional methods. While in vitro studies cannot fully replicate the complex oral environment, they provide a controlled and consistent approach for assessing and comparing the essential properties of these materials (24).

Water sorption and solubility play a fundamental role in determining the durability and clinical success of provisional restorations. Excessive fluid absorption can weaken the material and cause dimensional alterations, increasing the likelihood of deformation or failure (12,13,25). Likewise, elevated solubility may lead to the release of residual monomers or additives, which can irritate surrounding oral tissues. Consequently, it is crucial to choose materials exhibiting low water sorption and solubility to preserve structural integrity and achieve reliable long-term performance (26). Furthermore, these properties should be carefully evaluated when assessing different fabrication techniques, as factors such as polymerization method, layer orientation, or milling parameters can affect the material's interaction with oral fluids and, in turn, its clinical stability and performance.

Water sorption and solubility are significant parameters influencing the long-term durability and performance of provisional restorative materials. Water sorption is defined as the quantity of water taken up by the material, which can alter its mechanical and dimensional properties, leading to potential failure (12,13,25). High solubility would also lead to the leaching of unpolymerized entities that could be irritating to oral tissues. Therefore, good material should exhibit low water sorption and solubility to ensure clinical durability (26).

In this study, 3D printing, CAD/CAM, and conventional provisional materials were compared. Among the 3D printing groups, specimens printed at a 0° build angle exhibited significantly higher water sorption than those fabricated at 15° and 45°. This can be explained by the fact that 0° layer direction printing produces more interlayer gaps and micro voids through which water can be absorbed, whereas angled directions increase interlayer adhesion and density, with less sorption (27). No difference was found between 15° and 45°, meaning both are sufficient to provide interlayer bonding and less porosity. Moreover, the degree of polymerization saturation is critical: improved light exposure and thorough post-curing create a denser, more cross-linked polymer matrix, reducing micro-voids and subsequent water uptake. The combination of build orientation and polymerization saturation, therefore, jointly influences the ultimate water sorption behavior of 3D-printed provisional materials (28).

Within the CAD/CAM groups, no significant differences were observed between low and high milling speeds. This result is due to the somewhat industrial complete polymerization under controlled temperature and pressure, resulting in PMMA blocks that are dense and homogeneous with negligible porosity. As water sorption depends more on internal structure than on surface conditions, changes in milling speed have very little influence. However, milling speed was included in the study to determine whether different processing parameters might introduce microstructural or surface alterations influencing water interaction. Although the findings indicated negligible influence, assessing this factor ensured a more comprehensive evaluation of all

potential variables related to the fabrication process. Among all the fabrication methods, 45° built samples showed the lowest water sorption, whereas the low-speed CAD/CAM group showed slightly higher values. The higher sorption in the CAD/CAM low-speed group may be related to the generation of surface roughness and potential microcracks due to prolonged bur contact, which increases the surface area available for moisture uptake (29).

The findings highlighted the importance of manufacturing parameters, specifically the build angle during 3D printing, in resisting moisture and maintaining dimensional stability within the oral environment. Ultimately, optimized 3D-printing strategies, particularly those involving steeper build angles, may offer improved resistance to moisture, making them favorable for maintaining dimensional stability in the oral environment. The present results disagree with Song *et al.* (15), found that 3D-printed temporary restorations possess higher water sorption than conventional PMMA resin. Conversely, Berli *et al.* (27), found that certain 3D-printed resins absorb more water than pre-fabricated PMMA and that this depends on resin composition and printing parameters. Moreover, Şahin and Özer (2) confirmed that conventionally bis-acrylic materials have higher water sorption than digitally printed ones.

Water solubility refers to the amount of material that dissolves into water, which can lead to material degradation and release of components into the oral environment. Dimitrova *et al.* (13) stated that lower water solubility is desirable for long-term clinical success. All 3D-printed samples showed the least solubility, which did not differ significantly in different build angles, indicating that solubility is more influenced by the chemical structure and cross-link density of the polymer rather than its orientation. CAD/CAM specimens exhibited slightly higher solubility at low milling speed. This can be explained by the fact that both groups were fabricated from industrially polymerized PMMA blocks with high conversion rates, leaving minimal soluble compounds (30).

