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Thermal Diffusivity of Nano-Sized Additives on Flexible Denture Base Material

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ABSTRACT

Aims: To evaluate the thermal diffusivity of nano – sized additives (Al2O3, ZnO and Ag) with different concentrations (0.25% , 0.5 % , 1% and 2%) by Weight on flexible denture base material.

Materials and Methods: The total number of specimens were 65 which represent the control and additive groups . Cylindrical flexible denture base material specimens with dimension (15mm) in diameter and (45mm) length were prepared. Decagon devices KD2 pro thermal properties analyzer was used to measure thermal diffusivity. Statistical analysis including ANOVA and Duncan multiple range test were used. The statistical result were considered significant at $P \leq 0.05$.

Results: Thermal diffusivity of flexible with nano-sized additives (Al2O3, ZnO and Ag) with different concentrations (0.5 % , 1% and 2%) by Weight showed a significant increase than the 0.25% additives and control groups. Minimum thermal diffusivity (0.0866 mm2/s) represented control, while maximum (0.1256 mm2/s) represented 2% Al2O3.

Conclusion: The nano-sized additives to flexible denture base material were effective for enhancement of thermal diffusivity of flexible denture base material.

Keywords: thermal diffusivity, nano additives, flexible denture base.

INTRODUCTION

Acrylic resin was the most commonly used material for construction of complete and partial denture due to their esthetic value, easy use and ability for relining and rebasing [1 ,2] .

Thermoplastic material for dental prostheses, Valplast (United state) and flexible (Germany) were related to polyamides group and used for dental applications (Nylon Plastic) [3-5]. Both materials used to create flexible tissue – born partial denture. These materials were not strong enough to be used for conventional tooth born rest seat. The flexibility enhanced patient comfort and affect their satisfaction [4 ,6] .

Acrylic resin and flexible denture materials had low thermal conductivity and diffusivity compares to metallic denture base which might affect patient acceptance and conformance especially patients wearing complete dentures. The palate was covered by the denture base, the ability to sense transient temperature change at the palate might be affected by the thermal diffusivity of denture base materials and these thermal features of denture base play an important role on the gustatory response [7-9].

Addition of metal and fibers improved some physical and mechanical properties of acrylic resin, while the incorporation of silver, copper, and / or aluminum in the form of powder to acrylic resin material improved the thermal conductivity and diffusivity of acrylic resin material [10].

Addition of nano-sized particles to polymer resin denture base had been preferred to micro-sized particles because the nanoparticles characterized by better processing, smoother surfaces and larger total surface area [11].

Jasim and Ismail showed that the addition of Al_2O_3 nanoparticles at concentrations of (1%, 2% and 3%) by weight to acrylic resin improved thermal conductivity and diffusivity [12].

Rad et al. , showed that the mean thermal conductivity and compressive strength of acrylic resin reinforced with nano silver were significantly higher than the unmodified acrylic resin , while the tensile strength decreased significantly . Their results suggesting the favorable effect of silver nanoparticles on improving the thermal conductivity of acrylic resin and the use of this material in the palatal area of maxillary acrylic resin dentures was recommended [13].

This study was aimed to evaluate the thermal diffusivity of nano – sized additives (Al_2O_3, ZnO and Ag) with different concentrations (0.25% , 0.5 % , 1% and 2%) by Weight on flexible denture base material .

MATERIALS AND METHODS

The total number of specimens were 65 which represent the control and additive groups. Cylindrical flexible denture base material specimens with dimension (15mm) in diameter and (45mm) length were prepared . Five of the Valplast cartridge were emptied from their granules, and then weighted using electrical balance of 0.0001gm accuracy and the mean of the weights of five cartridge were recorded. Five of the Valplast cartridge were weighted and the mean of the weights was recorded. From this value the previously recorded mean value of the empty cartridge was subtracted so , the weight of the granules inside the cartridge was recorded. In the present study, Al_2O_3, ZnO and Ag powder nano particles (20-30nm, 20-30nm, and 80nm respectively) were used. The nano particles powder (0.25%, 0.5%, 1% and 2%) of the weight of the Valplast granules was weighted and replaced a side in a plastic tube .

