

Comparison of Water Sorption of Two Injection Acrylic Resins with a Conventional Pressure-Packed Acrylic Resin

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Abstract

Background and Aim: Water sorption is one of the most important properties that affects the quality of a prosthesis, and subsequently, the quality of treatment, and patient's quality of life. The aim of this study was to determine and compare the water sorption of two types of poly methyl methacrylate (PMMA) using the injection-molding systems with a traditional acrylic resin base material.

Materials and Methods: In this in vitro, experimental study, three groups of PMMA (n=10), consisting of two groups of injection molded PMMA samples (Vertex Castavaria and Ivo-Base High-Impact) were used for two different injection molding techniques and one group of conventional pressure-packed PMMA (Meliodent Heat Cure) was used for the conventional pressure-packed technique. After processing, 30 specimens were stored in distilled water at 37°C for 30 days. The water sorption test was then performed. Statistical analysis was carried out using SPSS version 23.0 via the Kruskal-Wallis and Mann-Whitney tests ($\alpha=0.05$).

Results: The mean value of water sorption was $17.88 \pm 1.08 \mu\text{g}/\text{mm}^3$ for IvoBase specimens, $28.45 \pm 2.19 \mu\text{g}/\text{mm}^3$ for Vertex specimens, and $21.76 \pm 3.26 \mu\text{g}/\text{mm}^3$ for Meliodent specimens ($P < 0.001$ for Ivobase-Vertex, $P < 0.007$ for Ivobase-Meliodent, and $P < 0.001$ for Vertex-Meliodent).

Conclusion: Water sorption of IvoBase was significantly lower than that of other materials. Despite such a significant difference, all of them completely fulfilled the requirements of EN ISO 20795-1:2008.

Key Words: Adsorption, Injections, Polymethyl Methacrylate

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Introduction

An ideal denture base material must have a few qualities, including minimal water sorption, maximal dimensional stability, fracture resistance, tissue compatibility, causing no allergic reaction, and optimal esthetics [1,2]. Polymethyl methacrylate (PMMA) resin is the most frequently used denture base material [3] initially produced in sheet form in 1936, and in

powder form in 1937. PMMA is available in two forms of chemically activated and heat activated [4]. New injection molding techniques were developed considering the polymerization shrinkage of conventional heat-polymerized PMMA. Thermoplastic resins have shown many advantages over conventional liquid or powder resin systems such as high impact strength, high flexural strength, transparency, flexibility,

fatigue endurance, high creep resistance, low water sorption, no or little residual monomer, no porosity, and resultantly higher dimensional stability in addition to almost ideal wear resistance with less odor and stains, and optimal color stability. These PMMAs are free of metal and have a microcrystalline structure; thus, they have easier finishing and polishing [4,5]. Water sorption of a material indicates absorption and adsorption of water when in function. Absorption of water can cause discoloration [6], softening, and loss of mechanical properties such as fatigue limit, transverse strength, and hardness as water serves as a plasticizer. In addition, water sorption causes three-dimensional expansion, and thus, can affect the dimensional stability of acrylic resin [7]. Limited studies have been performed on the injection acrylic resins, and little evidence is available on this topic [8-11]. Two recent reviews provided some evidence regarding material properties such as flexural strength, flexural modulus, bonding strength, absorbance, abrasion, surface hardness, and clinical application [12,13]. Considering the information gap on the injection-molding technique and its physical and mechanical properties, this study aimed to assess the water sorption of two PMMA denture base resins for injection molding techniques in comparison with a heat-polymerized PMMA acrylic resin. The null hypothesis was that there would be no significant difference in water sorption of these materials.

Materials and Methods

This was an in vitro experimental study. In order to fabricate the specimens, 5 stainless steel models with 3 mm thickness and 15 x 67 mm dimensions were fabricated (Figure 1).

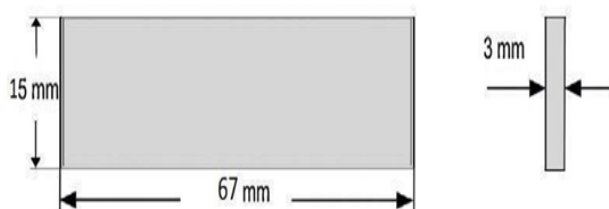


Figure 1. Stainless steel model specifications

Stainless steel models were produced using Robofil 4000 (Charmills technologies, Schaffhausen, Switzerland). The model was placed in special flasks for each type of material, and the specimens were fabricated as such. All the specimens were polymerized according to the setting time and techniques provided by the manufacturer (Figure 2). Specimens with any defect or inaccurate dimensions were excluded and replaced.



Figure 2. Fabricated specimens

In order to prepare Meliodent Heat Cure (Heraeus Kulzer, Germany) conventional specimens, the models were flaked after all surfaces were smeared with petroleum jelly in order to prevent adhesion of the stone to the stainless-steel model. The powder to liquid mixing ratio was 35 g/14 mL according to the manufacturer's instructions. Next, acrylic resin was packed under 2 bar pressure. The flasks were placed in boiling water for 20 minutes. After boiling the flasks, they were allowed to cool down to room temperature, and then they were deflaked.

Ivo-Base High-Impact (Ivoclar Vivadent, Liechtenstein) specimens were fabricated according to the manufacturer's instructions. After being smeared with petroleum jelly, the samples were flaked using special flasks of Ivo-Base injection system. Then, the flask was placed in the injection system and the rest of the process was completed automatically. After approximately 60 minutes, the flask was removed and cooled under cold water for 15 minutes, and then the specimens were deflaked.

In order to produce Vertex Castavaria (Vertex dental, Netherlands) specimens, stainless steel models were smeared with petroleum jelly and

placed in the flask along with the wax injection sprue.

