



Evaluation the mechanical properties of PMMA / ZrO₂ nanoparticles for dental application

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ABSTRACT

Polymethyl methacrylate (PMMA) mechanical strength still has a couple of disadvantages form long term denture. This work aims to evaluate the influence of Zirconium nanoparticle (ZrO₂) with various concentrations (0.15, 0.35, 0.6, 0.9) on tensile, compression, fatigue strength, and hardness test. The rise of the ZrO₂ nanoparticles ratio yielded to a proportional increase in the material composite strength of tensile. In addition, the compression test showed that the ZrO₂ ratio rise increased the compressive strength of the compound material. As for the hardness test, it has been noted that the article has a high hardness ratio and is almost perfect. Moreover, the rate of fatigue test, which is a measure of the susceptibility of corrosion-resistant material, yielded good result in which the content has shown the ability to resist erosion for a long time. All over, the results mentioned above showed reliable capacity for denture base material with improved strength, fatigue, hardness and compression with the of addition ZrO₂ nanoparticles to PMMA.

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INTRODUCTION

PMMA is the most used material in denture construction as it has many advantages; desired cosmetics, precise fit, easy laboratory preparation, oral environment stable, low-cost equipment and clinical freedom (Nejatian *et al.*, 2009).

However, despite being more applied in dentistry for synthetic of plate rules, the material yet has flawed mechanical properties for dental applications, especially in its fracture easiness and accumulation of

plaque (John *et al.*, 2001). It was found that nearly 70% of 10 types of denture base resins at dentures had been damaged within the first three years of implementation (Darbar *et al.*, 1994).

An evaluation study of the plate break, it was found that 33% of the repairs were due to teeth disbandment /detachment, 29% on account of the mid-line breaks which were more commonly detected in the supernormal dentures, while the remaining percentage has been divided among other types of fractures. In addition, the Mandibular partial denture has been reported to require more repairs than other denture failures (El-Sheikh and Al-Zahrani, 2006). The determination of mechanical properties of the denture base materials is essential to estimate the impact of adding various toughening elements (Vallittu *et al.*, 1994).

Numerous researches were profound to potentiate mechanical characteristics of denture rule materials either by chemical solutions addition (a polyfunctional cross-linking agent) or by mixing a rubber stage, fibres and metal oxides (Kanie *et al.*, 2000). Many trials to get better the break strength of PMMA

Table 1: Information of tensile test

1.000 mm/min	Test speed
80.000 mm	Sample length
10.000mm	Sample width
5.000mm	Sample thickness

Table 2: Result of tensile test

PMMA+0.9 ZrO	PMMA+ 0.6 ZrO	PMMA+ 0.35 ZrO	PMMA+ 0.15 ZrO	Pure PMMA	Parameters
1.285	1.211		0.598	0.583	Strain Yield
1.285	1.211	0.67	0.598	0.583	Strain Upper Yield
1.295	1.248	0.687	0.619	0.729	Strain Lower Yield
3.223	2.879	2.84	1.97	3.688	Strain Peak
3.229	2.881	2.869	1.978	3.689	Strain Break
0.620	0.431	0.669	0.575	0.478	Strain Proof
17.188	16.136	6.595	5.155	8.472	Stress Yield
17.188	16.136	6.595	5.155	8.472	Stress Upper Yield
17.185	16.696	6.545	5.253	6.110	Stress Lower Yield
38.306	36.180	29.8	24.987	34.914	Stress Peak
35.540	32.144	24.248	11.353	27.494	Stress Break
9.680	7.589	6.183	4.616	3.171	Stress-Proof
1755.456	1633.597	1571.154	1417.399	1342.134	Young's Modulus
1498.191	806.310	339.3	257.8	423.600	Force Yield
709.400	1808.510	1591	1259.8	1745.700	Force Peak
1777.000	1606.710	1321.9	577.6	1374.700	Force Break

Table 3: Information about a compression test

1.000 mm/min	Test Speed
23.000mm	Sample Height
10.000mm	Sample Diameter

Table 4: Result of compression test

PMMA+ 0.9 ZrO ₂	PMMA+0.6 ZrO ₂	PMMA+ 0.35 ZrO ₂	PMMA+ 0.15 ZrO ₂	Pure PMMA	Parameters
2.627	4.255	3.865	3.987	4.543	Strain Yield
2.627	4.255	3.865	3.987	4.543	Strain Upper Yield
2.645	10.227	16.230	10.000	21.843	Strain Lower Yield
32.554	36.554	33.244	33.257	31.623	Stress Yield (N/mm ²)
32.554	36.554	33.244	33.257	31.623	Stress Upper Yield (N/mm ²)
57.504	57.504	69.506	75.720	42.131	Stress Lower Yield (N/mm ²)

