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RESEARCH

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Evaluation of polyamide (NYLON) versus polymethyl methacrylate (PMMA) denture base materials regarding water solubility: in vitro research

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Abstract

Background Several denture base materials have evolved over the years. Beginning with metal and ending up with various types of acrylic materials in order to have a biocompatible, antimicrobial denture base. A flexible acrylic resin, such as Polyamides, has been introduced to address the drawbacks of heat-cured PMMA resin. This study was conducted to examine the water solubility and water sorption of flexible thermoplastic polyamides (Valplast) and two types of conventional heat-cured acrylic resin (PMMA) (Acrostone, Vertex).

Methods Specimens of thermoplastic polyamides and two types of conventional PMMA (Acrostone, Vertex) resin were manufactured and used in the current investigation in accordance with manufacturer instructions. A total of 45 specimens were milled into discs with a diameter of 50.0 mm diameter, 5.0 mm thick. To ascertain conformity with ADA Standard No. 12, water solubility and water sorption were measured.

Results All items complied with ADA regulations for water solubility and sorption. Flexible thermoplastic polyamide displayed less water solubility, and water sorption than heat-cured PMMA. Acrostone showed the higher water solubility, sorption followed by Vertex heat cure acrylic resin both heat cured showed significant higher water solubility than polyamides Valplast).

Conclusions Within the limitations of this in vitro experiment, heat cure PMMA resin demonstrated significantly greater water solubility and water sorption when compared to thermoplastic polyamides.

Keywords Denture base resins, Flexible polyamides, Heat cure, Water solubility, Water sorption

Background

Complete dentures are conventionally constructed in heat-cured polymethyl methacrylate (PMMA) acrylic resin and, although cobalt chromium (Co/Cr) partial dentures have many advantages All-acrylic removable partial dentures are frequently offered and seem to be chosen by many practitioners in many clinical conditions (Walmsley 2003).

Thermoplastics, which are used for the construction of removable partial denture prostheses, are usually referred to as flexible dentures, although other terms, such as non-clasp dentures, metal-free dentures, clasp-free dentures, and non-metal clasp dentures are also frequently used (Lowe 2004; Fueki et al. 2014).

The feature of a complete denture treatment is generated by good support, stability, and retention. However,

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some morphological factors can increase the difficulty of manufacturing a satisfying removable denture, such as a severe atrophy of the alveolar ridge, both in the upper and lower jaw. This atrophy, which occurred after teeth extraction, is more rapid when the patient is wearing ill-fitting dentures for a long period, due to the fact that the process of resorption is centrifugal in the mandible and centripetal in the maxilla. However, in maxillary bone, alveolar resorption can complicate achieving a proper occlusion (Helmy 2017).

Researchers have recently paid more attention to the type of acrylic resin used in denture fabrication (Aldabib and Ishak 2020). Traditionally, heat-cured PMMA acrylic resin has been used to make complete dentures. However, this material has significant disadvantages, including dimensional instability brought on by polymerization shrinkage during manipulation (Aboelroos and Rady 2016). As a result, flexible thermoplastic resins were developed to balance the need for RD retention with the aesthetic demands of the patients (Fueki et al. 2014).

Thermoplastic acrylic, as a denture base material, is distinguished by its internal memory, which allows it to easily return to its original shape when heated; it also comes in a variety of consistencies and is better suited to soft tissues (Singh 2012). The most classic example of these thermoplastic acrylics is polyamides (Hargreaves 1971).

Recently, polyamides has been reintroduced as a PMMA substitute. Manufacturers promote polyamides as an attractive, flexible, and allergy-free option to removable partial dentures. However, the precise chemical structure is not always disclosed by the manufacturers. Modern polyamides vary chemically from that used in the 1950s (Hargreaves 1971; Vojdani and Giti 2015).

Acrylic resins gradually absorb water over time due to the resin molecules polar properties (Tuna et al. 2008). The main variables influencing the amount and rate of water intake into polymer networks are resin polarity, which is depending on how many polar sites are accessible to form hydrogen bonds with water, network structure, and the rate of water ingestion into polymer networks (Arima et al. 1996). This study was conducted to examine the water solubility and water sorption of flexible thermoplastic polyamides (Valplast) and two types of conventional heat-cured acrylic resin (PMMA) (Acrostone, Vertex).

Methods

This study was designed as experimental in vitro study. One type of thermoplastic polyamides (Valplast) and two types of heat cure acrylic resins denture base materials were selected.

