The effect of adding single walled carbon nanotube with different concentrations on mechanical properties of heat cure acrylic denture base material

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ABSTRACT

Background: The most widely used material for fabrication of denture base is poly methyl methacrylate, despite its popularity, the main problems associated with it as a denture base material are poor strength particularly under fatigue failure inside the patient mouth, impact failure outside the patient mouth, which are the main causes for fracture of denture, several studies was done to increase mechanical properties of denture base. The present study was conducted to evaluate and compare the effect of addition single walled carbon nanotubes in different concentrations to polymethyl methacrylate on some mechanical properties (surface hardness, surface roughness, impact strength and transverse strength).

Materials and methods: Forty eight samples were prepared for pilot study divided into four groups according to the concentrations of singled walled carbon nanotubes (0%, 0.5%, 1% & 1.5%) added to heat cure acrylic resin , each group was divided into four subgroups according to the tests conducted (Surface hardness , surface roughness, impact strength and transverse strength) and the results obtained were evaluated to determine the concentration of singled walled carbon nanotubes (SWCNTS) that improve the mechanical properties of heat cure acrylic resin to be used to complete our study, so another 80 samples were made divided into two main groups (0% SWCNTS as control group) and (1.5% SWCNTS test group) and all the tests were done again.

Results: Impact strength and transverse strength were significantly increased after adding 1.5% SWCNTS While surface hardness was significantly decreased and surface roughness was non-significantly affected when compared with control group.

Conclusions: Impact strength and transverse strength of hot cure acrylic resin reinforced with 1.5% SWCNTS were greatly increased.

Keywords: Carbon nanotubes, transverse strength, impact strength. (J Bagh Coll Dentistry 2015; 27(3):28-32).

INTRODUCTION

The most widely used materials in dentistry due to its satisfactory mechanical and physical properties, aesthetics, biocompatibility with oral tissues, low coast, ease in production and reparability is Polymethylmethacrylate (PMMA), however these material are subjected to intraoral or extra oral stresses which may cause fracture in acrylic denture bases which is a time consuming and costly problem besides the fact that they are very inconvenient for the patient [(1-3)].

The most common reasons of fracture of the denture is its low resistance to impact which may lead to fracture in any accidental dropping while cleaning or due to fatigue which will lead to cracking caused by high masticatory force [(4,5)] in order to overcome this problem, several attempts were made to modify and improve the strength and hardness of PMMA. These attempts included the additions of filler particles such as zirconia, glass fiber, alumina [(6,7)].

Recent experimental studies have suggested that Carbon Nanotube which are10-100times higher than the strongest steal at a fraction of the weight when incorporated in PMMA, which result in enhanced properties of the matrix remarkably. SWCNTs are extremely strong resilient and very light in weight, however their disadvantage are high cost and dark in color but it could be used in area that are frequently fractured like the midline of the upper denture when there is large labial notch [(8,9)] .

There are two types of carbon nanotube singled wall that posses the fundamental cylindrical structure and multiwalled tubes that are made from two or more coaxial cylinders, both types of nanotubes can improve properties of polymer system [(10)].

MATERIALS AND METHODS

Sample preparation

A mould of stone in dental flask was prepared by using a metal pattern with dimensions of (80mm, 10 mm and 4mm) length, width and thickness for impact test and (65mm, 10mm and 2.5 mm) for transverse strength, hardness and roughness according to ADA specifications No. 12 (1999) then the mould was coated with separating medium and dry for 15 minutes.

For preparing **control group samples**, according to the manufacturer's instructions, a powder / liquid ratio for acrylic was 22 g/10 ml weighted by electronic balance with accuracy of (0.0001g) (Sartorius BP 30155, Germany), then the acrylic was mixed and packed in the dough stage in the mould and cured by heating the flask in water bath at 74Cº for 1.5 hours after that

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increase the temperature to boiling for 30 minutes and then cool the flask for another 30 minutes at room temperature, finally for 15 minutes under tap water according to ADA specifications No.12 (1999).

Test group samples were prepared by the addition of the single walled carbonanotubes from sigma Aldrich 50-70% carbon basis, D ×L 1.2-1.5nm×2-5 nm, bundle dimensions were added to the monomer. The fillers were well dispersed in the monomer by ultra-sonication using sonication apparatus (Soniprep -150, England) at 120 W, 60 KHz for 3 minutes to break them into individual nanotubes. The monomer with the nanopowder was immediately mixed with acrylic powder to reduce the possibility of particle aggregation phase separation. The mixing was carried out by a clean wax knife in a clean and dry vessel and mixed for 30 seconds. The mixture was then covered and left to stand until a dough stage was reached, then the packing and flasking is the same as control group.