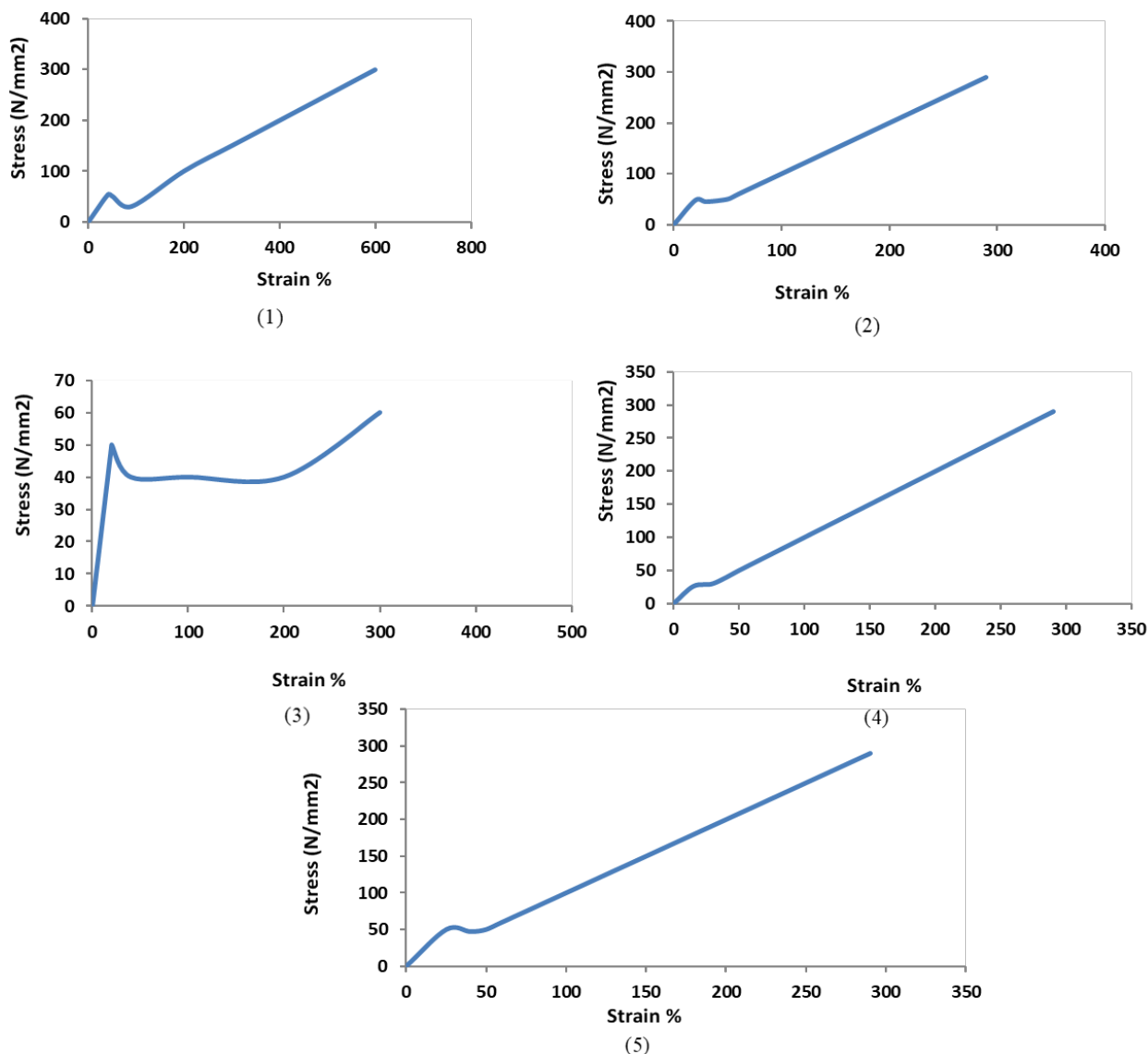


Figure 1: The(stress-strain) relationship for the tensile test of sample for (1) pure PMMA, (2) PMMA +0. 15 of the ZrO₂, (3) PMMA +0. 35 of the ZrO₂,(4) PMMA +0. 6 of the ZrO₂, and (5) PMMA + 0.9 of the ZrO₂

have been performed; however, few have shown promising results (Franklin *et al.*, 2005). Studies were conducted to reinforce the polymers applied in dentistry with metal-composite methods has the main research focus (Asar *et al.*, 2013).

ZrO₂ nanoparticles have been chosen to enrich the characteristic of PMMA, as a bio-compatible composite that has high break strength, and to get better break toughness via improving a new product of composites (Saad-Eldeen *et al.*, 2007; Shukla and Seal, 2003). Since few documents considering the impact of metal oxides on PMMA are found in the letters, this investigation aims to survey the effect of the extension of ZrO₂ nanoparticls on mechanical properties of PMMA.

