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Evaluate the Effect of Adding Strontium Titanate Nano Particles on Thermal Conductivity and Tensile Strength of Heat Cured Denture Base Material

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KEYWORDS

Thermal conductivity,

tensile strength, strontium titanate (SrTiO3)

ABSTRACT:

Consider a new revolution in dental prostheses termed Nano dentistry as a result of the phenomenal expansion of nanotechnology. With the addition of certain nano components, chemical polymeric structures have been modified in order to improve mechanical quality. Different concentrations of strontium titanate (0.5, 1, 1.5, and 2 weight percent) were added to heat-cured acrylic resin to assess its thermal conductivity and tensile strength. 100 samples of acrylic resin that has been heat-cured. The specimens were divided into two groups of fifty each using the tensile strength and thermo conductivity tests. ten samples of heat-sensitive acrylic resin (control group) without any additions, and ten samples of heat-sensitive acrylic resin with nano additions (SrTiO3) at various concentrations (0.5%,1%,1.5%,2%), According to (ASTM D412) (American Society for Testing and Materials; 2002), we created specimens measuring 33 mm in length, 3 mm in width, and 6 mm in depth to measure tensile strength, and specimens measuring 40 mm in diameter, 2.5 mm thick, and 6 mm in depth to assess thermal conductivity (Hasan and Ali, 2018; Kamil and Al-Judy, 2018). The statistical analysis of the data was performed using one-way ANOVA and LSD tests. Thermal conductivity tests showed statistically significant differences at all concentrations, with the exception of the range of (0.5%) to (1%), where there was no variation. Conclusion: After strontium titanate (SrTiO3) was added to the denture base material, improvements in concentration-dependent thermal conductivity and tensile strength were observed

Material and methods: Heat-curing acrylic denture base material effect on tensile strength and thermal conductivity . In this study, 100 specimens were divided into 2 foremost groups (tensile strength and thermal conductivity), fifty for each test. 10 only were made according to the percentages of SrTiO3 powder used. Auto CAD 2018 was used to design the specimen form and dimension in order to create plastic patterns for acrylic specimen molds that would meet the test requirements.

Results: Statistical analysis:

The following statistical data analysis approaches were used in order to analyze and assess the results of the study under application of the statistical package (SPSS):

1. Descriptive statistics which include:

a- Mean value, Standard Deviation, Standard Error, and (95%) Confidence interval of mean values and the two extremes values (minimum and maximum).

b- Graphical presentation by using bar chart .

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2. Inferential statistics:
a- One-Way ANOVA (analysis of variance test) was used to test the equality of mean values.
b- Least Significant Difference (LSD) was used to compare between each two groups and show the significance of difference between them.
The comparison significant (P. value) were:
- NS: Non-significant difference at $P>0.05$.
- S: Significant difference at $P\leq 0.05$.
- HS: Highly significant difference at $P<0.01$

This study demonstrated appropriate power for both factors, "material" for the number of specimens used to assess denture base acrylic resins' tensile strength and thermal conductivity qualities (n=10).

. Conclusion: The heat conductivity and tensile strength of denture base material were increased with the addition of strontium titanate ($SrTiO_3$), and this effect was concentration dependent. There was a considerable decline in the mean values, with the exception of the concentration of 2% in the tensile strength test.

Introduction

PMMA is often the dental material utilized in clinical dentistry to manufacture the foundation for removable dentures. It can be described as a polymerization method that is simple to change and has excellent mechanical, physical, and chemical qualities [1]. PMMA is often robust, simple to handle, inexpensive, abrasion-resistant, easily sterilizable, decomposable, and very resilient; PMMA has a propensity to water absorption by imbibition. Due to its non-crystalline form, it possesses a high internal energy [2]. The material most frequently used for dentures is poly methyl methacrylate. However, it suffers from a number of flaws, including inadequate mechanical and fatigue strength, thermal shrinkage, and a Poor impact resistance, colorless stability, particularly in self-cured resins, allergy to residual monomer, mechanical retention, and porosity need are among the drawbacks of PMMA, along with poor thermal conductivity to the underlying mucosa. Nevertheless, numerous reporters made an effort to enhance the resin's qualities by strengthening it with various techniques and materials [3], [4], [1].

