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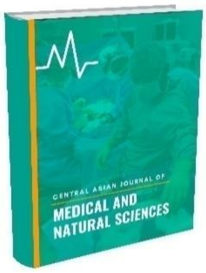

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Evaluate the Solubility of PMMA Denture Base Material Incorporated with Zeolites Loaded with Transition Elements

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Abstract: Aim: Determine the effect of incorporating of zeolites loaded with transitional elements on the solubility of dentures base materials. Material and Methods: The process of preparing zeolites were carried out in laboratory of industrial chemistry in the education college at Mosul university, also the polymerization process for PMMA were carried out according to manufacturer instructions, after that; the PMMA were loaded with transition elements; (silver , copper and nickel) at different concentrations, the proportions were (2%, 3% and 5%) and with several elements at fixed concentration in the dentistry college at Mosul university. Results: the solubility values showed that the zeolite denture base material loaded with silver was the best compared to others elements, the bests proportion (2%) foe silver compared others proportions. Conclusion: The incorporation of zeolite for the transitional elements as a whole led to an increase in the solubility of the PMMA denture base material.

Key words: PMMA Solubility, Poly acrylates, Denture Base Material Properties, Loading Materials & Zeolites.

Introduction

There are a large group of polymers which are commonly used for various applications in prosthodontics, but the denture material was and still is the preferred treatment as the most stable basic material in dental uses, which made it a suitable and popular vital material for various applications, despite the spread of dental implants around the world and for several reasons, including what is medical, including what is economic, as to this day, when these materials are immersed in water, two reactions occur, plasticizers and other soluble agents enter water, or the polymer absorbs water, gradually resulting in changes in the mechanical and physical properties, polymethyl methacrylate is still the most developed as a basic material for dentures by many researchers around the world for several reasons, including its low cost, and the process of including materials in the bases of dentures is a good way to improve its mechanical properties thermal and chemical properties [(1-6)], and there are a lot of materials and elements that were added to it to improve its properties, including (polyethylene, zirconium oxide and hydroxyapatite)[(7)], where some important factors must be evoked for the material to have clinical applications, including it to be non-toxic and non-allergic. as well as acceptability such as color stability, the absence of an unacceptable odor, and most importantly for the patient, is the mechanical properties, where the durability of the resin must be high enough so that it does not affect the function of the mouth as well as its resistance to acid and alkaline substances, corrosion and low absorption of fluids. Zeolite is a class of microporous ionic aluminum silicate minerals with a highly regular structure of pores and chambers and has a variety of uses, both natural as well as synthetic zeolites are high potential for biomedical application in the present and future including antimicrobials, antioxidants, antidiarrheal drugs and adsorption of heavy elements and toxins(8-11). This material in the mouth cavity is recognized as the most effective delivery platform for antimicrobial agents.(12)All studies dealt with (the mechanical or physical) properties of both, the fine zeolite material, but despite the studies conducted on it, its applications have not been fully explored(13-15). The increase in the absorption of water molecules due to the addition of nanomaterial to the polymer mixture, could be due to the potential interaction between the polymerization initiators and the nanomaterial and thus negatively affect the polymerization rate(16). Recent studies have confirmed the existence of a significant differences in the water absorption process of a substance after mixing polymethyl methacrylate with zeolite powders(17).

Material and Methods

Devices and Tools:

1. Glass Desiccator

2. Digital Balance

3. Digital Vernier Caliper with accuracy of 0.01mm

Raw materials

The rapid thermal polymerization acrylic resin(18) PROCRYLA product was used to prepare all the specimens under study.