MATERIALS AND METHODS

Preparation of zirconium nanoparticle with (PMMA)

To prepare (ZrO₂) nanoparticle with (PMMA) Poly (methylmethacrylate), the PMMA powder must be dissolved using a solution of the special monomer to dissolve the (PMMA) and constantly stir to mix the solution. After the homogenizing of the solution, an amount of (ZrO₂) must be added to the solution, with an initial concentration of (0.15) of the (PMMA) solution. The same process must be repeated to change the amount of (ZrO₂) that is added to the solution. Hence the concentration can be increased to (0.35), (0.6) and (0.9) of the (PMMA), respectively.

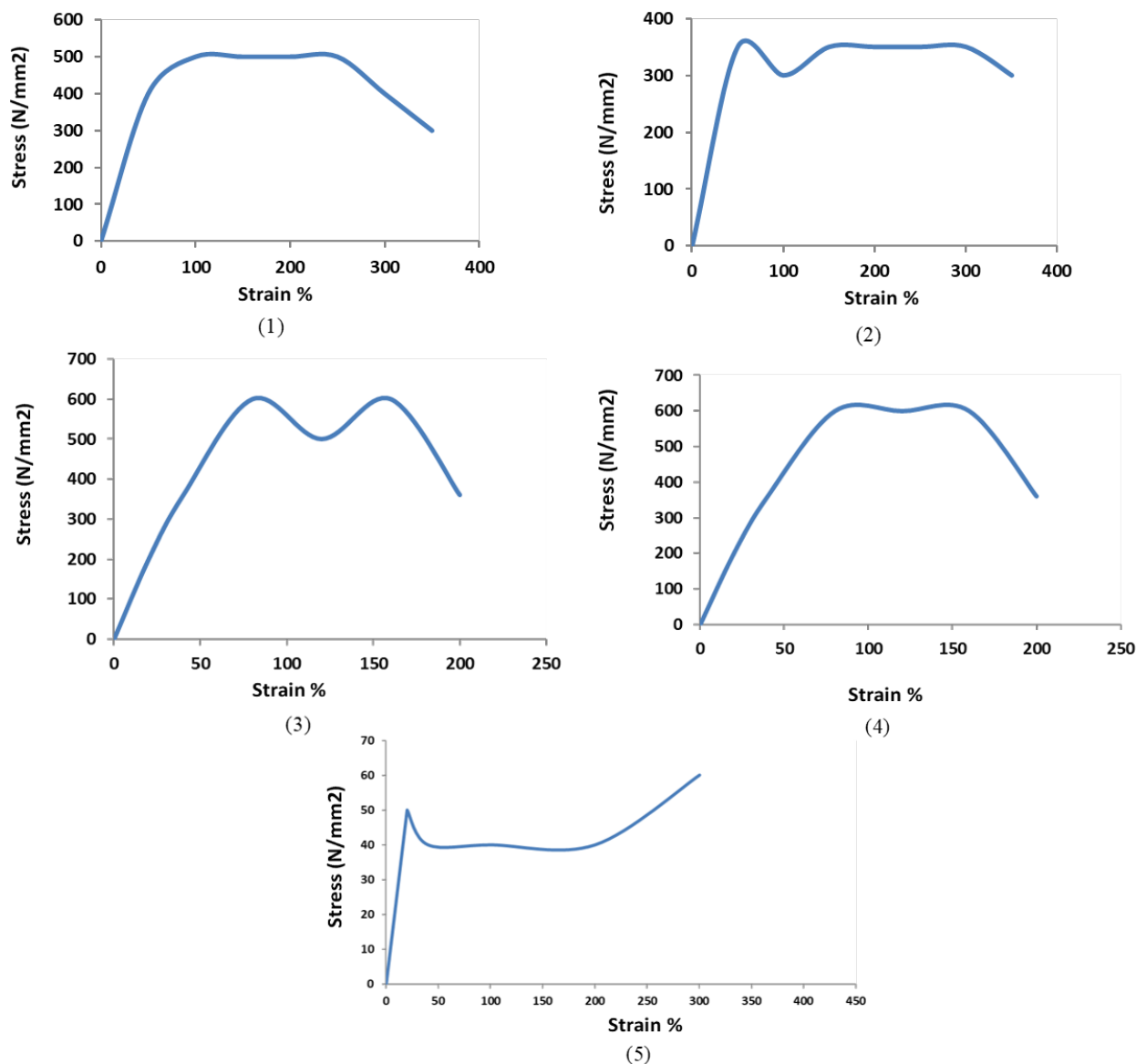


Figure 2: The (stress-strain) relationship for compression test of sample the: (1) pure PMMA, (2) PMMA + 0.15 of the ZrO_2 , (3) PMMA + 0.35 of the ZrO_2 , (4) PMMA + 0.6 of the ZrO_2 , (5) PMMA + 0.9 of the ZrO_2

RESULTS AND DISCUSSION

Tensile test

In this test, the relationship between (stress-strain) has been observed for each sample with respect to the variation of ZrO_2 ratio in each sample. The analysis showed that the higher the ZrO_2 rate resulted in more elasticity of the tested sample, as shown in Table 1, Table 2 and Figure 1.