A patient who experiences a hypersensitive reaction to PMMA monomer has been advised to utilize these materials, which the manufacturer claims to have greater hardness [5]. Then, various strategies of reinforcement polymeric material were introduced that were similar to rubber material in order to address the drawbacks of the typical poly methyl methacrylate denture materials. reinforcement, metallic materials reinforcement, zirconia Nanotechnology nanomaterials risks nanopowder precautions, (ZrO_2) nanoparticles reinforcement, titanium dioxide (TiO_2) nanoparticles reinforcement, rubber reinforced polymethyl methacrylate (PMMA), [6], [4].

A newera in dental treatment marked by Nano dentistry has emerged as a result of the amazing advancements in fibers and nanoparticles, as well as the chemical correction of polymer structure by the addition of specific components. Another way to enhance resins is by including fibers and particles. Fillers of the nanoscale and micrometer sizes are frequently added to the polymers to boost strength and stiffness, offer solvent resistance, or lower prices. [7].

Recently, titanium and strontium oxides were combined to form strontium titanate ($SrTiO_3$). Thin sheets of oxide are some of the modern materials for superconductors. For the construction of scaffolds for bone regeneration, strontium titanate may be used [8]. For instance, maxillofacial silicone had $SrTiO_3$ added as a filler, which may have enhanced some of the material's properties [9]. This study was used to improve the tensile strength and thermal conductivity of the acrylic denture base after adding strontium titanate ($SrTiO_3$) nanoparticles. structure.

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Material and Methods:

For this experiment, 100 samples of dental acrylic material were used and split into two primary groups to examine tensile strength and thermal conductivity .For each test, fifty samples were created based on the proportions of SrTiO3 powder used. In this study, Auto CAD 2018 was used to design the specimen form and dimension in order to create plastic patterns for acrylic specimen molds that would meet the test requirements. Complete dentures and acrylic specimens go through the same processing steps [11].

Fig (1)

Grouping sample:

100 samples divided into two main groups

Group A: 50 sample of acrylic material for thermal conductivity test divided into 5groups with different concentration of $SrtiO_3$

Group B: 50 sample of acrylic material for tensile strength test divided into 5groups with different concentration of $SrtiO_3$.

Acrylic resin designing:

According to the manufacturer's instructions, a mixture of polymer and monomer (21 g to 10 ml) was used to create it. The investigation used several quantities of strontium titanate Nano filler, polymer, and monomer. The (0.001g) accuracy of an electronic balance. Nano SrTiO3 was introduced to the monomer in the calculated amount, and the nanoparticles were disseminated equally throughout the monomer by probe sonication (120 W, 60 KHz) for three minutes [12]the resulting dough had the desired nanofiller concentration. (SrTiO3) powder (0.5%, 1%, 1.5%wt., and 2%) The parts are assembled and handled per the manufacturer's guidelines. To decrease particle aggregation and phase separation potential, the monomer containing Nano powder is immediately mixed with acrylic powder, then covered and left until the dough stage is reached. Then Packing, Curing, Finishing, and polishing of acrylic were done with a conventional method.

Acrylic resin packing:

When the acrylic reached the dough-like stage, the packing of the acrylic resin began. The resin was taken out of the jar, rolled, and then put into the molds. Finally, the flask's two sides were joined by applying pressure (through a hydraulic press) until metal-to-metal contact was made. This pressure was maintained for five minutes before the clamping and transfer to the water bath. [13]. fig (2)

Curing

In order to achieve this, the clamped flask was placed in a water bath as illustrated, heated for about 1.5 hours at 74°C, and then brought to boiling for 30 minutes. The acrylic specimens were removed from the die stone molds and the metal flask was deflasked once it had reached room temperature in the water bath [14].

Finishing and polishing

Two minutes on a low speed with an acrylic stone, followed by two minutes with a tungsten carbide bur, then one minute with 320 grit sandpaper. On the sandpaper, motions were made in a random direction. [15]. All burs used for the finishing technique were cylindrical in shape to ensure parallel cutting or grinding of the bur to the sample surface (to decrease irregularities and equalize pressure) [16]. Fig(3)

Thermal conductivity test specimen's design:

The Thermal conductivity and diffusivity specimens were made from acrylic resin and had dimensions of (40 mm *2.5mm) in diameter and thickness respectively were fabricated according to instrument's specification. Fig (4)

Testing procedure for Thermal conductivity:

The thermal conductivity of acrylic specimens were measured by using thermal conductivity apparatus(Lee disc) (Price and Jarratt, 2002; Abdulhamed and Mohammed, 2010). demonstrates the device, which consists of three copper discs(A, B, and C), each having a hole for thermometers. Figure (5)

tensile strength test *Specimen design:*

According to (ASTM D412) (American Society for Testing and Materials; 2002), a specimen with a central cross section area measuring 33mm in length, 3mm in width, and 6mm in depth . Fig (6)

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Testing procedure for tensile strength

The tensile strength of acrylic specimens were measured by using Instron testing machine Fig (7).