Preparation of Zeolite

Zeolite was prepared by mixing two solutions of potassium aluminate and potassium silicate at a pH of (11) at 70 C, Triethylene glycol anhydrous was added later with continuous stirring and heating for an hour. The precipitate was dried at (110) °C for (3) hours, After that, it was transferred to a ceramic lid to be treated thermally at (550) °C for (4) hours[19]

Zeolites Loading With Transition Metals

Mixed (10) grams of zeolite with (100) cm^3 of a 0.02ml for each of the (silver, copper, and nickel) solutions respectively, it was refluxed for 3hrs, then transferred to an oven at (120) °C. [20]

PMMA Loading with Transition Metal Zeolite

All samples in this work were prepared by mixing 10 grams of acrylic resin powder with zeolite nano powder for each of the transition elements (Ag, Cu, &Ni) with fixed percentages for each group, respectively (2%, 3%, and 5%). [21]

Water Solubility(W_{sl})

Thirty six specimens were prepared under study according to the specifications of ADA(2002), and were divided into three samples for each group. dimensions for each specimens: [(0.02) ± 4*10*12]mm[22]

Specimens were placed in a clean and dry glass desiccator, which contains activated silica gel until to reach stable weight as the follows;

The volume of each specimen was measured by an digital vernier caliper. The specimens were immersed in deionized water at (37 ± 1)°C for 7 days, the specimens were removed from the water with tweezers, wiped with clean dry towel until freeing them from visible moisture, waved in the air for 15 seconds and weighed 1 min after removal from the water. This mass was recorded as (m1), After that, the specimens were dried by placing in the desiccator that contain freshly dried silica gel at 37°C until a final constant mass was obtained which was recorded as (m2), as shown in tables (1-3).

The control group consisted of samples of polymethyl methacrylate alone, As for the test samples, they consisted of samples of polymethyl methacrylate of zolite loaded with transitional elements.

The water solubility values were calculated and expressed in microgram per cubic millimeter unit (µg/mm3) according to the following equation(23)

$W_{sl} = m_1 - m_2 / V$

m_1= dried mass of the sample,

m_2= The reconstituted mass of the sample,

V= Volume of specimens before immersing in deionized water.

Table(1): water solubility of PMMA-$_{ZAg}$

Sample	No.	Volume (v)	m_1 Wet Wt.$_{(g)}$	m_2 Dry Wt.$_{2(g)}$	$(m_1-m_2) / v$ Water Solubility	
					Sample	Mean
PMMA Ctr.	S_1	314.963	0.333	0.330	9.52493E-06	1.8239E-05
	S_2	306.020	0.316	0.309	2.28743E-05	
	S_3	313.653	0.333	0.326	2.23177E-05	
PMMA $Z_{Ag\ (2\%)}$	S_1	347.163	0.429	0.418	3.16854E-05	2.9078E-05
	S_2	329.563	0.360	0.352	2.42746E-05	
	S_3	351.731	0.438	0.427	3.12739E-05	
PMMA $Z_{Ag\ (3\%)}$	S_1	282.220	0.321	0.309	4.252E-05	2.8381E-05
	S_2	313.537	0.380	0.374	1.91365E-05	
	S_3	298.045	0.339	0.332	2.34864E-05	
PMMA $Z_{Ag\ (5\%)}$	S_1	346.512	0.406	0.396	2.8859E-05	2.82087E-05
	S_2	320.050	0.346	0.338	2.49961E-05	
	S_3	292.483	0.361	0.352	3.0771E-05	

Table(2): water solubility of PMMA-$_{ZCu}$

Sample	No.	Volume (v)	m_1 Wet Wt.$_{(g)}$	m_2 Dry Wt.$_{2(g)}$	$(m_1-m_2) / v$ Water Solubility	
					Sample	Mean
PMMA Ctr.	S_1	314.963	0.333	0.330	9.52493E-06	1.8239E-05
	S_2	306.020	0.316	0.309	2.28743E-05	
	S_3	313.653	0.333	0.326	2.23177E-05	
PMMA $Z_{Cu(2\%)}$	S_1	309.520	0.344	0.333	3.55389E-05	3.20965E-05
	S_2	312.843	0.357	0.348	2.87684E-05	
	S_3	281.407	0.344	0.335	3.19821E-05	
PMMA $Z_{Cu(3\%)}$	S_1	276.790	0.298	0.288	3.61285E-05	3.47234E-05
	S_2	281.302	0.326	0.317	3.19941E-05	
	S_3	277.411	0.304	0.294	3.60476E-05	
PMMA $Z_{Cu(5\%)}$	S_1	298.642	0.322	0.312	3.34849E-05	3.37328E-05
	S_2	281.184	0.299	0.291	2.84511E-05	
	S_3	305.637	0.327	0.315	3.92623E-05	

