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Studying Some Properties of Microwave-Cured Resin After Adding PP Fibers and ZrO_2 NPs

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Abstract

Aim of the study: Since the introduction of acrylic resin as a denture base material, it suffered from having unsatisfactory properties and processing method. So, the use of microwave cured technique for the acrylic as modified procedure to simplify the manipulation of laboratory procedure and reinforcing of polymer by materials such as fibers and nanoparticles can maintain good resin material and to overcome these limitations. This study was performed to evaluate the effect of adding polypropylene fibers with and without different concentration of ZrO_2nanoparticles into resin on some properties such as surface hardness and roughness.

Materials and methods: 100 samples were split into 2 groups depending on test type, 50 specimens were subdivided into 5 groups (control group without any reinforcement, reinforced with polypropylene fibers group alone and other three groups reinforced acrylic with polypropylene fibers with 0.5%,1%,1.5%ZrO_2 respectively).

Results: The results of polypropylene fibers addition into acrylic revealed a non-significant for both tests. The addition polypropylene fibers with ZrO_2 nanoparticles showed significant heightening in the hardness and significant decrease in surface roughness.

Conclusion: The conclusion of this study was both ZrO_2nanoparticles with polypropylene fibers addition into resin improved the surface hardness with reduction in the surface roughness of acrylic resin.

Keywords: polypropylene fibers, acrylic resin, ZrO_2nanoparticles.

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Introduction

The good properties of poly methyl methacrylate (PMMA) such as biocompatibility, simple handling, inexpensiveness, invariability in oral condition make it the basic material for make the denture-base prosthesis but it had inferior physical properties (1). In previous years, the demand to simplify the laboratory procedure with bettering features, therefore the changing in processing methods of PMMA polymerization have been enhanced (2). The modified procedure using microwave for the polymerization of PMMA resulting quality as water bath technique (3), that provide more fineness and adaptation products with time consuming and clean method (4). Many physical properties influence on longevity of denture like the surface roughness and hardness of acrylic resin (5).The definition of hardness is "the resistance of material to plastic deformity under an indentation load to expose to scarifying by usage" (6) . Many ways for evaluating this property such as Vickers, Rockwell, Brinell and Knoop tests, Vickers hardness was used in this study because it was suitable for acrylic resin (7). So, making the prosthesis with more withstanding to detriment (8), and low surface hardness resulted increased surface roughness (9). The small contravening found in surface is termed as surface roughness which played a major role in weakening scrubbing activity that cause retaining of bacteria and debris (10).

The alteration of resin chemically by fibers, macro-and Nano fillers incorporation one of trial to make better acrylic resins (11). Fibers are easier to incorporate in resin matrix and their reinforcement is dependent on many variables like fibers type, percentage in matrix, length, orientation, and form (12). The polypropylene fiber (PP fiber) as enhancing fibers to denture base which characterized by good properties regarding to its strength and super biocompatibility (13). As well as they are characterized by abrasion resistance. The PP fibers are inert with high impact resistance, high ductility, neutral color low density(14).A study was showed that incorporating of PP fibers into heat-cured resin significantly improved its hardness but surface roughness was minimized (15).Other researchers studied the effect of addition different fibers types on the acrylic properties (16,17).The previous study was demonstrated a decrease in the hardness and increase in surface roughness when the glass fibers were incorporated to the PMMA (18).

Nowadays, the reinforcement of polymers by Zirconium dioxide nanoparticles(nano-ZrO_2) were used as their excellent toughness and corrosion resistance. They had highest hardness among any oxide (19). Previous study by Zhang et al.,2011studied the nano-ZrO_2 impact on surface hardness of PMMA (20). Ahmed and Ebrahim,2014 revealed the effect of nano-ZrO_2addition on the hardness of heat-polymerized acrylic (21).

Although the incorporation of nano-ZrO_2 and PP fibers into PMMA to improve its physical properties has

been done separately but no research till now has been conducted to assess the impact of nano-ZrO_2/PP fibers mixture on the features of microwaved-cured acrylic. So, this study was oriented to evaluate the addition of the PP fibers alone and with different concentration of nano-ZrO_2 to the acrylic on surface hardness and roughness of acrylic.