The specimen was mounted in universal testing machine in which the lower member kept constant, while the upper member moved at a steady rate (500 mm / min) (Waters and Jagger, 1999), the maximum force when each specimen was broke by stretching was recorded by the computer software (Fig (7) **.**

Microscope test before and after adding of nano filler particles:

Using a scanning electron microscope (SEM), the affected surface of the thermal conductivity and hardness test specimens was evaluated. One specimen served as the control, while the other four specimens represented 0.5, 1%, 1.5, and 2 weight percent SrTiO3 nanocomposite. To improve picture resolution, the specimens were sputter-coated with a uniform 2 m layer of gold in a vacuum evaporator for two minutes at 25 mA. Using a 2KV working voltage, the back scattered electron mode was used to evaluate the fracture surface. As seen in Figure (8), the nanoparticles are equally distributed throughout the material with very few aggregations in groups inside the polymer matrix.

The surface of the control and additive samples used in the tensile strength and thermal conductivity test specimen was analyzed by SEM at various magnifications to assess the dispersions of nanoparticles in the resin matrix. As the filler concentration increased, there was some aggregation (Yellow arrows) seen in the SEM images of the SrTiO3 NPs inside the acrylic resin. Scanning electron microscope with magnification power (1000x) was used to estimate the acrylic with SrTiO3 specimen (control group) without any incorporation and also used to estimate the distribution of the SrTiO3 particles within the acrylic particles .

Results

The following tests were conducted on both the control and experimental groups, and the results are provided (0.5% $SrTiO_3$), (1% $SrTiO_3$), (1.5% $SrTiO_3$) and (2% $SrTiO_3$) in tables and bar charts:

1. Measurement of Thermal Conductivity.
2. Tensile test

Thermal conductivity test

Figure (9) represent represents the bar chart that showed an increase in mean values of the acrylic resin with incorporation of 1.5 % wt. $SrTiO_3$ group as compared to other studied groups.

A descriptive statistic is shown in Table (1) along with the mean values, standard deviation, standard error, and values for the lowest and maximum. The results showed that the control group had the lowest mean values (0.2920.007), while the acrylic resin group with the integration of 2% wt. SrTiO3 had the highest mean values (0.3740.008).

Table (2) displayed the LSD of the pomegranate group's inhibition zone. All concentration differences were extremely significant, with the exception of those between 0.5% and 1%) which were not significant.

In this study, the homogeneity of variance was assessed using the Levine's test, and the equality of means was assessed using the one-way ANOVA test, as indicated in table (3). While the one-way ANOVA test result revealed significant differences (P0.05) among all examined groups, Levine's test result revealed no differences between researched groups at $P>0.05$.

Tensile test

Figure (10) represents the bar chart that showed an increase in mean values of the acrylic resin with incorporation of 1.5 % wt. $SrTiO_3$ group as compared to other studied groups.

Table (4) presents descriptive data for the Tensile test, including mean values, standard deviation, standard error, minimum and maximum values. The results showed that the control group had the lowest mean values (39.895 9.316), while the acrylic resin group with 1.5% wt SrTiO3 inclusion had the greatest mean values (48.824 0.689).

Table (5) displayed the LSD of the pomegranate group's inhibition zone; all concentrations had extremely significant differences, with the exception of the controls (control% with 0.5%), (control% with 2%) (0.5% with 2%), (1% with 1.5%), and (1% with 2%) which were not significant.

As stated in table (6), the Levine's test was employed in this study to determine whether the variance was homogeneous and the one-way ANOVA test to determine whether the mean values were equal. While the one-way ANOVA test result revealed significant

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differences (P0.05) among all examined groups, Levine's test result revealed no differences between researched groups at $P>0.05$.