Table(3): water solubility of PMMA-$_{ZNi}$

Sample	No.	Volume (v)	m_1 Wet Wt.$_{(g)}$	m_2 Dry Wt.$_{2(g)}$	$(m_1-m_2) / v$ Water Solubility Sample	Mean
PMMA Ctr.	S_1	314.963	0.333	0.330	9.52493E-06	1.8239E-05
	S_2	306.020	0.316	0.309	2.28743E-05	
	S_3	313.653	0.333	0.326	2.23177E-05	
PMMA $Z_{Ni(2\%)}$	S_1	290.551	0.341	0.329	4.13008E-05	4.33185E-05
	S_2	283.287	0.309	0.297	4.23599E-05	
	S_3	302.410	0.340	0.326	4.62948E-05	
PMMA $Z_{Ni(3\%)}$	S_1	246.238	0.288	0.281	2.84278E-05	2.90435E-05
	S_2	256.820	0.292	0.283	3.5044E-05	
	S_3	253.605	0.267	0.261	2.36588E-05	
PMMA $Z_{Ni(5\%)}$	S_1	276.36	0.304	0.295	3.25662E-05	3.41935E-05
	S_2	279.883	0.346	0.335	3.93021E-05	
	S_3	293.045	0.318	0.309	3.0712E-05	

Results

The Statistical Analysis

1. PMMA-Z_{Ag}

The post comparisons test of water solubility of the three concentrations of PMMA-$_{ZAg}$, as well as the control group, were shown in figure (1). The results as the value reached (P= 0.147), therefore the results of post comparisons test showed that identical values with no statistically significant difference ($p>0.05$) among PMMA-$_{ZAg}$ (2%), PMMA-$_{ZAg}$ (3%), PMMA-$_{ZAg}$ (5%) and the control group. the mean water solubility values showed the PMMA-$_{ZAg}$ (5%) the lowest and considering that this characteristic is negative and the lower its value, the more it indicates progress compared to the control group, but we noticed the presence of silver has led to an increase in solubility, it`s showed in the table (1).

Figure (1) Descriptive statistics and the result of the post-comparisons of the mean Water Solubility of three concentrations of PMMA-$_{ZAg}$ as well as the control group

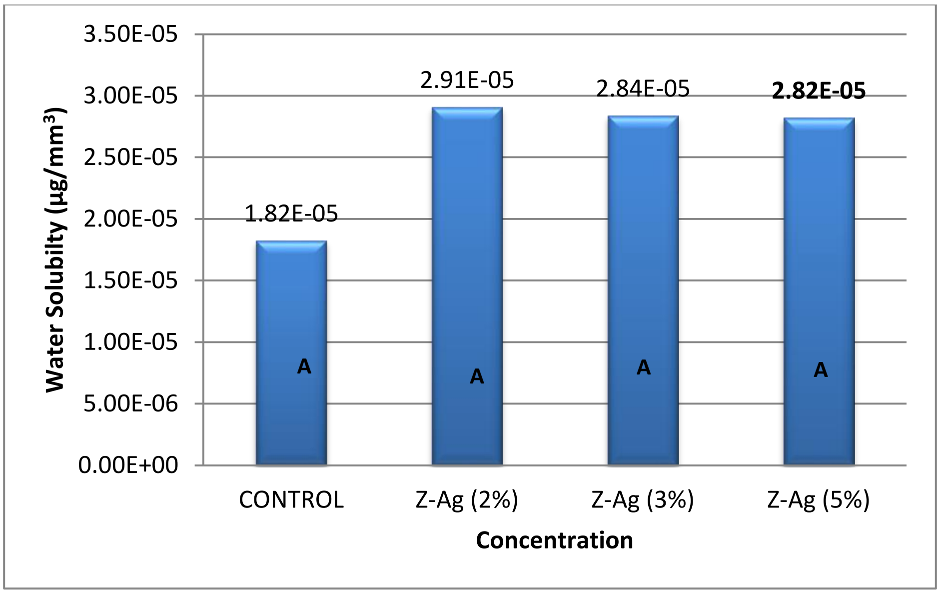

Table (1): Comparisons of the mean water solubility of three concentrations of PMMA-$_{ZAg}$ and the control group