The Valplast cartridge cover was removed then the Valplast was placed on a vibrator, the nanoparticles powder was added gradually in to the cartridge then the cover of the cartridge was closed by knocking the cover of the cartridge. The cartridge also was shacked very well manually for one minute to be ensure that the nanoparticles powder has been distributed uniformly among the granules, followed by placing the cartridge on the vibrator horizontally for two minute, the cartridge was vibrated and rolled manually to avoid accumulation of nanoparticles powder in the cartridge. The furnace was set to 288^{o}C which was decided in this study, the heating cylinder which was inserted into the slot present inside the furnace and the furnace was allowed to warm up till it reaches the preset heating which was 288^{o}C. The heating cylinder then removed from the furnace. The Valplast cartridge, the metal disc and finally the short solid metal cylinder inserted into the heating cylinder and left inside the furnace for 16 minutes to allow the granules inside the cartridge to melt. The two halves of the flask were placed in an oven at 65^{O}C for half an hour. Prior to the injection of the denture base material, the two halves of the flask were tightened by the 4 screws securely and returned to the oven, waiting for the granules to melt and to be injected later on[14].The flask removed from the oven and placed inside the injection unit in vertical position in its correct position with the aid of the projection present at the base of the injection unit. In this position the injection opening was to the top surface of the flask.

The heating cylinder together with the Valplast cartridge removed from the furnace by its wooden handle, and placed immediately on the injection opening hole of the flask, and the material was injected inside the flask by the use of the manual injection unit, to give a pressure of 5 bars. After 5 minutes the pressure was released and the flask is removed from the injection unit and allowed to bench cooling to room temperature. The flask then opened and the specimens were removed from the mold. The specimens were smoothed prior to polishing with the smooth blue rubber wheels on the mandrills. The specimens were incubated in distilled water at 37 ± 1 ^{o}C for 48 hours for conditioning .

In this study a decagon devices KD2 pro thermal properties analyzer was used to record thermal diffusivity. The KD2 Pro Analyzer consist of a hand held controller and sensors that can be inserted in to the specimen fig(1) . The hand held controller has a LCD display and keypad, which allows the user to conduct the tests. A 30 mm dual – needle SH-1 sensor was used to obtain thermal diffusivity data. The KD2 Pro used with SH-1 dual needle sensor, One of the needle contained a heating element and the other, a thermo couple. Energy was supplied to the heating needle in the form of heat, which was then transferred in to the medium between the needles to be measured by the thermocouple. Specimens were prepared with little resistance to SH-1 dual needle probe, which was inserted the full depth of the needles in to the specimens which were predrilled to obtain two circular opening 1.3mm diameter and 6 mm spacing to minimize the potential for bending of SH-1 sensor. The SH-1 sensor performance was verified each day of testing using the manufacturer provided Delrin block as shown in fig(1). Firstly, always allowed about 15 min for specimen and needle to equilibrate with ambient temperature before taking the measurements.

RESULTS

Thermal diffusivity of flexible resin, in comparison among different concentrations, figs (2,3, and 4) demonstrated the mean ± SD values for thermal diffusivity of flexible resin control and with(0.25%, 0.5%, 1%, and 2%) Al_2O_3, ZnO,

and Ag groups. The one way analysis of variance (ANOVA) as shown in tables (1, 2 and 3) of control and (0.25%,0.5%,1%, and 2%) of each additives (Al_2O_3, ZnO and Ag) groups demonstrated a significant differences ($p \leq 0.05$).Duncan's multiple range test figs(2, 3 and 4) showed no significant difference between control and 0.25% of (Al_2O_3, ZnO and Ag) groups. Also (0.5% , 1% and 2%) of (Al_2O_3, ZnO and Ag) groups showed a significantly increase of thermal diffusivity than the control and 0.25% of (Al_2O_3, ZnO and Ag) groups . The one way analysis of variance (ANOVA) as shown in table (4) , fig(5) of control and 0.25% (Al_2O_3, ZnO, and Ag) groups showed no significant differences.

The one way analysis of variance (ANOVA) as shown in table (5) of control and 0.5% (Al_2O_3, ZnO, and Ag) groups showed significant differences. Duncan's multiple range test fig(6) showed 0.5% Al_2O_3 group significantly higher than control and 0.5% Ag groups. No significant difference between 0.5% Al_2O_3 and 0.5% ZnO groups.0.5% (ZnO and Ag) groups significantly higher than control group. No significant difference between 0.5% ZnO and 0.5% Ag groups. The one way analysis of variance (ANOVA) as shown in table (6) of control and 1% (Al_2O_3, ZnO, and Ag) groups showed significant differences. Duncan's multiple range test fig(7) showed 1% Al_2O_3 group significantly higher than control and 1% Ag groups. No significant difference between 1% Al_2O_3 and 1% ZnO groups.1% (ZnO and Ag) groups significantly higher than control group. No significant difference between 1% ZnO and 1% Ag groups. The one way analysis of variance (ANOVA) as shown in table (7) of control and 2% (Al_2O_3, ZnO, and Ag) groups showed significant differences. Duncan's multiple range test fig(8) showed 2% Al_2O_3 group significantly higher than control and 2% Ag groups. No significant difference between 2% Al_2O_3 and 2% ZnO groups. 2% (ZnO and Ag) groups significantly higher than control group. No significant difference between 2% ZnO and 2% Ag groups.

