10.5005/jp-journals-10019-1218

ORIGINAL ARTICLE

Comparison of Water Conditioning Effects on Hardness and Dimensional Stability of Methyl Methacrylate and Polyamide Denture Base Materials

Sahar Elkholy

ABSTRACT

Aim: To evaluate the influence of water conditioning on the hardness and dimensional stability of polyamide denture material.

Materials and methods: The samples were conditioned in a water bath according to values of temperature (4°C and 43°C) and time (700 hours). To evaluate the hardness test, samples were fabricated from polyamide and heat cured acrylic resin materials and was divided into control, cold conditioning and hot conditioning groups and hardness were measured for all groups. For dimensional stability test, forty denture bases were divided into cold conditioning and hot conditioning groups. The gaps between the denture base and the cast were measured.

Results: The hardness of polyamide denture material was significantly decreased after hot water conditioning. Heat cured acrylic resin showed a significant increase in dimensional changes regarding cold water conditioning test.

Conclusion: Water conditioning at 43°C could decrease hardness and increase the flexibility of polyamide denture material. Water conditioning at 4°C could increase in dimensional instability of heat cure poly (methyl methacryolate) (PMMA) denture material.

Clinical significance: Use of dimensionally stable denture materials under the hot and cold condition are very important to retain the denture.

Keywords: Dimensional stability, Hardness, Polyamide, Poly-(methyl methacrylate), Water conditioning.

How to cite this article: Elkholy S. Comparison of Water Conditioning Effects on Hardness and Dimensional Stability of Methyl Methacrylate and Polyamide Denture Base Materials. Int J Prosthodont Restor Dent 2018;8(4):114-119.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

The denture base is the part of a denture that rests on the foundation tissues and to which teeth are attached.[1] The most common materials used for fabrication of denture base are polymers. Polymers were introduced in the 1920s and underwent many controversies and its acceptance is closely associated with the name of Staudinger who received the nobel prize in 1953.[2] Polymers are also called plastic, and have two divisions, the commodity plastics (characterized by high volume and low cost) and engineering plastics (higher cost and low volume).

Poly(methyl methacrylate) (PMMA) and polyamide (engineering plastics) are the most common denture base materials used due to its good mechanical properties and functional quality. PMMA has several advantages as good aesthetic, low water sorption and solubility, adequate hardness, low toxicity, ease of fabrication and repair, and it has some disadvantages as polymerization shrinkage, weak flexural, low impact strength, low fatigue resistance and a free monomer that may be cause allergy.[3]

Polyamide is a thermoplastic polymer and contains the amide groups -CO-NH- in its main chain. Polyamide is a crystalline polymer, whereas PMMA is amorphous so it is less soluble in the solvent, has high heat resistance and has higher elasticity than common heat polymerizing resins.[4-6]

Polyamide is partly crystalline, and the most important property of polyamide is water absorption which has a strong effect on their mechanical properties. The dry material is very brittle and has low impact strength and high tensile strength. Under dry as molded (DAM) condition the polyamide usually contains 0.1 to 0.3% of water and with the increase of water content its toughness and flexibility increases while the tensile strength decreases.[7]

The properties of dry as the molded material does not reflect the true properties as the material could absorb moisture from the surrounding environment and the moisture could affect the dimensional stability, mechanical properties and the performance of the product. The rate of moisture absorption increase with an increase in temperature and the humidity.[8,9]

Intraorally, the denture base is in wet condition due to salivary secretion. The materials of the denture base could be affected by variation of temperature from hot and cold, and this will affect the dimensional stability and the mechanical properties of these materials. Normal mouth

Associate Professor

Department of Removable Prosthodontics, Faculty of Oral and Dental Medicine, Delta University for Science and Technology, Mansoura, Egypt

Corresponding Author: Sahar Elkholy, Associate Professor Department of Removable Prosthodontics, Faculty of Oral and Dental Medicine, Delta University for Science and Technology, Mansoura, Egypt, e-mail: dr_saharelkholy@yahoo.com

temperature without any interference of hot or cold is about 35°C,[10] which could be increased and decreased with hot and cold foods and the denture is inside the oral cavity for about sixteen hours if the patient takes out his/her denture before going to sleep. Intraoral temperature could be affected by breathing, amount of salivary secretion and temperature of food intake.[11]

In the market there are many polyamide denture bases materials as (Lucitone FRS, Dentsply), (Valplast, Valplast Int. Corp) and Deflex (Nuxen S.R.L), and it was found that the material was not successful for denture construction due to high flexibility, high water absorption, low flexure strength, high dimensional instability, and color deterioration.[12-14] Nowadays there is new polyamide denture material called Vertex Thermo Sense rigid, (Vertex dental), which is rigid, monomer-free and unbreakable.