Test	Sample	N	Mean	Std. Deviation	Kruskal Wallis test	P	Compare
Water Solubility	Ctr.	3	1.8239E-05	7.55171E-06	5.359	0.147	A
	PMMA-$_{Z\_Ag\ (2\%)}$	3	2.9078E-05	4.16494E-06			A
	PMMA-$_{Z\_Ag\ (3\%)}$	3	2.8381E-05	1.24364E-05			A
	PMMA-$_{Z\_Ag\ (5\%)}$	3	2.8209E-05	2.94187E-06			A

If $P^* \leq 0.05$; significant difference ,$P^{**} \leq 0.01$; high significant difference, If P > 0.05; no significant difference

2. PMMA-Z$_{Cu}$

The post comparisons test of water solubility of the three concentrations of PMMA-$_{ZCu,}$ as well as the control group, were shown in figure (2). The results as the value reached (P= 0.07), therefore the results of post comparisons test showed that identical values with no statistically significant difference (p>0.05) among PMMA-$_{ZCu}$ (2%), PMMA-$_{ZCu}$(3%), PMMA-$_{ZCu}$(5%) and the control group. the mean water solubility values showed the PMMA-$_{ZCu}$(2%) as the lowest value, it`s shown in table (2).

Figure (2) Descriptive statistics and the result of the post-comparisons of the mean Water Solubility of three concentrations of PMMA-$_{ZCu}$ as well as the control group.

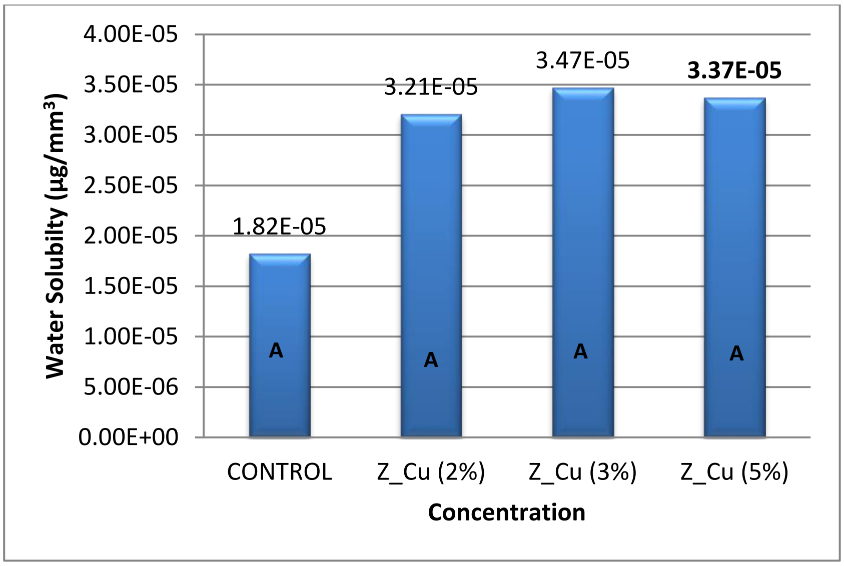

Table (2): comparisons of the mean Water Solubility of three concentrations of PMMA-$_{ZCu}$ and the control group

Test	Sample	N	Mean	Std. Deviation	Kruskal Wallis test	P	Compare
Water Solubility	Ctr.	3	1.8239E-05	7.55171E-06	7.051	0.07	A
	PMMA-$_{Z\_Cu\ (2\%)}$	3	3.2096E-05	3.38669E-06			A
	PMMA-$_{Z\_Cu\ (3\%)}$	3	3.4723E-05	2.36399E-06			A
	PMMA-$_{Z\_Cu\ (5\%)}$	3	3.3733E-05	5.40983E-06			A

3. PMMA-Z$_{Ni}$

The post hoc test of water solubility of the three concentrations of PMMA-$_{ZNi,}$ as well as the control group were shown in figure (3), The results as the value reached (P= 0.022), therefore the results of post comparisons test showed that identical values with statistically significant difference ($p<0.05$) among PMMA-$_{ZNi}$ (2%), PMMA-$_{ZNi}$ (3%), PMMA-$_{ZNi}$ (5%) and the control group.