1. Thermoplastic polyamides Valplast (Valplast International Corp).
2. Heat-cured Acrostone, (Acrostone, EGYPT).
3. Rapid simplified heat-cured acrylic resin Vertex (Dental Company, Germany).
4. Specimen size calculation:

According to analyses of water solubility and water sorption (Hemmati et al. 2015), specimen size calculation was undertaken via G power version 3.1 statistical software based on the following pre- established parameters: an alpha-type error of 0.05, a power test of 0.95, a total specimen of at least 45 specimens (15 specimens per group) appeared to be sufficient.

- Specimen grouping:

The acrylic resin specimens were divided with respect to their type of resin into three main groups as follow: Group I: Heat-cured acrylic resin PMMA (Acrostone) ($n = 15$), Group II: Heat-cured acrylic resin PMMA (Vertex) ($n = 15$), Group III: Thermo plastic Polyamides (Valplast) ($n = 15$).

Test specimens of a heat-polymerized PMMA (Acrostone, Vertex) and injection molded polyamides resins (Valplast) were investigated. Discs of each material were made according to the manufacturers' instructions. To ascertain conformity with ADA Standard No. 12, water solubility and water sorption were measured. The specimens were wet-grinded and polished to the size of 0.5 mm thick and 50 mm in diameter using FEPA P#220 silicon carbide paper. The volume (V, in mm^3) of each specimen was calculated.

- Testing procedures: Water solubility and sorption test:

The dimension of specimens for this test was d 0.8 ± 0.1 mm thick and 50 ± 1 mm in diameter. All disk specimens in each group ($n = 15$), were subjected to a drying process in order to achieve a constant weight. So, they were kept in racks inside vacuum desiccators containing freshly dried silica gel and stored at 37 for 24 h then and daily weighed on a digital analytical balance. Repeating the drying and weighing process until constant mass was reached 'conditioned mass' m1 was reached and the difference between sequential weight measurements was about 0.0001 g. After obtaining the constant mass, specimens were stored in a separate glass vessel with 20 ml of distilled water in a 37 °C incubator (vii)[1] and

[1] (vii); PA.3A, Advanced Technology, Egypt.

were also daily weighed until stabilization, but always after careful drying with absorbent paper.

After 5 days, the specimens were taken out of the water, gently wiped until no apparent moisture remained, then weighed 60 s later. After 4–5 days, the specimens were re-immersed in water, and the measurement process was repeated until a constant mass, or m2, known as "water saturation", was obtained. After that, the specimens were taken out of the water and put back inside the desiccator. The above-described desiccation process was continued until a consistent mass, m3, or "reconditioned mass", was reached. The following formula were used to calculate the water sorption and water solubility percentages (Figuerôa et al. 2018):

$$\text{Water Sorption}\,\% = 100 \times (m2 - m3)/m1 \quad (1)$$

$$\text{Water Solubility}\,\% = 100 \times (m1 - m3)/m1 \quad (2)$$

where m2 is the mass (mg) of the specimen after immersion in water; m3 is the mass (mg) of the specimen after the second drying, and m1 is the mass (mg) of the specimen after the first drying.

Statistical analysis

SPSS® Statistics Version 20 was used to collect, tabulate, and statistically analyse the data. The distribution's normality was confirmed using the Kolmogorov–Smirnov test. The range (minimum and maximum), mean, standard deviation, and median were used to characterise quantitative data. The mean and standard deviation were used to describe numerical data. Data were compared within groups using Tukey's post hoc tests and across groups using a one-way ANOVA. The significance threshold was set at.05.

Results

1. *Water solubility %* The revealing statistical analysis shows mean values and standard deviation (SD) of water solubility (wt.%) test results measured in microgram (μgm) for PMMA heat-cured and Polyamides tested groups are summarized in Table 1 and graphically illustrated in Fig. 1.

The statistical analysis of water solubility (wt.%) of tested groups revealed that the difference between the heat-cured acrylic resin (Acrostone, Vertex) and polyamides (Valplast) was statistically significant as the heat-cured acrylic resin showed increase in the water solubility and water sorption than polyamides. But there was no significant difference between the two types of heat-cured acrylic resin. Despite that Vertex showed less water solubility than Acrostone but there was no significant difference.

2. *Water sorption %* The revealing statistical analysis showed mean values and standard deviation (SD) of water sorption (wt.%). Results measured in microgram (μg) for PMMA heat-cured and polyamides tested groups are summarized in Table 2.