Materials and method

This study was utilized by adding nano-ZrO_2 (ZrO_2 Nanopowder,40-50 nm, 99.9 % purity, Hongwu nanometer, China) to acrylic resin (Heat-cured acrylic resin, spofa dental company, Czech Republic) in different concentration starting from:0.5%,1%, and1.5 Poly propylene fibers (SikaFiber PPM-12, Sika company, Egypt) (2.5%)as a constant percentage were added to PMMA in order to make a new composite.100specimens were divided according to the test: surface hardness and surface roughness. Each test divided into 5groups according to addition of PP fibers and nano-ZrO_2(Table1).

The wax pattern of the specimens was prepared by using sheet of base plate wax and cutting this sheet according to required dimension (65mm×10mm ×2mm) length, width and thickness respectively) (22). The preparation of the mould, conventional flasking technique for complete denture processing was followed for all specimens using the plastic flask (FRP Flask, GC America). The acrylic resin was mixed in proportion of (P:2.5mg/L:1ml); as recommended by manufacturer, amounts of nano-ZrO_2fillers, PP fibers, and polymer/ monomer were shown in Table1 by weighting the materials with an electronic balance (accuracy 0.0001g, Sartorius BP 30155, Germany).

The percentage of PP fibers selected in this study was 2.5% by weight added to the powder (15). Randomly and gently powder and fiber was mixed for about 3minutes by mortar and pestle. The nano-ZrO_2mixed with liquid after measuring ingredients them to the monomer (23), Acrylic powder that contained the PP fibers blended with monomer contained nano-particles immediately to prevent particle separation and clustering. Dough stage occurred after the mixture is covered and left for polymerization, the packing of the acrylic in the fiber flask that transferred into the microwave (Samsung TDS, Korea) and heated at(500W) for 3minutes (5). Then it removed and left for bench cooling 24 hours. Then acrylic samples were removed gently from the mould. The samples were finished with prosthetic engine with water cooling and then polished with a lathe- polishing tool 1500rpm the speed of polishing machine, the material used for polishing was pumice blended with water. Digital Vernier was used to measure perfect distances of samples and put in water at 37C° for 2days before testing (22).

Surface hardness:

Surface hardness was determined by using durometer hardness tester (TIME group, Inc. company, China) (Figure (1). A). The tester had spring-loaded indenter which was set into scale range from 0 to 100 units. The specimen was punctured by indenter to give the reading.

Surface roughness:

The profilometer device (Talysurf 4, Talyor Hobson, England) was used to study roughness of the surface (Figure (1). B). The sample was put on stable stage to select the location of the tested area where the analyzer was passed along it to get the reading values.

Results

Surface Hardness:

Descriptive statistic of the results of surface hardness for all groups showed highest mean values for the specimens of Group V with addition of 2.5% PP fibers and 1.5%ZrO_2 while the lowest mean values for the group II with addition of PP fibers only (Figure (2), Table (2)).

The means values of the surface hardness for 5groups were compared using one-way ANOVA-test that was showed a significant difference in the surface hardness (Table (3)). For further comparison between the tested groups the Post hoc Tukey's HSD-Test was showed there was a non-significant difference between control group and group of addition of PP fibers only, while there was a significant difference between the other tested groups (Table (4)).

Surface Roughness:

Descriptive statistic of the results of surface roughness for all groups showed lowest mean values for the group with addition of 2.5% PP fibers and1.5%ZrO_2while the highest mean values for the group without any addition (Figure 2, Table 2).

For comparison of means values of the surface roughness for all groups, the one-way ANOVA-test was showed there was a significant differences in the surface roughness(Table3).The Post hoc Tukey's HSD-Test was showed there was a non-significant difference between the control and the group II(addition of PP fibers only) and group of addition of PP fibers with 0.5% and between the groups of addition the 0.05% and 1% of ZrO_2 ,also there was non-significant difference between group III and group IV. In addition, the results were revealed significant differences between other tested groups (Table 4).