Discussion:

PMMA is a common material choice when it comes to dentures. It has been widely used since Dr. Walter Wright first introduced it in 1937 because of its many appealing operating characteristics, such as its ease of use, accuracy of fit, durability in the mouth, affordability of equipment, and visually good outcomes. Despite having several advantages, PMMA could still use improvements in terms of mechanical strength and heat conductivity [14]. Adding reinforcements to the polymer used to make denture bases was one way to solve this issue. The concept of using nanoparticles in conjunction with a matrix material for new composite reinforcement has shown to be quite successful [15].

Low thermal conductivity of poly ethyl methacrylate resin is a significant negative as it has an impact on patient acceptability of the prosthesis and the wellbeing of tissues supporting dentures [16]. PMMA's low heat conductivity, tensile strength, high water sorption, and insoluble nature are only a few of the problems associated with its application [17]. $SrTiO_3$ nanoparticles have the capacity to improve some properties of acrylic denture base material while having minor influence on others, hence this study was conducted to evaluate the material's performance. -The rate at which heat can be transported through a certain area of material samples in a given amount of time can be referred to as a material's thermal conductivity [16]. To improve the heat conductivity of denture base materials, changes can be made to the particle size of the nanoparticles used, the particle-to-polymer ratio, and the dispersion of the nanoparticles [18]. Since the base material of full dentures covers the palate of edentulous people wearing them, poly methyl methacrylate's Low thermal conductivity may affect the palate's capacity to sense temperature changes. The way a denture base material feels to the touch can also have a big impact on a person's sense of taste [13]. The inclusion of $SrTiO_3$ nanoparticles at a concentration of 2% considerably improved the thermal conductivity of PMMA. The addition of micro- and nano-fillers to a resin matrix enhances its thermal conductivity, according to numerous research, including this one. -Perseverance under pressure Sakaguchi and Powers (2012) found that the stress is the point at which local material deformation is irreversible. When specimens were evaluated by applying tension to them, it was discovered to be one of PMMA's most desirable mechanical characteristics [19] The quantity of cross-linking, the amount of filler, and the number of polymer chains that run perpendicular to the direction of the force all affect the material's tensile strength. At 1.5% by weight, the most improvement was observed. Lower cross-linking may be the cause of the $SrTiO_3$ nanoparticle concentration in polymethyl methacrylate (PMMA) [20]. The results of the current investigation suggested a higher.

Conclusion:

The effects of adding 0.5%, 1%, 1.5%, and 2% strontium titanate ($SrTiO_3$) to heat-cured acrylic resin were examined in the context of this study.

1- The heat conductivity and tensile strength of denture base material were increased with the addition of strontium titanate ($SrTiO_3$), and this effect was concentration dependent. There was a considerable decline in the mean values, with the exception of the concentration of 2% in the tensile strength test.

The c Conflict of interest statement: None.

Acknowledgments

Many great thanks extend to my supervisor and my beloved family.

2- oncentration of strontium titanate ($SrTiO_3$) significantly enhanced the thermal conductivity of heat-cured acrylic resin material.

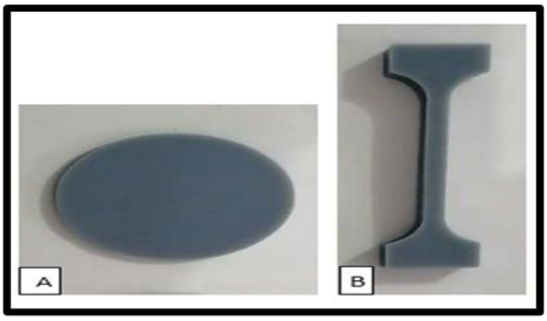

Fig (1) Acrylic resin designing

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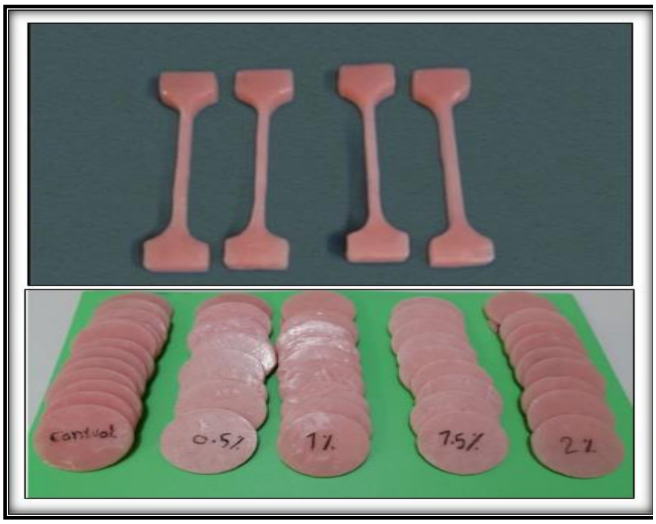