DISCUSSION

In this study a Decagon devices KD2 pro thermal properties analyzer was used to record thermal diffusivity by using the dual-needle SH-1 sensor which operates on principle of heat pulse technique [15] . One of the needles contains heating elements and the other, a thermo couple. Energy was supplied to the heating needle in the form of heat which was then transferred in to the medium between the needles to be measured by the thermocouple. According to the results of this study which showed that the (0.5%, 1% and 2%) of each additives (Al_2O_3, ZnO, and Ag) groups significantly increased thermal diffusivity than control group because the nano-sized particles (Al_2O_3, ZnO, and Ag) might act as a fillers which enhanced thermal diffusivity, as the thermal conductivity and diffusivity of polymer were low[16-19].The finding of the present study agreement with other studies that demonstrated the thermal conductivity of polymer had been traditionally enhanced by the addition of thermally conductive fillers, ceramic or metal particles [20,21] .

Flexible denture base material was processed at elevated temperature often above their melting temperature. This process might be challenged because of the low thermal conductivity and diffusivity of flexible denture [22]. Nanoparticles have unique –sized dependent properties that can be used as additives [23].In this study the nano-sized additives might improve the thermal diffusivity of flexible denture base material so, melting of flexible denture base material and injection procedure might be enhanced.

Significant improvement of thermal diffusivity of flexible denture base material with the increase concentration of nano-sized additives (Al_2O_3 , ZnO and Ag) because of increasing concentration of fillers result in increasing thermal conductivity [19,24].This study showed a differences in thermal diffusivity performance of the nano-sized additives, this might due to the particle shape and size, as thermal conductivity and diffusivity of polymer was affected by filler size, shape, volume fraction and spatial arrangement in the polymer matrix [24].

The particle size in the composite affect the distance among particles which affect the thermal conductivity, diffusivity and mechanical properties of the composite[25,26]. The inter particles distance might be smaller due to very small size filler [26], that to say nano-sized additives were used in this study which might result in paths or bridges that might conduct heat and enhanced significantly the thermal diffusivity of composite when compared to the control. The addition of nano-sized additives to flexible denture base material might affect its crystallinity even to minimum degree which might affect its thermal diffusivity as the thermal conductivity and diffusivity of polymer became raised with crystallinity[17].

CONCLUSION

The nano-sized additives to flexible denture base material were effective for enhancement of thermal diffusivity of flexible denture base material.

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Figure (1): KD2 Pro Analyzer

Table (1) : ANOVA for comparison thermal diffusivity among Al_2O_3 groups

SOV	SS	df	MS	F-value	P-value
Between Groups	.005	4	.001	126.815	.000*
Within Groups	.000	20	.000		
Total	.005	24			

SOV : Source of variance ; SS : Sum of Squares ; df : degree of freedom ;MS: Mean Sequare

