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Comparison of Water Sorption of Three Provisional Crown and Bridge Materials: An In Vitro Study

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Abstract

Background and Aim: Water sorption of provisional crown materials decreases their mechanical properties and longevity, depending on the material type. This study aimed to compare the water sorption of three provisional crown materials in vitro.

Materials and Methods: In this in vitro experimental study, 14 disc-shaped specimens measuring 1 x 15 mm were fabricated from Telio CAD polymethyl methacrylate (PMMA) computer-aided design-computer-aided manufacturing (CAD-CAM) block (Ivoclar Vivadent), self-cure PMMA acrylic resin (Tempron GC), and ProviTemp K acrylic-based composite resin (Provi Temp K). The specimens were randomly coded and their weight (with 0.0001 g accuracy) and volume (with 0.001 mm accuracy) were measured. The water sorption of the specimens was calculated after 7 and 30 days. One-way ANOVA was applied for data analysis (α=0.05).

Results: On day 7, the highest water sorption was noted in Bisco acrylic-based composite resin (mean: 22.84±5.04 μg/mm^3) and the lowest water sorption was recorded in PMMA CAD-CAM block (mean: 14.22±3.23 μg/mm^3) (P=0.023). At 30 days, the highest water sorption was recorded in Tempron GC self-cure acrylic resin (mean: 48.53±18.44 μg/mm^3) and the lowest water sorption was noted in PMMA CAD-CAM block (mean: 40.24±5.33 μg/mm^3) (P=0.002).

Conclusion: The water sorption of Bisco acrylic-based composite resin and Tempron GC self-cure acrylic resin was very high in the short-term. However, after 30 days, the water sorption of Bisco acrylic-based composite resin and PMMA CAD-CAM block was the same. It appears that all three tested materials can provide acceptable clinical performance for the fabrication of provisional restorations.

Keywords: Acrylic Resins; Composite Resins; Dental Restoration, Temporary

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Introduction

Temporary restorations play an important role in treatment planning and preserve the health and natural structure of periodontal tissues [1]. Thus, it is important to pay attention to the physical and mechanical properties of

different provisional crown materials, particularly their water sorption.

Water sorption is related to solubility, which includes the release of residual materials such as monomers and oligomers [2]. Such products can not only adversely affect the temporary crown and cause voids and microcracks, but also may affect the tooth structure [3]. Several studies have reported the adverse effects of water sorption on provisional crown materials such as their discoloration, reduction of mechanical properties [4-7], reduction of wear resistance, and degradation of bonds, especially between the matrix and fillers on the restoration surface [8,9]. Water sorption can also affect the dimensional stability, dimensional accuracy, mechanical properties, and eventually the longevity of temporary restorations [10-13]. Evidence shows that the water sorption of temporary restorations is influenced by a number of factors [14,15], and even two provisional resin materials with the same chemical formulation but different commercial brands do not have the same level of water sorption.

Provisional crown materials can be divided into two main groups of resin-based materials (i.e., acrylic-based composite resin) and polymer-based materials such as polymethyl methacrylate (PMMA). Self-cure acrylic resin, acrylic-based composite resin, and PMMA computer-aided design-computer-aided manufacturing (CAD-CAM) blocks are among the commonly used provisional crown materials available in the market. Acrylic-based composite resin has advantages such as optimal esthetics and easy application. However, it has drawbacks such as brittle structure and difficult repair, compared with polymer-based crown materials. Thus, it is only used for single-unit temporary restorations [16].

On the other hand, PMMA has properties such as high strength, low cost, color stability, and repairability, and is suitable for the fabrication of long bridges and multi-unit temporary restorations [16]. Nonetheless, it has drawbacks such as tissue irritation, high heat generation during polymerization, and low wear resistance. Considering all the above, this study aimed to compare the water sorption of three provisional crown materials including self-cure acrylic resin, acrylic-based composite resin, and PMMA CAD-CAM block.