The results showed that there is no statistically significant difference between of PMMA-$_{ZNi}$ (2%) and the control group side, and there is no statistically significant difference among PMMA-$_{ZNi}$ (3%), PMMA-$_{ZNi}$ (5%) and the control group on the other side. But there is a statistically significant difference between PMMA-$_{ZNi}$ (2%) and other concentrations (PMMA-$_{ZNi}$ (3%) and PMMA-$_{ZNi}$ (5%)) themselves.

the mean water solubility values showed the PMMA-$_{ZNi}$ (3%) as the lowest value, which indicates progress compared to the control group, it`s showed in table (3).

Figure (3) Descriptive statistics and the result of the post-comparisons of the mean Water Solubility of three concentrations of PMMA-$_{ZNi}$ as well as the control group.

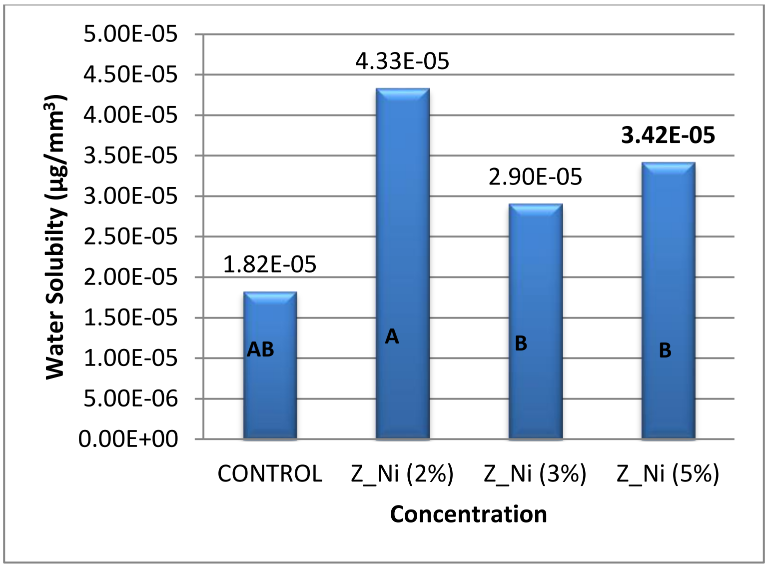

Table (3): Comparisons of the mean water solubility of three concentrations of PMMA-Z_{Ni} and the control group

Test	Sample	N	Mean	Std. Deviation	Kruskal Wallis test	P	Compare
Water Solubility	Ctr.	3	1.8239E-05	7.55171E-06	9.667	0.022(*)	B
	PMMAZ$_{-Ni\ (2\%)}$	3	4.3318E-05	2.63136E-06			A
	PMMAZ$_{-Ni\ (3\%)}$	3	2.9044E-05	5.7175E-06			AB
	PMMAZ$_{-Ni\ (5\%)}$	3	3.4193E-05	4.52034E-06			AB

4. Concentration 2%

The post comparisons test of water solubility of the three additives (PMMA-$_{ZAg}$ PMMA-$_{ZCu,}$ and PMMA-$_{ZNi}$) at a constant concentration of 2% as well as the control group were shown in figure (4).

The results which as the value reached ($P= 0.022$), therefore the results of post hoc (Dun`s test) showed identical values with statistically significant difference ($p<0.05$) among the three additives and the control group, whereas no statistically significant difference among the three additives themselves, there was no statistically significant difference among PMMA-$_{ZAg}$, PMMA-$_{ZCu}$ and control group. But there was a statistically significant difference between PMMA-$_{ZNi}$ and the control group. the mean water solubility values showed that PMMA-$_{ZAg}$ was the best additive, due to being the lowest among other additives, it`s showed in table (4).