* significant differences exist at p≤0.05

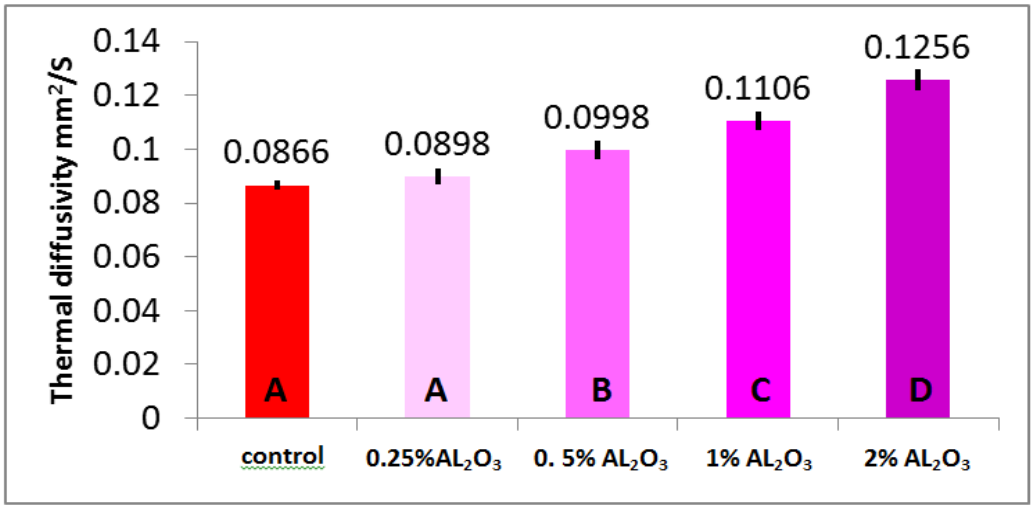

Figure (2): Mean ± SD of thermal diffusivity for comparison among Al_2O_3 groups

Table (2) : ANOVA for comparison thermal diffusivity among ZnO groups

SOV	SS	df	MS	F-value	P-value
Between Groups	.004	4	.001	77.403	.000
Within Groups	.000	20	.000		
Total	.005	24			

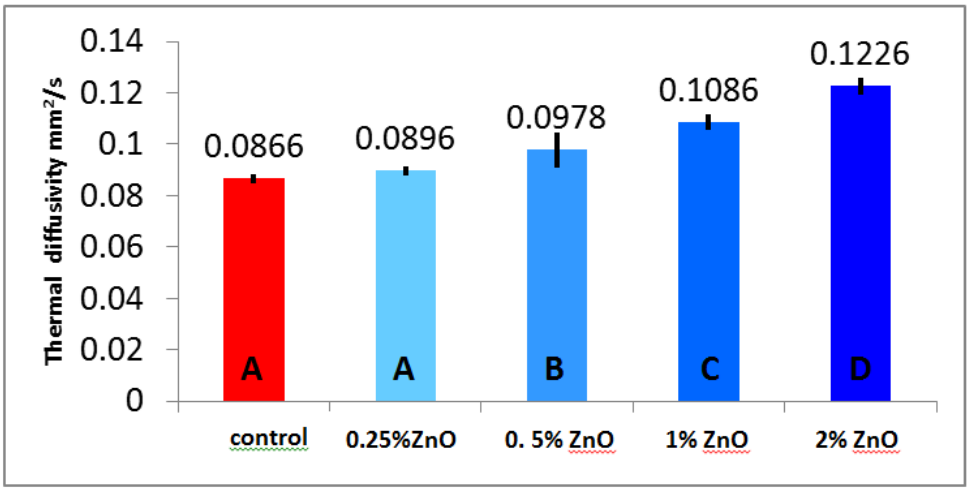

Figure (3): Mean ± SD of thermal diffusivity for comparison among ZnO groups

Table (3) : ANOVA for comparison thermal diffusivity among Ag groups

SOV	SS	df	MS	F-value	P-value
Between Groups	.004	4	.001	84.467	.000
Within Groups	.000	20	.000		
Total	.004	24			

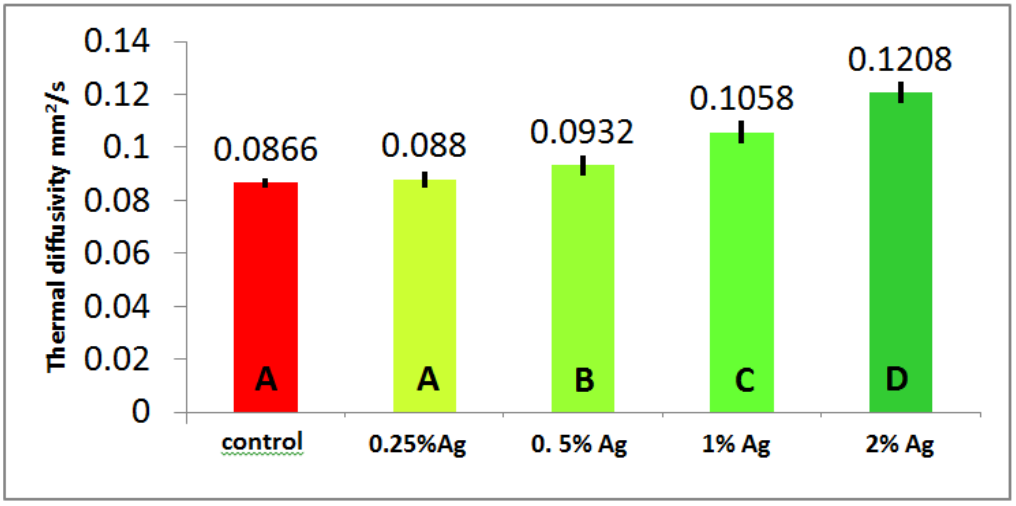

Table (4) : ANOVA for comparison thermal diffusivity among additives groups with 0,25%