Conventional materials showed the highest solubility, which can be explained by the residual monomers and incomplete polymerization for self-cured resins.

All of our findings are in agreement with research by Stansbury and Idacavage (31), who stated that optimum photo-polymerization and increased polymer cross-linking in 3D-printed resins reduce leachable components and improve stability. Sahin and Ozer (2). Also confirmed that CAD/CAM and 3D-printed materials generally show lower water sorption and solubility than conventional resins. Conversely, other studies have reported that certain 3D-printed resins, particularly PMMA and photopolymer resins, can exhibit higher solubility than CAD/CAM and some conventional materials (16). According to Mudhaffer *et al.*(32), observed that the build angle has a governing influence on the performance of the material. However, while significant differences in water sorption were observed between different build angles, no significant differences were found in water solubility (Wsl).

The lower solubility values observed in 3D-printed materials reflect their enhanced photopolymerization efficiency and densely cross-linked polymer structure, which minimizes the leaching of soluble components and improves hydrolytic stability. This finding is consistent with Aldhafyan *et al.*(33), who reported that curing mode significantly influences monomer elution, sorption, and solubility in resin-based materials.

These findings underscore the applicability of digital fabrication techniques and optimization of process parameters to enhance the physical and chemical stability of temporary restorations, supporting their long-term clinical resilience.

In summary, 3D-printed temporary materials, especially those fabricated at inclined build angles, exhibited improved resistance to water sorption and solubility compared with CAD/CAM and conventional resins. The results highlighted the importance of digital fabrication techniques and optimized production parameters for enhancing the physical stability and clinical longevity of temporary dental restorations.

CONCLUSIONS

Within the limitations of the current study, it is possible to conclude that:

The present study shows that water sorption and solubility of temporary restorative materials are significantly influenced by the manufacturing method. 3D-printed materials, particularly those fabricated at higher building angles (45°), showed the least water sorption and solubility compared to the test groups, indicating greater dimensional stability and resistance to water. CAD/CAM materials showed intermediate performance, while conventional resins exhibited the greatest water absorption and solubility.

Editorial Independence Statement

Dr. Mohammed Abdullatif Abdulla is a co-author of this article and serves as Editorial Manager of *Al-Rafidain Dental Journal*. In accordance with the journal's editorial conflict-of-interest and independence policies, he was fully excluded from all editorial and peer-review processes related to this manuscript. This submission was processed under the journal's standard peer-review procedures and was handled independently by Dr. Omar Abdulla (Associate Editor), who declared no conflict of interest and had full responsibility for the editorial evaluation and final publication decision. The Editor-in-Chief had no involvement in the editorial handling or decision-making for this manuscript.

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Authors' Contribution

Qasim HH, Abdulla MA, and Mohialdeen HKh completed Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing-review editing by Abdulla MA. All authors have read and approved the final manuscript.

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Ethical statement: This research was conducted in compliance with ethical standards and received approval from the Research Ethics Committee and Scientific Committee of the College of Dentistry, University of Mosul.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript

Availability of data and materials: All data generated or analyzed during this study are included in this published article and its supplementary information files.

Declaration of Generative AI and AI-assisted technologies

During the preparation of this work, the authors used grammar tools to improve certain statements. The authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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سلوك امتصاص الماء وذوبان مواد الترميم المؤقتة المصنعة بالطرق التقليدية، وتقنيات التصميم بمساعدة الحاسوب، والطباعة ثلاثية الأبعاد

حسين حيدر قاسم¹, محمد عبد اللطيف عبد الله², حسن خير الدين محي الدين³

1 المركز التخصصي الأول لطب الأسنان، مديرية صحة كركوك، كركوك، العراق

2 فرع صناعة الاسنان، كلية طب الأسنان، جامعة الموصل، الموصل، العراق

3 طالب دكتوراه، كلية طب الأسنان، جامعة شيفيلد، المملكة المتحدة

الملخص

الأهداف: هدفت الدراسة الحالية إلى تقييم ومقارنة مستويات امتصاص الماء وذوبان مواد الترميم المؤقتة المصنعة بالطرق التقليدية أو CAD/CAM أو الطباعة ثلاثية الأبعاد. **المواد وطرائق العمل:** تم تصنيع 42 عينة دائرية بأبعاد (قطر 15 مم × سمك 2 مم) وقُسمت إلى ثلاث مجموعات (7 عينات لكل مجموعة): المجموعة أ: طبعت بتقنية الطباعة ثلاثية الأبعاد بزوايا بناء 0° و 15° و 45° باستخدام طابعة معالجة الضوء الرقمية (DLP) (Creality LD-006، الصين) مع راتنج (FREEPRINT® temp، ألمانيا). المجموعة ب: تم تحضيرها بتقنية CAD/CAM بسرعة عالية (5-8 م/ث) ومنخفضة