The final properties of polyamide could be determined by heat treatment or water conditioning which takes place above the surrounding temperature. In order to obtain the desired properties of the material, the time and the temperature of the water bath must be controlled.[7] In this regards ISO-291 stated two standard atmospheres for conditioning, 23/50 (temperature in °C and humidity in %) for all applicants and 27/65 for tropical regions. It was found that the rate of water absorption is very law in 23°C and to accelerate this process the temperature or/and the humidity must be increased.[15]

The present study was conducted to evaluate the influence of water conditioning on hardness and the dimensional stability of the polyamide denture base material comparing with the conventional denture base material (PMMA).

MATERIALS AND METHODS

Hardness Test

Specimens were prepared from silicone mold of stainless steel die (12 × 12 × 3), and sixty wax patterns were fabricated and divided into two groups. Group 1: Thirty samples were fabricated from Vertex Thermo Sense rigid (Vertex dental, Soesterberg, Netherlands) and group 2: Thirty samples were fabricated from conventional heat cure acrylic resin (Acrostone, Cairo, Egypt).

Water Conditioning

The samples were conditioned in the water bath according to values of temperature (4°C and 43°C) and time (700 hours). For 4°C water conditioning, the samples stored in the water bath in a refrigerator and for 43°C the samples stored in a water bath in a glass container with heater and stabilizer to stabilize the temperature at 43°C.

For hot water conditioning test, ten samples of each material were taken as test group 1(A) and test group 2(A). For cold water conditioning, ten samples of each material were taken as test group 1(B) and test group 2(B). Ten samples of each material were left at room temperature as control group 1 and control group 2. Hardness for all samples was measured by Wolpert Wilson instruments (Vickers hardness tester) by applying 1960 mN for 10 seconds.

Dimensional Stability Test

Samples were prepared from a silicon mold of stainless steel maxillary model. Forty casts were poured using dental stone and divided into two groups. Group 1: Twenty denture bases were fabricated from heat cure acrylic resin, group 2: Twenty denture bases were fabricated from polyamide (vertex thermo-sense rigid). At the posterior end of the cast three-point were drawn, one at the middle of the cast, one at the left crest and one at right crest (Fig. 1). The gap between the denture base and the cast were measured at the three points for all samples using stereomicroscope.

Water conditioning: The samples were conditioned in water according to values of temperature (4° C and 43°C) and time (one month or 700 hours) as with hardness test. For hot conditioning test, two groups were divided into two subgroups, group 1(A) and group 2(A) with ten denture bases each and for cold conditioning test as group 1(B) and group 2(B) with ten denture bases each. After 700 hours in water conditioning (4°C and 43°C), the samples were removed from the container, were dried with tissue and the gaps between the denture bases and the casts were measured at the three points (right crest, mid-palatal and left crest) for the all samples using stereomicroscope.

Statistical Analysis of the Data

For hardness test, the mean values and standard deviation were calculated, and the results were statistically analyzed using Microsoft Excel 2010 to detect differences between the study groups by analysis of variance (ANOVA) and significant difference between groups was done using post-hoc test (LSD). For dimensional stability

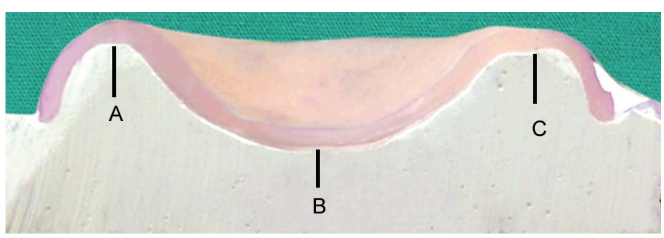


Fig. 1: Three reference points for measuring the gap between the denture base and the cast (A) Right crest; (B) Mid-palatal point; (C) Left crest

test data were analyzed using Statistical Package for the Social Sciences (SPSS) software package version 18.0 (SPSS, Chicago, IL, USA). Quantitative data were expressed using range, mean, standard deviation and median. Not normally distributed quantitative data were analyzed using the Mann–Whitney test for comparing two groups. The p-value was assumed to be significant at 0.05.