Materials and Methods

The sample size was calculated to be a minimum of 7 specimens in each group, according to a study by Tuna et al. [17], assuming $\alpha = 0.05$, $\beta = 0.2$, effect size of 0.75 μg/mm^3, and a mean standard deviation of 0.72 μg/mm^3 using PASS 11 software (PASS 11; NCSS). This study was approved by the ethics committee of the Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran (IR.IAU DENTAL.REC 1399.223). This in vitro, experimental study compared the water sorption of three provisional crown materials, including Provi Temp K acrylic-based composite resin (Provi Temp K, Bisico, Germany), PMMA self-cure acrylic resin (Tempron GC, Dental Product Co., Japan), and Telio CAD CAD-CAM block (Ivoclar, Vivadent). For this purpose, 14 disc-shaped specimens measuring 1 x 15 mm [18] were fabricated from each material (a total of 42). A brass ring-shaped mold measuring 1 x 15 mm was used to fabricate self-cure acrylic resin and acrylic-based composite resin specimens [18]. The acrylic-based composite resin specimens were cured with a laboratory curing unit (LABO Light LV-III-120W-GC, Japan) with 220 nm to 480 nm wavelength and 1500 mW/cm^2 intensity by the overlapping technique. Each side was cured for 40 seconds [19]. The output intensity was measured by a radiometer (Coltolux, Coltene, Switzerland) before each time of curing [3].

To fabricate self-cure acrylic resin specimens, the powder and liquid of PMMA (Tempron GC,

Dental Product Co., Japan) were mixed within 20-30 seconds as instructed by the manufacturer, applied into the mold, and removed after 3 minutes [20]. Excess material was polished with 500, 1000, and 2000-grit abrasive paper (Atlas, Istanbul, Turkey), and removed with air spray [18,20]. The dimensions of the specimens were then measured using a digital caliper (Mitutoyo 500-193-30; Mitutoyo Co., Kanagawa, Japan) with 0.01 mm accuracy.

PMMA CAD-CAM discs (1 x 15 mm) were prepared from blocks in a CAD-CAM machine (Ceramill Map 400 , Amann Girrbach, Germany). All specimens were checked to be homogenous with no distortion. Finally, all specimens were inspected by the naked eye, and defective ones were replaced with intact specimens. After fabrication, the specimens were dried in an oven at 120°C for 6 hours (Memmert, USA) and placed in a desiccator (Pyrex; SIMAX, Czech) containing silica gel according to ISO4049 [18,19]. Silica oil was applied on the desiccator opening to become air-tight, and then the desiccator was connected to a vacuum pump to remove air and moisture [18,19]. The specimens were placed in the desiccator (Pyrex; SIMAX, Czech) at 37°C for 22 hours, and were then removed and weighed by a digital scale with 0.0001 g accuracy (AJ100; Mettler, Sweden). Next, they were placed back in the desiccator for 2 hours and weighed. This process was repeated until the weight change between two consecutive measurements became smaller than 0.1 mg (the weight of specimens was stabilized). M1 was calculated as such.

The volume of the specimens was also measured by a micrometer (Cenco Enco, Germany) with 0.001 mm accuracy. The mean diameter of each specimen was calculated by measuring the two diagonals perpendicular to each other, and calculating of their mean value. The mean thickness of each specimen was calculated by measuring the thickness at 5 points with equal distances from each other, and the mean value was calculated [18]. The volume of each specimen was then calculated using the following formula:

$V = \pi r^2 h$

Where V is the specimen volume before water immersion, h is the thickness, and r is the radius of the specimen. After initial measurement of weight and volume, the specimens were assigned to two groups for evaluation after 7 days (n=21) and 30 days (n=21). They were then incubated in pure distilled water at 37°C (108/53/246 model; Memmert, USA). According to ISO4049, the specimens were immersed vertically in water with a minimum distance of 3 mm between them, and a minimum of 10 mm^2 water per each specimen. The incubator was then closed, and the volume of water was measured daily to ensure its adequacy. After 7 and 30 days, the specimens were removed from the incubator, rinsed, and exposed to air for 15 seconds. One minute after water elimination, the specimens were weighed to record M2. After weighing, the specimens were placed back in the desiccator to reach a constant weight, and then M3 was measured. Water sorption was calculated in microgram per cubic millimeter ($\mu g/mm^3$) using the following formula [19]:

$$\frac{M_2 - M_3}{V}$$

M1: Specimen weight before water immersion

M2: Specimen weight immediately after water immersion

M3: Specimen weight after placement in desiccator and drying following immersion

V: Specimen volume before water immersion

The water sorption of the specimens was calculated using the abovementioned formula [16].

Statistical analyses were performed using GraphPad Prism software (CA, USA). Quantitative data were reported as mean ± standard deviation. One-way ANOVA was applied for the comparison of normally distributed data. $P<0.05$ was considered statistically significant.

Results

On day 7, the highest water sorption was recorded in acrylic-based composite resin (Bisco) (mean: 22.84±5.04 µg/mm^3) and the lowest water sorption was noted in PMMA CAD-CAM block (mean: 14.22±3.23 µg/mm^3). However, at 30 days, the highest water sorption was recorded in Tempron GC self-cure acrylic resin (mean: 53.48±18.44 µg/mm^3), and the lowest water sorption was seen in PMMA CAD-CAM block (mean: 24.40±5.33 µg/mm^3) (Table 1).

The three materials were compared at each time point. On day 7, the results showed no significant difference in water sorption of Bisco acrylic-based composite resin and Tempron GC self-cure acrylic resin (P=0.93). However, Bisco acrylic-based composite resin had a significant difference with PMMA CAD-CAM block in water sorption (P=0.01). The water sorption of Tempron GC self-cure acrylic resin and PMMA CAD-CAM block had a significant difference as well (P=0.02, Table 2).

At 30 days, the water sorption of Bisco acrylic-based composite resin and Tempron GC self-cure acrylic resin was significantly different (P=0.02). However, the water sorption of Bisco acrylic-based composite resin had no significant difference with that of PMMA CAD-CAM block (P=0.48). Also, the water sorption of Tempron GC self-cure acrylic resin and PMMA CAD-CAM block was significantly different (P=0.002, Table 3).

At 7 days, the water sorption of Bisco acrylic-based composite resin and Tempron GC self-cure acrylic resin was very high. However, after 30 days, the water sorption of Bisco acrylic-based composite resin had a descending trend; while, the water sorption increased in Tempron GC self-cure acrylic resin and PMMA CAD-CAM block. After 30 days, the water sorption of Bisco acrylic-based composite resin and PMMA CAD-CAM block was the same. However, the water sorption of Tempron GC PMMA self-cure acrylic resin experienced an ascending trend (Figure 1).

Table 1. Frequency distribution of water sorption in Bisco acrylic-based composite resin, GC PMMA self-cure acrylic resin, and PMMA CAD-CAM block at 7 and 30 days (in µg/mm^3)

Variable		Minimum	Maximum	Mean	SD
Bisco	7 Days	15.25	29.12	22.84	5.04
	30 Days	10.22	49.05	32.67	12.59
PMMA(GC)	7 Days	10.92	28.44	21.92	5.76
	30 Days	40.35	93.22	53.48	18.44
PMMA (CAD/CAM)	7 Days	8.83	18.81	14.22	3.23
	30 Days	17.46	33.33	24.40	5.32

SD: Standard deviation

Table 2. Pairwise comparisons of the three materials regarding water sorption at 7 days

Compared materials		Mean Difference (I-J)	Std. Error	P value*	95% Confidence Interval	
					Lower Bound	Upper Bound
Composite	PMMA	0.91857	2.63419	0.935	-5.8043	7.6415
	CAD	8.62000*	2.63419	0.011	1.8971	15.3429
PMMA	Composite	-0.91857	2.63419	0.935	-7.6415	5.8043
	CAD	7.70143*	2.63419	0.023	0.9785	14.4243
CAD	Composite	-8.62000*	2.63419	0.011	-15.3429	-1.8971
	PMMA	-7.70143*	2.63419	0.023	-14.4243	-0.9785

*. The mean difference is significant at 0.05 level.