Fig(3)Finishing and polishing

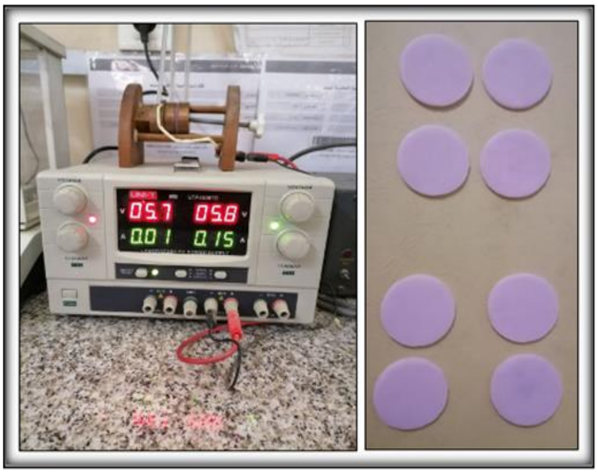

Figure (5) Thermal conductivity appliance

Figure(7) Tensile strength test specimen mounted on the Instron testing machine .

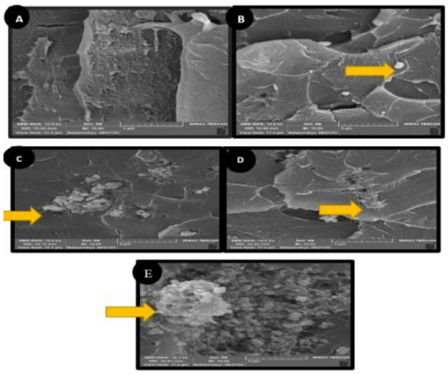

Fig (8), (a): SEM of control specimen, (b): SEM of experimental specimen with 0.5% of (SrTiO3) nanoparticles, (C): SEM of experimental specimen with 1% of SrTio3 nanoparticles, (D): SEM of experimental specimen with 1.5% of SrTio3 nanoparticles (E): SEM of experimental specimen with 2% of SrTio3 nanoparticles.

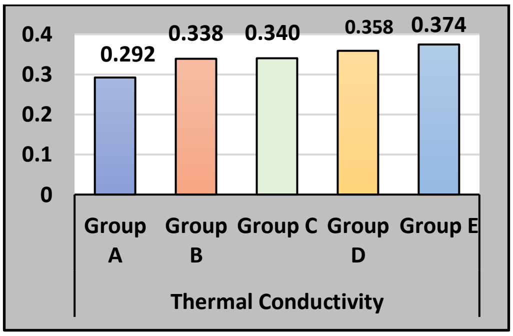

Fig (9) .represent represents the bar chart that showed an increase in mean values of the acrylic resin with incorporation of 1.5 % wt. $SrTiO_3$ group as compared to other studied groups.

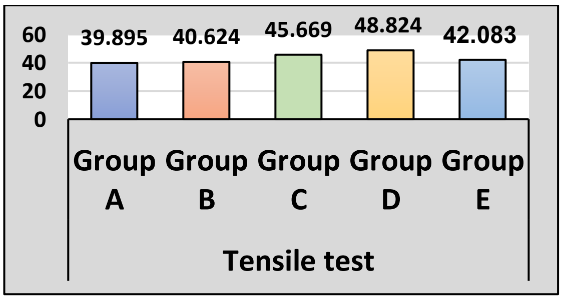

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Table (1) Descriptive statistic of thermal conductivity

Descriptives								
Thermal Conductivity								
Groups	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Group A Control Group	10	.292	.007	.002	.286	.297	.281	.307
Group B 0.5% wt. $SrTiO_3$	10	.338	.008	.002	.332	.345	.322	.350
Group C 1% wt. $SrTiO_3$	10	.340	.012	.004	.330	.349	.312	.354
Group D 1.5% wt. $SrTiO_3$	10	.358	.016	.005	.347	.370	.343	.389
Group E 2% wt. $SrTiO_3$	10	.374	.007	.002	.368	.379	.364	.386