RESULTS

Hardness

With heat cure acrylic resin the results showed that heat and cold had no significant effect on the hardness (Table 1). With vertex thermo sense the results showed that the cold had no significant effect of the hardness of the material, but the hot had a significant effect on decreasing the hardness of the material (Table 2).

Dimensional Stability

Regarding the hot test, vertex thermo sense showed the least dimensional change at the left crest and the highest dimensional change at the middle and right crest with no significant difference between them. Regarding the cold test, vertex thermo sense showed the least dimensional change at the left crest, and the gap between the trial denture base and the cast was decreased. The highest dimensional change at the middle followed by the right crest, with no significant difference between them (Table 3).

Table 1: Effect of hot and cold water conditioning on hardness of heat cured acrylic resin (in HV)

	Cold	*Hot*	*Control*	*F*	*p*
Heat cured acrylic					
Min. – Max.	23.35–32.10	21.85–51.75	24.15–28.05		
Mean ± SD	27.33 ± 3.33	32.73 ± 11.35	26.10 ± 2.76	0.782	0.486*
Median	26.55	30.25	26.10		

*: Statistically significant at p ≤ 0.05
F,p: F and p values for ANOVA test, Significance between groups was done using Post Hoc Test (LSD)

Table 2: Effect of hot and cold water conditioning on hardness of vertex thermo sense (HV)

	Cold	*Hot*	*Control*	*F*	*p*
Vertex thermo sense					
Min.–Max.	16.25–34.25	9.20–15.25	22.60–26.0		
Mean ± SD	22.65 ± 6.87	11.57 ± 2.40	24.30 ± 2.40	8.122*	0.010*
Median	21.55	10.75	24.30		
Significance between groups	$p_1 = 0.006^*$, $p_2 = 0.698$, $p_3 = 0.013^*$				

*: Statistically significant at p ≤ 0.05
F, p: F and p values for ANOVA test, Significance between groups was done using Post Hoc Test (LSD)
p1: p value for comparing between cold and hot
p2: p value for comparing between cold and control
p3: p value for comparing between hot and control

Table 3: Comparison between the effects of hot and cold water conditioning according to % of dimensional change from control in vertex thermo sense (μm)

Vertex thermo sense	*Hot test*	*Cold test*	*U*	*p*
Left Crest (μm)				
Min.–Max.	–41.84 – –21.05	–43.89 – –12.01		
Mean ± SD.	–34.37 – 8.18	–27.98 ± 11.27	11.0	0.262
Median	–35.84	–28.0		
Middle (μm)				
Min. – Max.	6.39 – 67.07	48.26 – 102.7		
Mean ± SD	33.08 ± 21.92	72.93 ± 19.51	2.0*	0.010*
Median	31.26	71.65		
Right Crest (μm)				
Min.–Max.	3.11 – 130.9	–26.93 – 60.74		
Mean ± SD	49.17 ± 50.16	11.90 ± 31.60	9.0	0.150
Median	40.26	9.39		
Average				
Min.–Max.	–6.77 – 45.20	9.63 – 26.98		
Mean ± SD	15.96 ± 18.80	18.95 ± 6.19	15.0	0.631
Median	14.33	19.27		

U, p: U and p values for Mann–Whitney test for comparing between the two groups
*: Statistically significant at p ≤0.05

With heat cure acrylic resin regarding the hot test, the result showed the least dimensional change at the left crest and the highest dimensional changes at the middle followed by a right crest with no significant difference between the three groups. Regarding the cold test, heat cure acrylic resin showed the least dimensional changes at the left crest and the highest at the middle, with no significant changes between the middle and the left (Table 4).

Regarding the dimensional changes related to all points, there is no significant difference between vertex thermo sense and heat cure acrylic resin according to percentage of change from control groups with hot water conditioning test, but heat cured acrylic resin showed a significant increase in dimensional changes regarding cold water conditioning test (Table 5 and Graph 1).

