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# Evaluation the mechanical properties of PMMA / $ZrO_2$ 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 ($ZrO_2$) with various concentrations (0.15, 0.35, 0.6, 0.9) on tensile, compression, fatigue strength, and hardness test. The rise of the $ZrO_2$ nanoparticles ratio yielded to a proportional increase in the material composite strength of tensile. In addition, the compression test showed that the $ZrO_2$ 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 $ZrO_2$ 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 midline 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 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).

$ZrO_2$ 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 $ZrO_2$ nanoparticals on mechanical properties of PMMA.

## MATERIALS AND METHODS

### Preparation of zirconium nanoparticle with (PMMA)

To prepare ($ZrO_2$) 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 ($ZrO_2$) 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 ($ZrO_2$) that is added to the solution. Hence the concentration can be increased to (0.35), (0.6) and (0.9) of the (PMMA), respectively.

## RESULTS AND DISCUSSION

### 1. 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 andFigure 1.

### 2. 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 4and Figure 2.

### 3. Hardness Test

In this test, the relationship between weight, hardness and material hardness ratio after adding $ZrO_2$ have been examined as shown in Figure 3.

### 4. Fatigue test

The resistances of the material to erosion and the extent to which it will be tolerated have been tested, as shown in Figure 4.

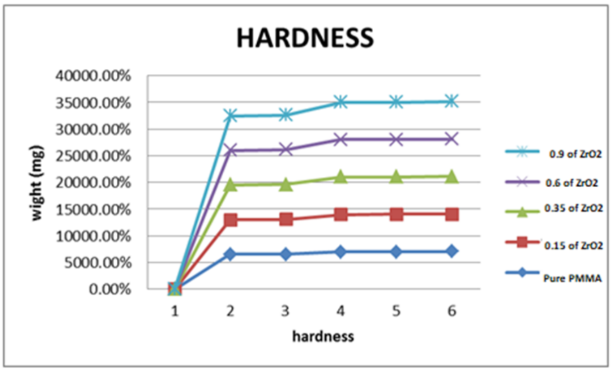


**Figure 3: The relationship between the hardness and weight fraction for (PMMA) with ($ZrO_2$)**

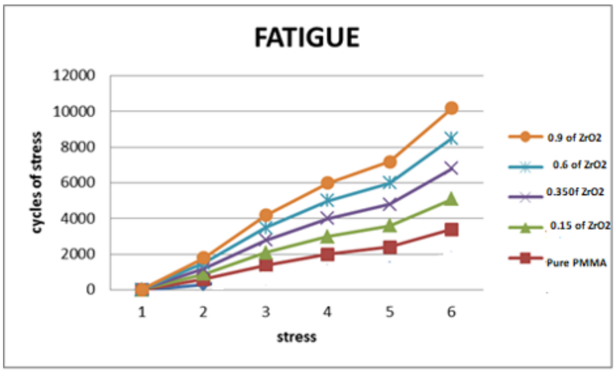


**Figure 4: The relationship between the stress and cycles of stress for (PMMA) with (ZrO2)**

The aim of this study is to evaluate possible increases in the mechanical characteristics of PMMA, the compression, hardness, strength and fatigue of $ZrO_2$ nanoparticles.

$ZrO_2$ has been chosen to be added to PMMA due to its excellent biocompatible properties, the availability of white colour $ZrO_2$ nanoparticles, it yields a better diffusion, and increases it is 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 $ZrO_2$ 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

**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 ZrO2 | PMMA+0.6 ZrO2 | PMMA+ 0.35 ZrO2 | PMMA+ 0.15 ZrO2 | 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 ($N/mm^2$) |

 