SOV	SS	df	MS	F-value	P-value
Between Groups	.000	3	.000	1.934	.165
Within Groups	.000	16	.000		
Total	.000	19			

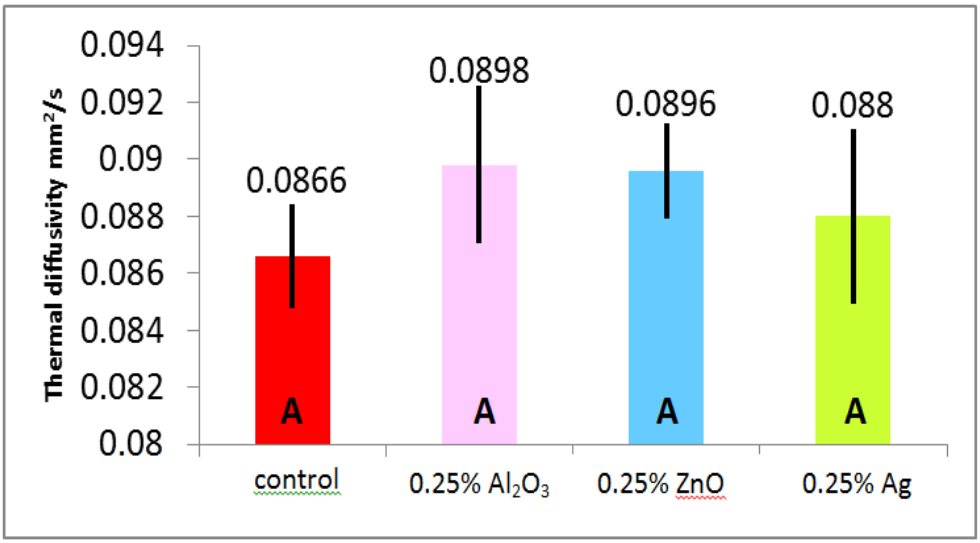

Figure (5): Mean ± SD of thermal diffusivity for comparison among additives groups with 0.25%

Table (5) : ANOVA for comparison thermal diffusivity among additives groups with 0.5%

SOV	SS	df	MS	F-value	P-value
Between Groups	.001	3	.000	9.228	.001
Within Groups	.000	16	.000		
Total	.001	19			

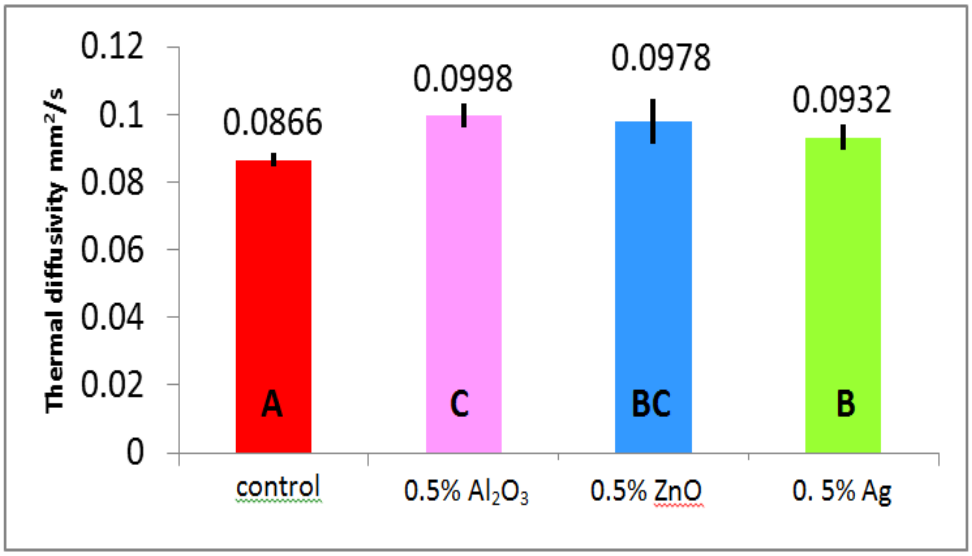

Figure (6): Mean ± SD of thermal diffusivity for comparison among additives groups with 0.5%