The statistical analysis of water sorption (wt.%) of tested groups revealed that the difference between the heat-cured acrylic resin (Acrostone, Vertex) and polyamides (Valplast) was statistically significant as the heat-cured acrylic resin showed increase in the water sorption than polyamides. But there was no significant difference

Table 1 Comparison of water solubility of tested groups (Acrostone, Vertex, Valplast)

Variable	No of specimens	Mean	Standard of deviation	*Df*	*P* value
Acrostone	15	2.87	±0.85	28	>0.54**
Vertex	15	2.69	±0.76		
Valplast (polyamides)	15	1.33	±0.42	28	<0.0001*

*Significant at $P<0.05$

**Non-significant at $P>0.05$

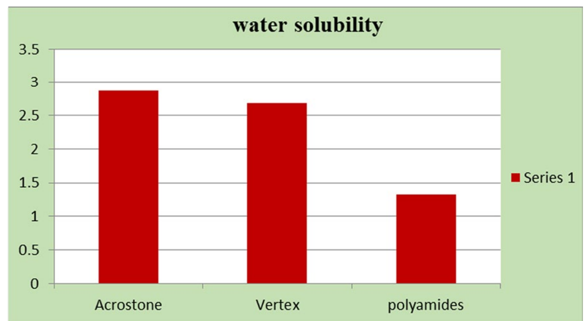

Fig. 1 Comparison of water solubility of tested groups

Table 2 Comparison of water sorption of tested groups (Acrostone, Vertex, Valplast)

Variable	No of specimens	Mean	Standard of deviation	*Df*	*P* value
Acrostone	15	16.13	±0.53	28	>0.19**
Vertex	15	15.89	±0.46		
Valplast (polyamide)	15	13.33	±0.28	28	<0.0001*

*Significant

**Insignificant

between the two types of heat-cured acrylic resin. Despite that Vertex showed less water sorption than Acrostone but there was no significant difference.

Discussion

Denture fabrication involves the use of a variety of materials, and each type of material has an impact on the fabrication of the denture base as well as other clinically relevant factors like stability, support, retention, flexibility, impact resistance, colour stability, and water sorption and solubility (Al-Somaiday et al. 2018).

It may be challenging to directly compare the results from different studies because different methods for calculating sorption and solubility have been used, such as percentage changes in mass, mass changes per unit volume, or percentage weight change between the initial weight and the weight at a given time (Garg and Shenoy 2016). However, in the present study we select to measure the solubility of the both tested resins via percentage weight change to illustrate simply the effects of water aging on the solubility of those resins.

In the current study the distilled water was selected as storage medium to test the solubility of heat-cured PMMA and polyamides to get the possible maximum solubility to simulate the longer possible clinical period. This because it was found that the solubility of the denture base materials was higher in distilled water when compared to artificial saliva and disinfectant solution (Chladek et al. 2014; Parker and Braden 1990). This was due to the fact that lower water uptake in artificial saliva will prevent material from leaching from the matrix by reducing matrix swelling (Parker and Braden 1990; Garg and Shenoy 2016).

The results of the current study showed that the polyamides resin has significant ($P = 0.0001$) higher solubility when compared to the conventional heat-cured PMMA after storage in distilled water for 4 weeks. These results agreed with the results of Shah et al. (2014), who stated that a considerable difference in the solubility values between flexible resin and PMMA was seen.

It was reported that Acrylic resins contain initiators, plasticizers, and free monomer as soluble components. 18.19 Within the first few days of water storage, acrylates often release the greatest quantity of residual monomer (Arima et al. 1996). This could explain solubility results in this study due to the different amount of leachable component in heat-cured acrylic resins.

According to Hayashi et al., because the flexible resin has a high contact angle with water and a low surface energy, their resistance to water is similarly great leading to reduced water sorption (Thakral et al. 2012). Flexible resin has less water sorption than traditional PMMA because of the strong hydrogen bonding among amide groups and a reduction in the places where water molecules can adhere. The greater levels of solubility of PMMA may possibly be connected to the larger residual monomer concentrations (Arima et al. 1996). There was statistically significant solubility between PMMA and flexible (thermoplastic polyamide nylon).

Conclusions

Both types of heat-cure PMMA resin has a significant higher water sorption and solubility when compared to the thermoplastic resin polyamides.

Heat cured (Acrostone) showed a higher water solubility and water sorption than heat cured (Vertex) but with no significant difference.