Vertex Castavaria powder and liquid were mixed with the ratio of 1.7 g/0.95 g. The mixture was poured into the flask and after approximately 5 minutes, it was placed inside the pressure vessel with

2.5 bar pressure at 55°C. Thus, a total number of 30 specimens were fabricated, 10 specimens in each group of materials. The specimens were kept at room temperature for the next 30 minutes. Once the specimens were completely set, only one of the surfaces of each specimen was polished using progressively smoother (200-grit followed by 400 and 800-grit) aluminum oxide sandpapers (Norton; Saint-Gobain Abrasivos, Brazil). Next, all specimens were weighted using a digital scale (Kia Electronic Aras Co. Ltd., Tehran, Iran).

In order to measure the water sorption, the specimens were immersed in distilled water in a bath at 37°C for 30 days using a digital incubator (Behdad, Tehran, Iran). The specimens were weighted after this period using a digital scale (Kia Electronic Aras Co. Ltd., Tehran, Iran). The following formula was used to quantify water sorption:

$$\text{Water sorption} = \frac{M_2 - M_1}{V}$$

Where M_1 is the conditioned mass in micrograms (μg) prior to immersion in water, M_2 is the mass of the specimen in micrograms (μg) after immersion in water, and V is the volume of the specimen in cubic millimeters (mm^3).

Thus, water absorption of each group during 30 days was quantified and compared using the Kruskal-Wallis and Mann-Whitney tests.

Results

There were statistically significant differences between the materials regarding water sorption ($P < 0.001$ for Ivobase-Vertex, $P < 0.007$ for Ivobase-Meliodont, and $P < 0.001$ for Vertex-Meliodont comparisons). All of the tested denture base materials fulfilled the requirements of ISO 20795-1 regarding water sorption ($< 32 \mu\text{g}/\text{mm}^3$) [14]. The mean value of

water sorption was $17.88 \pm 1.08 \mu\text{g}/\text{mm}^3$ in Ivobase specimens, $28.45 \pm 2.19 \mu\text{g}/\text{mm}^3$ in Vertex specimens, and $21.76 \pm 3.26 \mu\text{g}/\text{mm}^3$ in Meliodent specimens. (Table 1)

Discussion

The null hypothesis was that there would be no significant difference between the water sorption of two injection acrylic resins with a conventional pressure-packed acrylic resin; however; this study showed that there was a significant difference between the groups. The aim of this study was to determine and compare the water sorption of three types of acrylic resins, with different preparation techniques, including two self-cure acrylic resins with the injection-molding techniques and one heat-cure acrylic resin with the conventional compression molding technique. Due to the fact that the conventional method is much more common due to its simplicity and relatively high accuracy, this method was chosen for the purpose of comparison in our study as the gold standard. The mean water sorption was $17.88 \pm 1.08 \mu\text{g}/\text{mm}^3$ in Ivobase specimens, $28.45 \pm 2.19 \mu\text{g}/\text{mm}^3$ in Vertex specimens, and $21.76 \pm 3.26 \mu\text{g}/\text{mm}^3$ in Meliodent specimens. Therefore, Ivobase with $17.88 \pm 1.08 \mu\text{g}/\text{mm}^3$ water sorption showed the least amount of water sorption in this study. However, according to the manufacturer (Ivoclar Vivadent), the water sorption of Ivobase High Impact is $21.6 \mu\text{g}/\text{mm}^3$. It shows that there is a slight difference between the results achieved in this study and the manufacturer's claims. As the Ivobase system uses predosed monomer and polymer cartridges, user-related mistakes in ratio or polymerization process would be prevented. This difference may be due to the thickness of the specimens during the study, which can affect the amount of water sorption.

In this study, Vertex Castavaria showed much higher water sorption than the manufacturer's claim ($23.2 \mu\text{g}/\text{mm}^3$). In this study, this material showed a mean water sorption of $28.45 \pm 2.19 \mu\text{g}/\text{mm}^3$, which ideally shows $3 \mu\text{g}/\text{mm}^3$ difference. In a study by Latif [7], water sorption and water solubility of Vertex Castavaria were analyzed based on different

Table 1. Mean water sorption of samples in the three groups (n=10)

Material	Mean ($\mu\text{g}/\text{mm}^3$)	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
IVOBASE	17.88	1.08	0.34	17.10	18.65	16.28	19.35
VERTEX	28.45	2.19	0.69	26.88	30.02	25.51	31.53
MELIODENT	21.76	3.26	1.03	19.42	24.09	17.18	26.38

ratio and temperature values. The samples were stored in distilled water at 37°C for 7 days. Water sorption in the control group was 25.13 $\mu\text{g}/\text{mm}^3$, which was also higher than the manufacturer's claim, and was closer to our obtained value. In a study by Golbidi et al, [15] water sorption and water solubility of Meliodent Heat Cure and Acropars were tested according to the ADA standards. In their study, the mean water sorption of Meliodent Heat Cure specimens was $30.5 \pm 0.41 \mu\text{g}/\text{mm}^3$. This value was $30.7 \pm 0.35 \mu\text{g}/\text{mm}^3$ for Acropars specimens. The difference between our results and those of Golbidi et al, [15] might be related to the thickness of specimens, since the fabrication and the storage condition of the specimens were the same in both studies.

Conclusion

Water sorption of IvoBase was significantly lower than that of other materials. Meliodent Heat Cure showed a slightly higher water sorption, and Vertex Castavaria showed the highest water sorption. Although there was a significant difference in water sorption of the materials, all of them completely fulfilled the requirements of EN ISO 20795-1:2008.

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