Table (2) displayed the LSD of the pomegranate group's inhibition zone. All concentration differences were extremely significant, with the exception of those between 0.5% and 1%) which were not significant

ANOVA: Thermal Conductivity					
Groups	**Sum of Squares**	**Df**	**Mean Square**	**F**	**p-value Sig.**
Between Groups	0.038	4	0.01	77.2	<0.001
Within Groups	0.006	45	0.001		
Total	0.044	49			

	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	p-value	Sig
LSD	**Group A control**	0.5%	-.046*	.004	.000	HS
		1 %	-.048*	.004	.000	HS
		1.5%	-.066*	.004	.000	HS
		2%	-.082*	.004	.000	HS
	Group B 0.5%	control	.046*	.004	.000	HS
		1%	-.001	.004	.795	NS
		1.5%	-.019*	.004	.000	HS
		2%	-.035*	.004	.000	HS
	Group C 1%	control	.048*	.004	.000	HS
		0.5%	.001	.004	.795	NS
		1.5%	-.018*	.004	.001	HS
		2%	-.034*	.004	.000	HS
	Group D 1.5%	control	.066*	.004	.000	HS
		0.5%	.019*	.004	.000	HS
		1%	.018*	.004	.001	HS
		2%	-.015*	.004	.003	HS
	Group E 2%	control	.082*	.004	.000	HS
		0.5%	.035*	.004	.000	HS
		1%	.034*	.004	.000	HS
		1.5%	.015*	.004	.003	HS

Table (3): Levene’s and One-way ANOVA tests for all thermal conductivity studied groups.

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Descriptives							
Tensile test							
Groups	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum
					Lower Bound	Upper Bound	
Group A **Control Group**	10	39.895	9.316	2.946	33.230	46.559	36.360
Group B **0.5% wt. $SrTiO_3$**	10	40.624	.522	.165	40.250	40.998	40.050
Group C **1% wt. $SrTiO_3$**	10	45.669	.601	.190	45.238	46.100	44.740
Group D **1.5% wt. $SrTiO_3$**	10	48.824	.689	.217	48.331	49.316	48.040
Group E **2% wt. $SrTiO_3$**	10	42.083	.676	.214	41.598	42.567	41.040

Table (4) Descriptive statistic of tensile strength

Table (5) displayed the LSD of the pomegranate group's inhibition zone; all concentrations had extremely significant differences, with the exception of the controls (control% with 0.5%), (control% with 2%) (0.5% with 2%), (1% with 1.5%), and (1% with 2%) which were not significant.

	Multiple Comparisons					
	Dependent Variable: Tensile test					
	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	p-value	Sig
LSD	Group A control	0.5%	-.729	1.880	.700	NS
		1%	-5.774*	1.880	.004	HS
		1.5%	-8.929*	1.880	.000	HS
		2%	-2.188	1.880	.251	NS
	Group B 0.5%	control	.729	1.880	.700	NS
		1%	-5.045*	1.880	.010	HS
		1.5%	-8.200*	1.880	.000	HS
		2%	-1.459	1.880	.442	NS
	Group C 1%	control	5.774*	1.880	.004	HS
		0.5%	5.045*	1.880	.010	HS
		1.5%	-3.154	1.880	.100	NS
		2%	3.586	1.880	.063	NS
	Group D 1.5%	control	8.929*	1.880	.000	HS
		0.5%	8.200*	1.880	.000	HS
		1%	3.154	1.880	.100	NS
		2%	6.741*	1.880	.001	HS
	Group E 2%	control	2.188	1.880	.251	NS
		0.5%	1.459	1.880	.442	NS
		1%	-3.586	1.880	.063	NS
		1.5%	-6.741*	1.880	.001	HS

table (6) Levene's and One-way ANOVA tests for all Tensile test strength studied groups

ANOVA: Tensile test					
	Sum of Squares	**Df**	**Mean Square**	**F**	**p-value Sig.**

Between Groups	562.943	4	140.736	7.963	<0.001
Within Groups	795.346	45	17.674		
Total	1358.288	49			

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