A pilot study was done to estimate the proper amount of SWCNTs that will improve the mechanical properties of PMMA by testing the surface hardness, roughness, impact strength and transverse strength. First, 48 samples were prepared and divided into four groups according to the concentrations of SWCNTs that was added to it: 0.0 % (served as control group), 0.5%, 0.1% and 1.5% .

According to the result obtained from the pilot study as shown in table (1), the addition of 1.5**%** SWCNTs to PMMA resulted in significant increase in impact strength and transverse strength with significant decrease in surface hardness, therefore; the decision was made to take this percentage (1.5%) to complete this research. New samples were prepared they were divided into 2 groups first group with no additives (control group), the other with 1.5 % carbon nanotubes, ten samples for each test were made as previously mentioned.

Surface hardness test: shore D hardness device was used for measuring the acrylic samples, three measurements were recorded on three areas (one on the middle of the specimen and the other two, 1cm away from each end of each specimen) and an average of these three reading was recorded.

Surface roughness test: a profilmeter device was used to study the surface roughness property of acrylic samples, three points were selected to be tested (one on the middle of the specimen and the others 1cm away from each end) and the mean of the three readings were recorded for each specimen.

Impact strength test: the samples were tested with Charpy type impact testing device (Impact tester, N.43-1, INC. USA) of 2 joules capacity, impact strength was calculated by this formula:

$$\text{Impact strength} = \frac{E}{b.d} X10^3 \quad \text{in KJ/m}^2$$

E=impact energy, b= width of sample, d = thickness of sample [11].

Transverse strength test: the samples were tested by Flexural measuring device (Jian, Qiao, Japan). The full scale load was (7.5 KN), the distance between 2 parallel supports was (50 mm) and transverse strength was calculated by this formula:

$$\text{Transverse strength} = \frac{3XloadXI}{2\ bXd2} \quad \text{in N/mm}^2$$

I= distance between 2 support, b= width of the samples, d= thickness of the samples [11].

RESULTS

In table (1) the pilot study revealed that hardness was significantly decreased with the increase in the percentage of SWCNTS added and its lowest value was (69.3) with 1.5% of SWCNTS while there were no significant difference in surface roughness with different concentrations of SWCNTS and the results of both impact strength and transverse strength were significantly increase to be (12.87 Kj/m^2 ,127.7 N/mm^2) when the concentrations of SWCNTS were increase and show its greatest value with 1.5 % of SWCNTS.

Table (2) showed the mean, standard divisions, standard of error, minimum and maximum values of hardness, roughness, impact strength and transverse strength for the control group, while in table (3) it showed the results for 1.5% concentration of CNTS added to the acrylic resin.

The mean value of hardness was decreased (69.55) after adding the 1.5% of SWCNTS when compared with control group (80.78) while the mean value of roughness was nearly the same after adding 1.5% SWCNTS (1.43 Mm) .

Meanwhile the mean value of impact strength and transverse strength was greatly increased to be (12.83 Kj/m^2) and (127.36N/mm^2) after adding 1.5% SWCNTS as shown in tables (2) and (3).

In table (4) and figure (1) T test between 1.5% SWCNTs and control group show that there is highly significant difference in hardness, impact strength and transverse strength while for roughness there were non-significant difference between them.

Table 1: The mean values of pilot study

Test groups	Hardness	Roughness µm	Impact strength Kj/m^2	Transverse strength N/mm^2
Control	80.96	1.447	5.92	84.56
0.5%	77.43	1.427	7.04	96.03
1 %	71.83	1.447	8.92	107.9
1.5 %	69.3	1.455	12.87	127.7

Table 2: Descriptive statistics of control group

	Hardness	Roughness µm	Impact strength Kj/m^2	Transverse strength N/mm^2
Mean	80.78	1.4528	5.978	84.84
SD	1.132	0.057	0.446	1.641
SE	0.360	0.018	0.142	0.522
Min	79.31	1.38	5.33	81.1
Max	82.3	1.541	6.9	86.4

Table 3: Descriptive statistics of 1.5 % of SWCNTs

	Hardness	Roughness µm	Impact strength Kj/m^2	Transverse strength N/mm^2
Mean	69.55	1.4349	12.833	127.36
SD	1.413	0.087	0.786	6.979
SE	0.450	0.027	0.251	2.222
Min	67.3	1.311	11.97	120.2
Max	72.1	1.535	14.5	145.1

Table 4: t-test between control and 1.5 % SW CNTS

	Hardness	Roughness µm	Impact strength Kj/m^2	Transverse strength N/mm^2
t-test	20.075	0.528	23.491	18.533
p-value	P<0.01	0.61	P<0.01	P<0.01
Sig.	HS	NS	HS	HS