Table (6) : ANOVA for comparison thermal diffusivity among additives groups with 1%

SOV	SS	df	MS	F-value	P-value
Between Groups	.002	3	.001	56.594	. 000
Within Groups	.000	16	.000		
Total	.002	19			

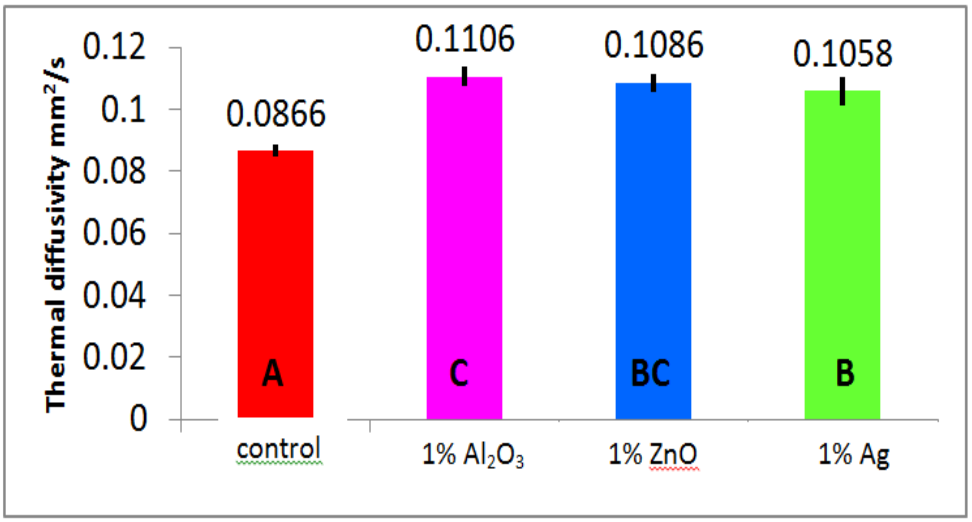

Figure (7): Mean ± SD of thermal diffusivity for comparison among additives groups with 1%

Table (6) : ANOVA for comparison thermal diffusivity among additives groups with 2%

SOV	SS	df	MS	F-value	P-value
Between Groups	.005	3	.002	150.296	. 000
Within Groups	.000	16	.000		
Total	.005	19			

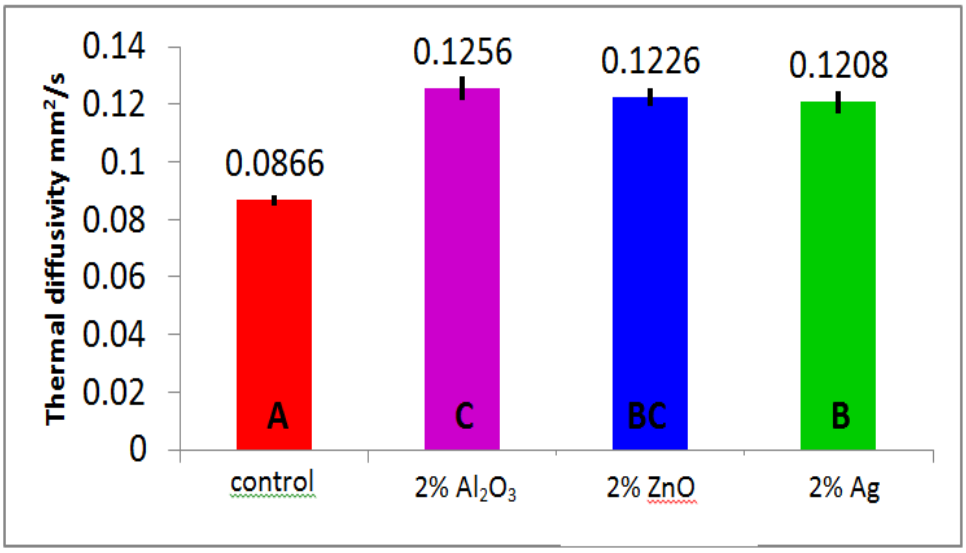

Figure (7): Mean ± SD of thermal diffusivity for comparison among additives groups with 2%