Compression test

In this test, the tolerability of the composite material with the impact of pressure exerted on it and how much to bear to the crash have been examined and recorded as shown in Table 3, Table 4 and Figure 2.

Hardness Test

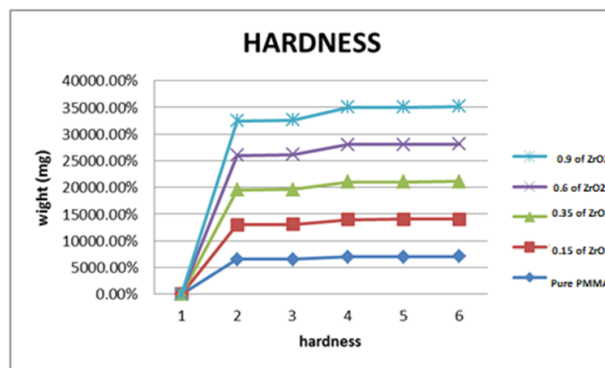


Figure 3: The relationship between the hardness and weight fraction for (PMMA) with (ZrO_2)

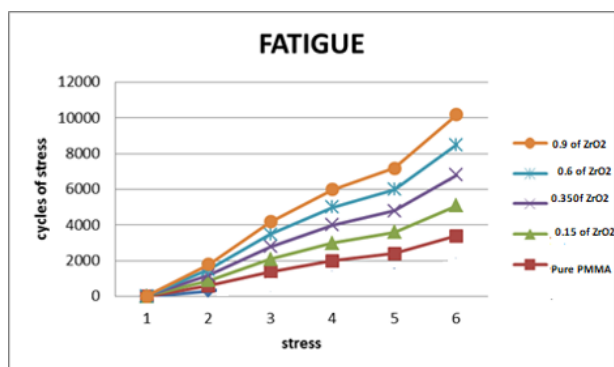


Figure 4: The relationship between the stress and cycles of stress for (PMMA) with (ZrO₂)

In this test, the relationship between weight, hardness and material hardness ratio after adding ZrO₂ have been examined as shown in Figure 3.

Fatigue Test

The aim of this study is to evaluate possible increases in the mechanical characteristics of PMMA, the compression, hardness, strength and fatigue of ZrO₂ nanoparticles.

ZrO₂ has been chosen to be added to PMMA due to its excellent biocompatible properties, the availability of white colour ZrO₂ nanoparticles, it yields a better diffusion, and increases its compatibility with an organic polymer.

Good % range of zirconium nanoparticle (0.15, 0.35, 0.6, 0.9 by weight) was selected, since adding more than 9% has been shown to cause changes in the colour of acrylic due to ultra-ions activity (Jian-ming *et al.*, 2004).

The present work explains a significant rise in compression, tensile resistance, and hardness fatigue as the ratio of ZrO₂ nanoparticle evaluated. This enhancement in mechanical characteristics could be referred to the very high interfacial shear resistance amidst the nanoparticles and PMMA as a product of the structure of network or buckler molecular mooring which protects or corset the nanoparticles which in transformation avoid spread of rift. Moreover, total moistening of the nanoparticle by resin leads to a raise in compression, tensile, hardness and fatigue as volume increases.

Also, the products of the current study agree with those reported by other researchers resolved that support, dental healing resins as well as PMMA with ZrO₂ nanoparticles could cause revelation advance in the mechanical characteristics.

Finally, good bonding between ZrO₂/PMMA leads to an increase in mechanical properties.

CONCLUSION

In this study, the compound substance resulted from the mixing of polymer (PMMA) with different weights of (ZrO₂) was studied tested with several tests mentioned earlier in this paper. It has been noted that this compound has strength and durability approaching that of regular teeth. Also, it could be shaped to give an aesthetic similarity to regular teeth. All of this was observed through the tests carried out by testing the strength of the material, strength of tension, and the strength of compression. Also, a test that the article has higher hardness strength than that of regular PMMA, which leads to it being ready to withstand any resistance within the body. In the examination of fatigue, it has been noted that the material has high resistance to corrosion and face for a long time, and this indicates that it will be strong teeth. It was also pointed out in the compressive examination that the material has high strength of compression that helps to resist any external interference of the teeth. As for the tensile test, it was noticed that increasing (ZrO₂) ratio increases the tightening force, indicating that the material has the ability to resist any external tension.

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