Abbreviations

PMMA	Polymethyl methacrylate
ADA	American Dental Association
SPSS	Statistical package for scientific studies
SD	Standard deviation

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Author contributions

MH and AA performed the data collection and laboratory procedures; they also conducted the statistics and generated the manuscript. The final manuscript was read and approved by the authors.

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Availability of data and materials

On adequate request, the corresponding author will provide access to the datasets created during and/or analysed during the current work.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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References

Aboelroos EM, Rady AA (2016) The effect of two packing techniques on adaptation of resin denture base materials. Egypt Dent J 62:1169–1176

Aldabib JM, Ishak ZAM (2020) Effect of hydroxyapatite filler concentration on mechanical properties of poly (methyl methacrylate) denture base. SN Appl Sci 2:732–739

Al-Somaiday HM, Moudhaffer M, Fatihallah AA (2018) Comparing the impact strength and transverse flexure strength of three different dentures base materials. Biomed Pharmacol J 11(1):255–263. https://doi.org/10.13005/bpj/1370

Arima T, Murata H, Hamada T (1996) The effects of cross-linking agents on the water sorption and solubility characteristics of denture base resin. J Oral Rehabil 23(7):476–480
Chladek G, Zmudzki J, Kasperski J (2014) Long-term soft denture lining materials. Materials (basel) 7(8):5816–5842. https://doi.org/10.3390/ma7085816
Figuerôa RMS, Conterno B, Arrais CAG, Sugio CYC, Urban VM, Neppelenbroek KH (2018) Porosity, water sorption, and solubility of denture base acrylic resins polymerized conventionally or in microwave. J Appl Oral Sci 26:e20170383
Fueki K, Ohkubo C, Yatabe M et al (2014) Clinical application of removable partial dentures using thermoplastic resin-part I: definition and indication of non-metal clasp dentures. J Prosthodont Res 58(1):3–10. https://doi.org/10.1016/j.jpor.2013.12.002
Garg A, Kk S (2016) A comparative evaluation of effect on water sorption and solubility of a temporary soft denture liner material when stored either in distilled water, 5.25% sodium hypochlorite or artificial saliva: an in vitro study. J Indian Prosthodont Soc 16(1):53. https://doi.org/10.4103/0972-4052.167931
Hargreaves AS (1971) Nylon as a denture-base material. Dent Pract Dent Rec 22:122–128
Helmy M (2017) Evaluation of the retention in the thermoplastic acetal resin distal extension partial denture prosthesis with different denture base extensions. Egypt Dent J 63(4):3519–3526. https://doi.org/10.21608/edj.2017.76271
Hemmati MA, Vafaee F, Allahbakhshi H (2015) Water sorption and flexural strength of thermoplastic and conventional heat-polymerized acrylic resins. J Dent (tehran) 12(7):478–484
Lowe LG (2004) Flexible denture flanges for patients exhibiting undercut tuberosities and reduced width of the buccal vestibule: a clinical report. J Prosthet Dent 92(2):128–131. https://doi.org/10.1016/j.prosdent.2004.04.026
Parker S, Braden M (1990) Formulation of tissue conditioners. Biomaterials 11(8):579–584. https://doi.org/10.1016/0142-9612(90)90082-2
Shah J, Bulbule N, Kulkarni S, Shah R, Kakade D (2014) Comparative evaluation of sorption, solubility and sorption of heat cure polymethylmethacrylate denture base resin and flexible (thermoplastic polyamide nylon) denture base resin. J Clin Diagn Res 8(8):1–4. https://doi.org/10.7860/JCDR/2014/8707.4770
Singh K (2012) Injection molding technique for fabrication of flexible prosthesis from flexible thermoplastic denture base materials. World J Dent 3(4):303–307. https://doi.org/10.5005/jp-journals-10015-1178
Thakral GK, Aeran H, Yadav B, Thakral R (2012) Flexible partial dentures—a hope for the challenged mouth. People's J Sci Res 5(2):17–21
Tuna SH, Keyf F, Gumus HO, Uzun C (2008) The evaluation of water sorption/solubility on various acrylic resins. Eur J Dent 2:191–197
Vojdani M, Giti R (2015) Polyamide as a denture base material: a literature review. J Dent (shiraz) 16(1 Suppl):1–9
Walmsley AD (2003) Acrylic partial dentures. Dent Update 30(8):424–429. https://doi.org/10.12968/denu.2003.30.8.424

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