Figure (4) Descriptive statistics and the result of the post-comparisons of the mean Water Solubility of 2% concentrations of additive as well as the control group.

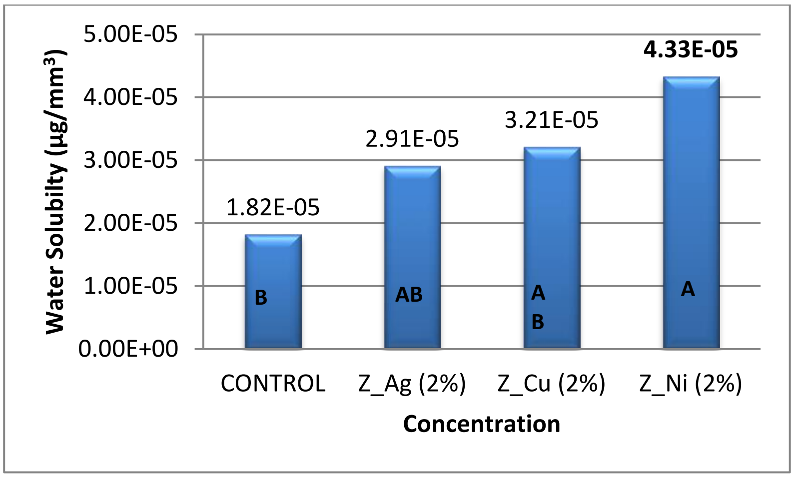

Table (4): Comparisons of the mean water solubility of 2% concentration of additives and the control group

Test	Sample	N	Mean	Std. Deviation	Kruskal Wallis test	P	Compare
Water Solubility	Ctr.	3	1.82E-05	7.5517E-06	9.667	0.022(*)	B
	PMMA-$_{Z\_Ag}$	3	2.91E-05	4.1649E-06			AB
	PMMA-$_{Z\_Cu}$	3	3.21E-05	3.3867E-06			AB
	PMMA-$_{Z\_Ni}$	3	4.33E-05	2.6314E-06			A

5. Concentration 3%

The post comparisons test of water solubility of the three additives materials (PMMA-$_{ZAg}$, PMMA-$_{ZCu}$, PMMA-$_{ZNi}$) at a constant concentration of 3% as well as the control group were shown in figure (5). The results which as the value reached (P= 0.118), therefore the results of the post comparisons test showed identical values with no statistically significant difference (p>0.05) among the three additives and the control group. the mean water solubility values showed the PMMA-$_{ZAg}$ the lowest value, it is shown in table(5).

Figure (5) Descriptive statistics and the result of the post-comparisons of the mean Water Solubility of 3% concentrations of additive as well as the control group

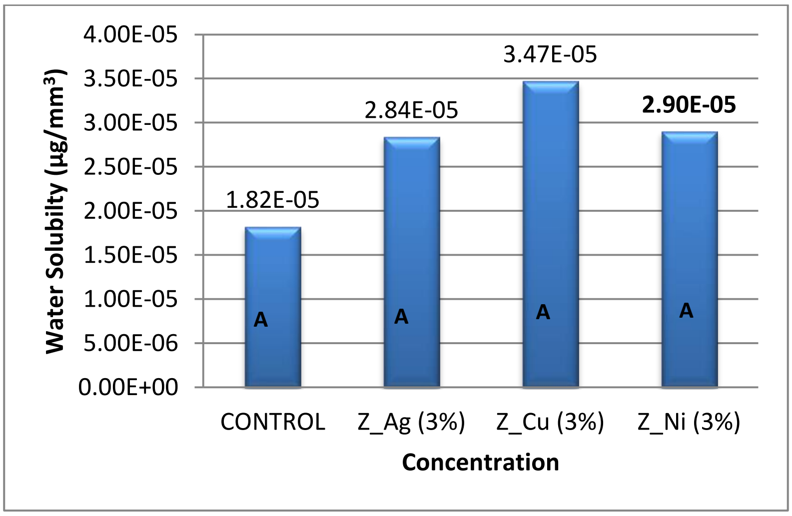

Table (5): Comparisons of the mean Water Solubility of 3% concentration of additives and the control group