(8-15 م/ث) باستخدام كتل PMMA مُبلّمة مسبقاً (Dental Direct polyX ML، ألمانيا) باستخدام آلة الخراطة خماسية المحاور (Zahndent، الصين). المجموعة ج: راتنج IMICRYL® المؤقت ذاتي التصلب التقليدي (مسحوق Imident، تركيا). خضعت جميع العينات لاختبارات امتصاص الماء والذوبان. تم تحليل البيانات المجمعة إحصائياً باستخدام تحليل التباين أحادي الاتجاه (ANOVA) واختبارات t المستقلة، مع تحديد مستوى الدلالة عند 0.05. **النتائج:** أشارت نتائج اختبار تحليل التباين أحادي الاتجاه إلى وجود تباين ذي دلالة إحصائية ($P \leq 0.01$) في قيم امتصاص الماء بين الترميمات المؤقتة المطبوعة ثلاثية الأبعاد والمصنعة بزوايا بناء 0° و 15° و 45°، ولكن لم يُلاحظ أي فرق ذي دلالة إحصائية في قابلية الذوبان في الماء ($P > 0.05$). ومع ذلك، لم تُظهر اختبارات t للعينات المستقلة أي فرق ذي دلالة إحصائية ($P > 0.05$)، مما يشير إلى أن التباين في سرعات الخراطة، المنخفضة (8-15 م/دقيقة) مقابل العالية (5-8 م/دقيقة)، لم يكن له تأثير ملحوظ على امتصاص الماء أو قابلية الذوبان في مجموعات CAD/CAM. وبمقارنة جميع عمليات التصنيع، أشار تحليل التباين إلى وجود فروق ذات دلالة إحصائية ($P \leq 0.05$) في كلا المعيارين. أظهر اختبار دنكان أعلى امتصاص للماء في المواد المطبوعة ثلاثية الأبعاد بزوايا 0° (1.0029 ميكروغرام/مم³)، تليها المواد بزوايا 15° (0.878 ميكروغرام/مم³) ثم بزوايا 45° (0.8177 ميكروغرام/مم³). وبلغ امتصاص الماء في عملية الخراطة البطيء باستخدام تقنية CAD/CAM 1.1501 ميكروغرام/مم³، وفي عملية الخراطة السريعة 1.1069 ميكروغرام/مم³، بينما بلغ في مادة PMMA التقليدية 1.0078 ميكروغرام/مم³. أما بالنسبة لذوبان الماء، فقد سجلت مادة PMMA التقليدية أعلى متوسط (0.0887 ميكروغرام/مم³)، بينما سجلت مجموعة المواد المطبوعة ثلاثية الأبعاد بزوايا 0° أدنى متوسط (0.0183 ميكروغرام/مم³). **الاستنتاجات:** تشير النتائج إلى أن طريقة التصنيع واتجاه الطباعة يؤثران على امتصاص الماء وذوبانه في مواد الترميم المؤقتة. أظهرت الترميمات المطبوعة بتقنية الطباعة ثلاثية الأبعاد، وخاصةً تلك المطبوعة بزوايا بناء 0 درجة، أقل قابلية للذوبان ومقاومة جيدة للماء مقارنةً بمجموعات CAD/CAM ومجموعات PMMA. تُبرز هذه النتائج إمكانية استخدام معايير الطباعة ثلاثية الأبعاد المُحسّنة في إنتاج ترميمات مؤقتة طويلة الأمد ومقاومة للماء.

الكلمات المفتاحية: التصميم والتصنيع بمساعدة الحاسوب، الطباعة ثلاثية الأبعاد، الترميمات المؤقتة، امتصاص الماء، الذوبان في الماء