DISCUSSION

Polymers as PMMA and polyamides are the most common materials used for the construction of denture bases for complete and partial dentures. Dimensional stability and hardness are very important properties when selecting the denture base material. Water absorption is the very important property of the polyamide which could affect the mechanical properties and dimensional stability of the material. Toughness and flexibility increase with the increasing water absorption while the tensile strength decrease.[7] Heat treatment and water conditioning could improve the mechanical properties of the polyamides.

In the current study, the tested materials were vertex thermo sense (polyamide 12) and conventional curing PMMA and two tests were done to evaluate the hardness and dimensional stability of the selected materials after water conditioning at two temperatures 43°C and 4°C. It was reported that the following mouth rinses with water at 10°C, 35°C and 55°C, for 5 seconds the resulting mean intraoral temperatures measured by the infra-red thermometer were 27°C, 35°C and 43°C, respectively,[11] this statement explains why water conditioning at 43°C was used in the present study.

Table 4: Comparison between the effects of hot and cold water conditioning according to % of dimensional change from control in heat cure acrylic (µm)

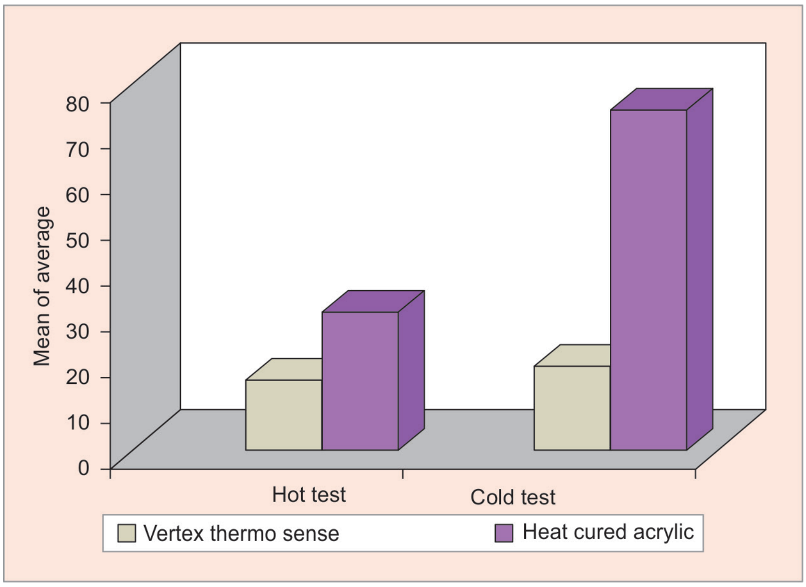
Left crest (µm)	*Heat test*	*Cold test*	*U*	*p*
Min.–Max.				
Mean ± SD	–21.98–19.91	–48.06–84.26	17.0	0.873
Median	0.78 ± 14.97	11.58 ± 47.45		
Middle (µm)	1.68	8.33		
Min.–Max.				
Mean ± SD.	–12.07–99.64	79.20–179.1	4.0*	0.025*
Median	55.88 ± 42.19	120.6 ± 36.82		
Right Crest (µm)	61.93	116.40		
Min.–Max.				
Mean ± SD	–7.0–125.4	61.89–129.7	0.50*	0.037*
Median	35.83 ± 46.32	92.57 ± 24.30		
Average				
Min.–Max.	27.37	90.95		
Mean ± SD	–0.53–50.22	39.08–131.0	4.0*	0.025*
Median	30.83 ± 18.87	74.93 ± 34.79		

U, p: U and p values for Mann–Whitney test for comparing between the two groups
*: Statistically significant at p ≤0.05

Table 5: Comparison between the effect of hot and cold water conditioning on vertex thermo sense and heat cured acrylic regarding the all points according to % of dimensional change from control (µm)

Average	*Vertex thermo sense*	*Heat cured acrylic*	*U*	*p*
Hot test				
Min. – Max.	-6.77 – 45.20	-0.53 – 50.22		
Mean ± SD.	15.96 ± 18.80	30.83 ± 18.87	10.0	0.200
Median	14.33	31.47		
Cold test				
Min. – Max.	9.63 – 26.98	39.08 – 131.02		
Mean ± SD.	18.95 ± 6.19	74.93 ± 34.79	0.000*	0.004*
Median	19.27	69.88		