Table 3. Pairwise comparisons of the materials regarding water sorption at 30 days

(I) material		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Composite	PMMA	-20.81000*	7.08465	0.023	-38.8912	-2.7288
	CAD	8.26143	7.08465	0.488	-9.8197	26.3426
PMMA	Composite	20.81000*	7.08465	0.023	2.7288	38.8912
	CAD	29.07143*	7.08465	0.002	10.9903	47.1526
CAD	Composite	-8.26143	7.08465	0.488	-26.3426	9.8197
	PMMA	-29.07143*	7.08465	0.002	-47.1526	-10.9903

*. The mean difference is significant at 0.05 level.

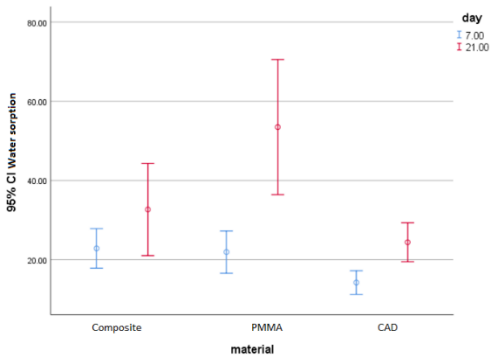

Figure 1. Water sorption of the three provisional materials at 7 and 30 days

Discussion

This study compared the water sorption of three provisional crown materials, including self-cure acrylic resin, acrylic-based composite resin, and PMMA CAD-CAM block at 7 and 30 days under in vitro conditions. The results showed that the water sorption of GC PMMA self-cure acrylic resin had an ascending trend until 30 days, while Bisco acrylic-based composite resin had the highest water sorption at the study onset and showed the lowest water sorption, comparable to that of PMMA CAD-CAM block, at 30 days.

Search of the literature by the authors yielded no study comparing the water sorption of the abovementioned three provisional crown materials. Tuna et al. [17] evaluated the water sorption of 9 different brands of self-cure acrylic resins and showed that their mean water sorption ranged from 30.46±0.55 μg/mm^3 to 33.11±0.33 μg/mm^3; also, they found no significant correlation between solubility and water sorption of resin materials. Asar et al. [21] reported the water sorption of self-cure acrylic resin materials to range from 17.5±0.2 μg/mm^3 to 21.3±0.2 μg/mm^3, depending on their filler content. Saini et al. [22] showed that the water sorption of self-cure resin materials increased from 12.75±0.55 μg/mm^3 to 19.75±1.04 μg/mm^3. Arima et al. [23] evaluated the effect of cross-linkers on water sorption of acrylic resins and showed that the mean water sorption of self-cure acrylic resin increased from 12.75 μg/mm^3 to 27.25 μg/mm^3 within 7 days. Golbidi and Taherian [24] assessed the water sorption of two different brands of acrylic resins and found that their water sorption ranged from 30.5±0.1 μg/mm^3 to 30.7±0.87 μg/mm^3.

Variations in the reported results in the literature regarding water sorption can be due to the different types and brands of provisional crown materials, type of environment (distilled water), method of measurement of weight and volume of specimens, and the assessment time points.

According to the present results, although Tempron GC PMMA showed higher water sorption than PMMA CAD-CAM block and Bisco acrylic-based composite resin at 30 days, due to the presence of slight differences in water sorption of the three tested materials, it may be

stated that all three materials may be suitable for provisional crown fabrication in patients. The standard water sorption reported by ISO in 1999 was maximally 32 μg/mm^3 for light-cure and self-cure resins [25]. The water sorption values observed in the present study were in accordance with this standard, except for Tempron, which showed higher water sorption than the ISO standard after 30 days.