***P>0.05 (Non-significant), p<0.01 (Highly Significant)**

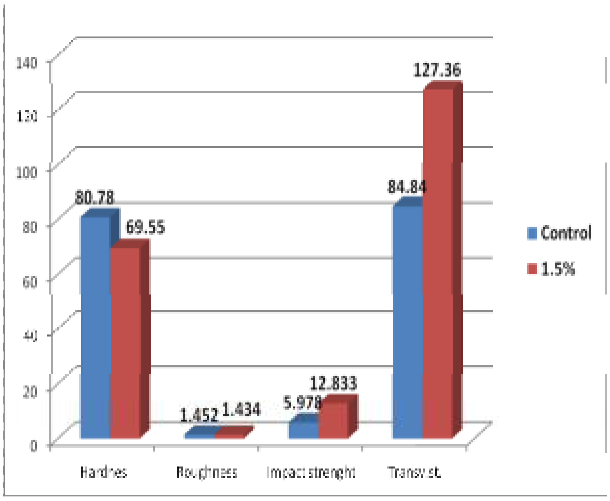

Figure 1: Bar chart of the mean values for hardness, roughness, impact strength and transverse strength for both control group and 1.5 % SWCNTS

DISCUSSION

A lot of studies with different nanofillers were done to evaluate the effect of adding the fillers on the mechanical properties of PMMA, in this study, the effect of adding SWCNTS was investigated.

In the present study, this material because there is limited studies in compare with its advantages as one of the strongest material in nature, elastic and also light in weight [12] .

The results of pilot study was used in order to select the proper concentration of SWCNTS to be added to PMMA which it was (1.5% concentration),as it give use the lowest value of surface hardness with the greatest value of impact and transverse strength in comparing with other percentage of SWCNTS.

Surface hardness

Hardness is the resistance of a material to the plastic deformation typically measured under an indentation load. Hardness is an important property of denture base material as it determines its flexibility, and it is desirable to have material with softness that is similar to the oral mucosa softness [13].

In this study, the results indicated that there was a highly significant difference in hardness after adding 1.5 % of SWCNTS to PMMA in comparing with control group, this decrease in hardness could be explained based on elastic property of CNTS that the nanotubes are remarkably flexible, that they found that in addition to its strength, CNTS are soft and elastic because CNTS by geometry have different properties in axial and radial direction. It has been shown that the CNTS are very strong in axial direction on the other hand there were evidence that in the radial direction they are rather soft [14,15]. This agreed with Mahmood [16] who investigated the effect of adding SWCNTS on high impact denture base material and found significant decrease in hardness, also agreed with Al-Qenae [17] who reported that addition of nano alumina ceramic fiber to silicone decrease the hardness value. However, the results did not agree with Dahham [18] who added zinc oxide nanofiller to the acrylic denture base and reported significant increase in hardness; this could be due to the use of different nanofiller was added and different technique.

Roughness

Achieving a smooth surface with no scratches has always been important to the materials used in denture base; this is because it is related to the adherence of plaque, debris and stain that will affect the oral health of the soft tissue in direct contact with denture [19].

In the present study, there were no significant difference in roughness between 1.5% CNTS and control group this is may be due to that the SWCNTS have very small size and well dispersion, and profilometer device which was used is concerned the outer surface only and did not measure inner part of nanocomposite so when we add a small amount of CNTS only few particles will be on the surface of the specimens [20].

The result of this study was coincide with the result of Jasim [21] who added alumina nanofiller to the acrylic and found that there were no significant difference in roughness, also coincide with Nabil [22] who added ZrO_2 nanoparticles to PMMA and he found that there was no significant difference in roughness.

Impact strength

Impact strength is an important property for acrylic denture base which are commonly fractured when it accidentally dropped into hard object it is simply the amount of energy absorbed by the material when it is suddenly broken [4].

In this study, significant increase in impact strength was shown with test group (1.5% SWCNTS) in compare with control group this may be due to the interfacial shear strength between nanofiller and matrix was high due to formation of cross links or supra molecular bonding which cover or shield the nanofiller that in turn prevent propagation of crack [8,23].

This results agreed with Al Kheraif [24] who investigated the effect of adding carbon nanotubes to increase impact strength of light cure denture base and also agree with Al Husayni [25] who found increase in impact strength compared to control after adding silver nitrate to the denture base, but disagreed with Abdul Razzaq 26) who found impact strength decrease with the use of glass flakes to reinforce denture base materials.

Transverse strength

Transverse strength defined as material ability to resist deformation under mastication load [4]. In this study, transverse strength was significantly increase with 1.5 % SWCNTS in compare to control group; this is due to use of very fine size nanofillers enable them to enter and fill the space between the chains of polymer , so it restrict the motion of chains and lead to increase rigidity and this will increase the transverse strength [27].

Mahmood [16] also found significant increase in transverse strength after adding SWCNTs to high impact denture base material, and also agreed with Jasim [22] who investigate the effect of adding 1% and 2% alumina nanofiller to PMMA and found increase in the transverse strength.

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