U, p: U and p values for Mann Whitney test for comparing between the two groups
*: Statistically significant at p ≤0.05



Graph 1: Comparison of dimensional changes between vertex thermo sense and heat cured acrylic resin regarding all points according to % of change from control

Regarding the hardness test, the results of the current study revealed that there was a significant decrease in hardness with polyamide after hot water conditioning for 700 hours due to water absorption. Polyamide is partly crystalline and after heat treatment and water conditioning the crystal phase increases in the polymer structure and the viscoelasticity of the elastic part increases.[16] Polymers absorb fluids, according to Fick, slow the rate of absorption increase with time until saturation or equilibrium and the rate of absorption also increase with an increase in the temperature.[17,18]

Vertex thermo sense is polyamide 12 and water absorption value is, 31.2 ± 0.8 µg/mm^3 and ISO standard is 32 µg/mm^3. It was mentioned that higher the amide group concentration, more the water absorption.[19] Water act as a plasticizer which leads to increase the distance between molecules thus enabling the molecules to shift more smoothly against each other.[7] The higher of the water content, the more flexible of the material and the lower of the rigidity and hardness.

With conventional PMMA the hot and cold water conditioning had no significant effect on the hardness of the material. This may be due to high monomer-polymer ratio, the presence of methyl methacrylate monomer and existing of cross-linked agent.[3] Regarding dimensional stability, the volume of polyamide material increased underwater conditioning and it was greater with increasing of the water temperature then absorption rate gradually reduces until an equilibrium.

It was seen that the linear swelling of the polyamide is different when considering the thickness (T), width (W), length (L) direction, swelling in T direction was about 60% of volumetric changes.[20] The linear changes in the polyamide due to absorption of water does not reflect the normal condition inside the oral cavity where the denture base does not flat, but it is arch-shaped.

From the results of the current study regarding dimensional stability after water conditioning at 43° C, with polyamide material, the right crest, and the mid-palatal area showed an increase in dimensional changes. With conventional PMMA denture base material, the mid-palatal area showed the greatest dimensional changes which in agreement with all previous studies.[21,22] Regarding all points measurements, there was no significant difference between the polyamide and conventional PMMA regarding dimensional stability because of water absorption under hot water conditioning.

In another study, it was found that conventional PMMA immersed in water at 37 ± 1°C for 7 days had more water sorption than the polyamide denture base.[23] Dimensional changes in bases in the median regions of the palate and the alveolar ridges appear to be related to a supposed lateral-lateral denture base distortion and this lead to less adaptation.[21,22,24]

With cold water conditioning (4° C) the conventional PMMA revealed a significant increase in dimensional instability due to shrinkage. The most dimensionally unstable area is the mid-palatal followed by the right crest, and the explanation for this, the edentulous maxilla consists of a relatively flat portion in the middle of the hard palate and inclined slopes towards the residual ridge. Due to the shape of palatal concavity, shrinkage occurs toward the residual ridge leads to a lifting of the record base in the mid-palatal region.[25] The dimensional changes related to the posterior palatal area is very important because it will affect the adaptation and at the end the retention of the maxillary denture.[26,27]

With vertex thermo sense denture base material, the results showed that the cold water conditioning had no effect on the dimensional stability of the material and there was no volume shrinkage.

CONCLUSION

Water conditioning at 43°C is an important factor in decrease hardness meanwhile increases the flexibility of polyamide denture material. Hot and cold water conditioning had no significant effect on the dimensional stability of the polyamide denture base material. Cold water conditioning at 4°C could increase dimensional changes especially at the mid-palatal area of conventional heat cure PMMA due to shrinkage.

CLINICAL SIGNIFICANCE

Increase flexibility of denture material is very useful especially with the patients have a sharp ridge, bony exostosis, and deep undercut areas. Also using dimensional stable denture materials under the hot and cold condition are very important to retain the denture.

ACKNOWLEDGMENTS

Special thank for Amr Sabry, Abd Elsalam Elsheikh, Omar Mokhtar, Mohannad Eldaqaq, Ahmed Hosni and Marwan Mustafa for their great work in helping in the preparation of samples, and fabrication of hot conditioning container and doing statistics. The current study did not receive any financial support.

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