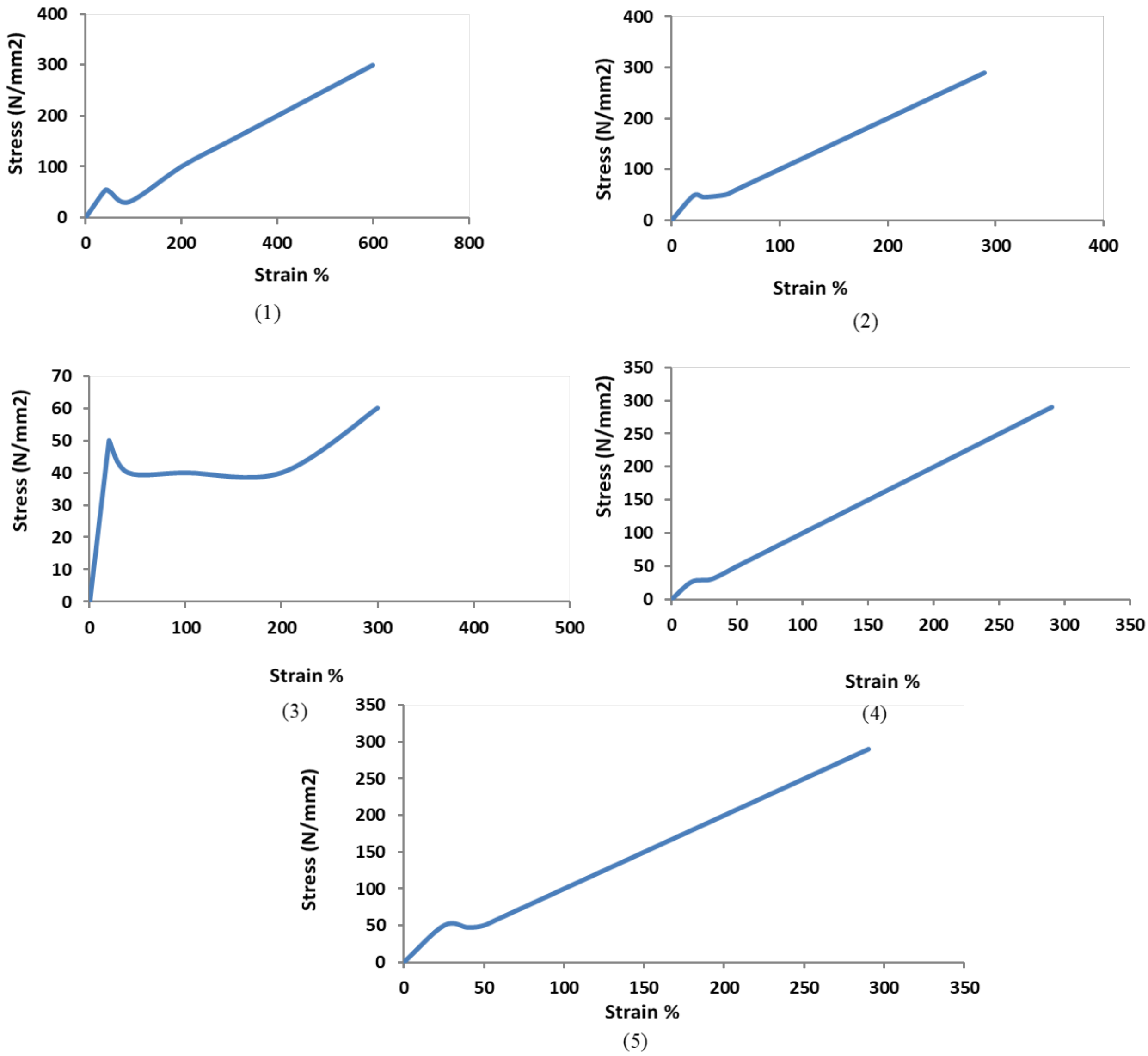


**Figure 1: The(stress-strain) relationship for the tensile test of sample for (1) pure PMMA, (2) PMMA +0. 15 of the $ZrO_2$, (3) PMMA +0. 35 of the $ZrO_2$,(4) PMMA +0. 6 of the $ZrO_2$, and (5) PMMA + 0.9 of the $ZrO_2$**

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 $ZrO_2$ nanoparticles could cause revelation advance in the mechanical characteristics.