Test	Sample	N	Mean	Std. Deviation	Kruskal Wallis test	P	Compare
Water Solubility	Ctr.	3	1.82E-05	7.5517E-06	5.872	0.118	A
	PMMA $_{Z\_Ag}$	3	2.8381E-05	1.24E-05			A
	PMMA $_{Z\_Cu}$	3	3.47E-05	2.364E-06			A
	PMMA $_{Z\_Ni}$	3	2.9E-05	5.7175E-06			A

6. Concentration 5%

The post comparisons test of water solubility of the three additives materials (PMMA-$_{ZAg}$, PMMA-$_{ZCu}$, PMMA-$_{ZNi}$) at a constant concentration of 5% as well as the control group were shown in figure (6). The results which as the value reached (P= 0.053), therefore the results of the post comparisons test showed identical values with no statistically significant difference (p>0.05) among the three additives and the control group. the mean water solubility values showed the PMMA-$_{ZAg}$ the lowest and considering that this characteristic is negative and the lower its value, the more it indicates progress compared to the control group, it`s shown in table(6).

Figure (6) Descriptive statistics and the result of the post-comparisons of the mean Water Solubility of 3% concentrations of additive as well as the control group.

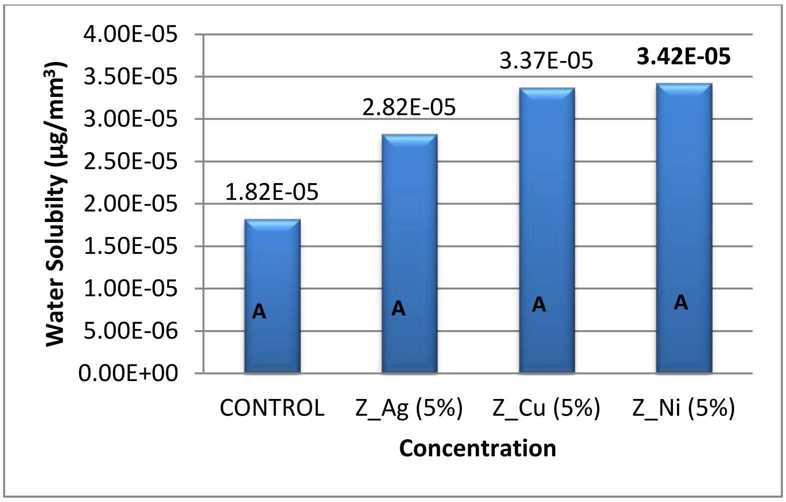

Table (6): Comparisons of the mean water solubility of 5% concentration of additives and the control group

Test	PMMA	N	Mean	Std. Deviation	Kruskal Wallis test	P	Compare
Water Solubility	Ctr.	3	1.82E-05	7.5517E-06	7.667	0.053	A
	PMMA $_{Z\_Ag}$	3	2.82E-05	2.9419E-06			A
	PMMA $_{Z\_Cu}$	3	3.37E-05	5.4098E-06			A
	PMMA $_{Z\_Ni}$	3	3.42E-05	4.5203E-06			A

The Discussion

The absorption of water by any substance is the amount of water that will be absorbed on the surface of that substance, so any appreciable loss in the weight of the substance will be a measure of solubility the results were identical with principles of solubility theories , explanation is that hydrophilic surfaces are highly polar and contain water adsorbed by silica particles. Silica is a component of zeolite, and the increase in wettability can be explained by its hygroscopic property and its content in the composition may lead to increased water absorption. It can be summarized from the ability of zeolite surfaces to absorb water, and its framework structure that contains ions, which have great freedom of movement allowing ion exchange, which leads to an increase in PMMA denture base material water absorption and solubility.

Conclusion

It is clear that when incorporate additives of different types from salt silicate as the synthetic zeolite clay with different concentrations, the solubility increased of PMMA denture base material compared with the control groups.

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