Dixon et al. [26] revealed that the amount of residual monomer in the final polymer can affect its water sorption and polymer expansion. In a study by Sahin and Ozer [27], acrylic base composite showed the highest water absorption compared to restorations fabricated by digital methods (CAD/CAM and printing) and acrylic materials. Their results were in line with the present findings, showing lower water sorption of Telio CAD PMMA CAD-CAM block (Ivoclar Vivadent) in the short-term and long-term. It appears that since the CAD-CAM blocks are fabricated and polymerized by the manufacturer, they have a more homogenous structure and lower amount of monomer, which decreases the water sorption of CAD-CAM blocks compared with the other two materials.

Previous studies demonstrated that the amount of residual monomer in self-cure resins was higher than that in light-cure and heat-cure resins [28,29]. This additional monomer can increase the water sorption of self-cure resins. The results obtained in the present study in the short-term (7 days) were in contrast to this statement, since the water sorption of Bisco light-cure composite was higher than that of Tempron self-cure resin. However, the results obtained in the long-term (30 days) were in agreement with this statement and as expected, the water sorption of Tempron self-cure composite resin was higher than that of Bisco light-cure resin.

Lauvahutanon et al. [30] reported that the water sorption of composite resin block was 39.7 μg/mm^3 while the water sorption of self-cure acrylic resin was 32.2 μg/mm^3. Rayyan et al. [31] found that the water sorption of PMMA CAD-CAM block was, on average 8.7±0.7 μg/mm^3. However, in the present study, the water sorption of PMMA CAD-CAM block was 14.22±3.23 μg/mm^3 at 7 days and 24.40±5.32 μg/mm^3 at 30 days, which were higher than the values reported in the literature. Kerby et al. [32] indicated that the water sorption of Bisco acrylic-based composite resin was 25±0.8 μg/mm^3 after 24 hours. Also, Ortengren et al. [33] reported that the mean water sorption of Bisco acrylic-based composite resin was 15 μg/mm^3 after 72 hours. Furthermore, Cuevas-Suárez et al. [34] demonstrated the mean water sorption of Bisco acrylic-based composite resin to be 93.10±.79 μg/mm^3 after 24 hours. However, the mean water sorption of this material was 22.48±5.04 μg/mm^3 at 7 days and 32.67±12.59 μg/mm^3 at 30 days in the present study, which were much higher than the values reported in the abovementioned studies. This controversy may be mainly attributed to differences in water sorption measurement time points.

Evaluation of water sorption over a longer period of time was an advantage of the present study. Also, simultaneous assessment of water sorption of three commonly used provisional crown materials at 7 and 30 days was another strength, which provided accurate results to aid in selection of the most appropriate provisional crown material.

One limitation of this study was absence of a study comparing the water sorption of PMMA CAD-CAM blocks and Bisco acrylic-based composite resin at specific time points to compare our results with. Using only 3 materials with 3 specific brands, limited number of samples examined in this study, and the short period of 7 and 30 days for testing of the samples were some other limitations of this study. Considering the differences in methodologies and assessment periods (24 to 72 hours), differences between the

present results and the available literature were expected, which highlight the significance of further assessments and comparison of different materials with respect to their water sorption for the fabrication of temporary crowns with the best material available for this purpose.

Conclusion

The current results showed that:

- In the short-term (7 days), the water sorption of Bisco acrylic-based composite resin and Tempron GC self-cure acrylic resin was very high.
- In the long-term (30 days), the water sorption of Bisco acrylic-based composite resin and PMMA CAD-CAM block was the same. However, the water sorption of Tempron GC self-cure acrylic resin experienced an ascending trend.

It appears that all three tested materials may serve as an excellent option for the fabrication of temporary restorations.

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