Finally, good bonding between $ZrO_2$/ 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 ($ZrO_2$) 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 ($ZrO_2$) ratio in-

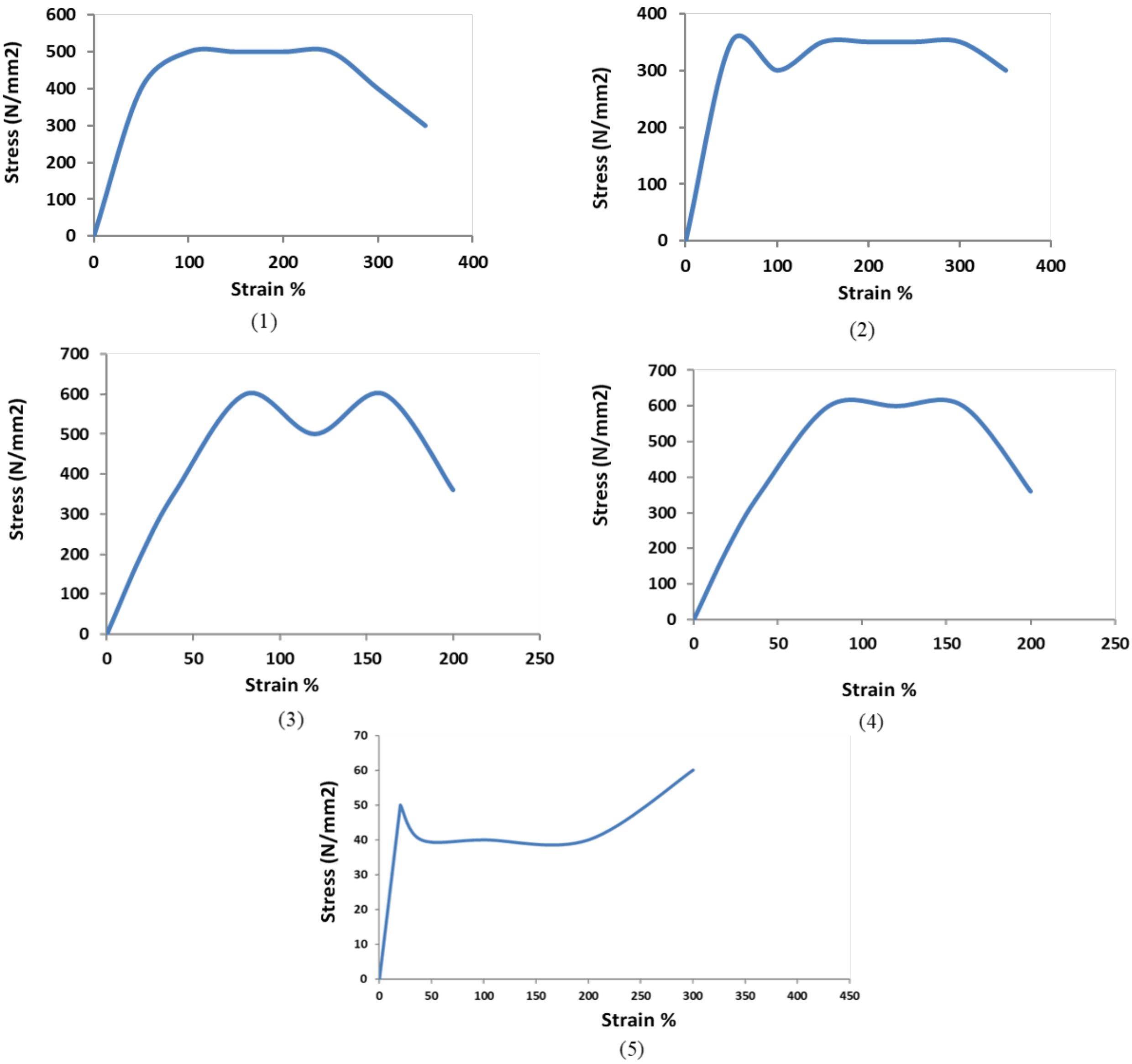


**Figure 2: The (stress-strain) relationship for compression test of sample the: (1) pure PMMA, (2) PMMA +0.15of the $ZrO_2$, (3) PMMA +0.35of the $ZrO_2$ , (4) PMMA +0.6 of the $ZrO_2$ ,(5) PMMA + 0.9 of the $ZrO_2$**

creases the tightening force, indicating that the material has the ability to resist any external tension.

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