Discussion

Surface hardness:

It can be recognized from the obtained results that 1.5%zircon and 2.5% polypropylene fiber group had the highest mean value among the studied groups that revealed an increase in hardness significantly in comparison to control group; except between control and group of PP fiber only there was none significant difference. This may be attributed to the position of fibers close to surface that was given hardness and stiffness of the acrylic (24). These outcomes disagreed with findings of previous research who found raised in surface hardness when they manipulated of polyether fibers with heat cured acrylic resin (15).On the other hand, a better hardness when a nano-ZrO2with PP fibers were added to PMMA that lead to the union between nanofillers and PMMA and improved the rigidity of the linking and resilience of nano-composite (25) .Other factors theZrO2 had ionic linking with oxygen ions together filling voids to provide suitable material properties with high toughness and high hardness (26).

Surface roughness:

From the outcome of the result the incorporation of 2.5%PP fiber showed there was no change in roughness in comparison with control group, that in accordance to the result of other studies (14-17),and disagreed with result of previous research who indicated an increase in the surface roughness when addition of fiber (18).On the other hand, there was significant decrease in surface roughness of specimens after incorporation of 2.5%fibers with1.5% ZrO2, the cause of that the tangling form transversely between the polypropylene fibers and resin that was minimized the content of residual monomer in the polymer and smooth

surface of PP fibers(15), and surface morphology appeared uniform distribution of the filler when the nano fillers concentration increased (27).

Conclusion

Within limitations of the present study, the following conclusions can be withdrawn:

1.There were increase the surface hardness by incorporation of 2.5% polypropylene fibers and 1.5% nano-ZrO_2 into acrylic.

2.There was decreased in surface roughness of microwaved-cured acrylic with incorporation of 2.5%PP fibers and1.5% nano-ZrO_2 into acrylic.

Conflicts of Interest

The authors reported that they have no conflicts of interest.

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Table (1): The percentage and weight of ZrO_2filler/PP fiber/acrylic powder (polymer/monomer).

Groups		ZrO_2 (g)	PP Fiber(g)	polymer(g)	monomer(ml)
Group I	Control group	0	0	15	6
Group II	0% ZrO_2 +2.5% PP fiber	0	0.375	14.625	6
Group III	0.5% ZrO_2 + 2.5% PP fiber	0.075	0.375	14.55	6
Group IV	1% ZrO_2 +2.5% PP fiber	0.15	0.375	14.475	6
Group V	1.5% ZrO_2+2.5% PP fiber	0.225	0.335	14.4	6

Table (2): Descriptive statistics of surface hardness and surface roughness tests for all groups.

Study Groups	N	Surface hardness test		Surface roughness test (µm)	
		Mean	SD	Mean	SD
Group I	10	81.580	0.35839	0.7993	0.03000

Group II	10	81.350	0.40893	0.6750	0.21004
Group III	10	82.730	0.56578	0.6851	0.02996
Group IV	10	83.510	0.16633	0.6669	0.03567
Group V	10	84.850	0.33747	0.5448	0.03955

Table (3): O-way ANOVA-Test between groups of surface hardness and surface roughness.

		Sum of Squares	Df	Mean Square	F-test	P-value	Sig.
Surface hardness	Between Groups	83.023	4	20.756	137.032	0.000	S
	Within Groups	6.816	45	0.151			
	Total	89.839	49				
Surface roughness	Between Groups	0.326	4	0.081	8.353	0.008	S
	Within Groups	0.439	45	0.010			
	Total	0.765	49				

S: significant at $P \leq 0.05$

Table (4): Post hoc Tukey's HSD-Test of for comparsion between all groups of surface hardness and surface roughness.

Groups		Surface hardness		Surface roughness	
		P-value	Sig.	P-value	Sig.
Group I	Group II	0.679	NS	0.053	NS
	Group III	0.000	S	0.09	NS
	Group IV	0.000	S	0.034	S
	Group V	0.000	S	0.000	S
Group II	Group III	0.000	S	0.999	NS
	Group IV	0.000	S	1.000	NS
	Group V	0.000	S	0.039	S

Group III	Group IV	0.000	S	0.994	NS
	Group V	0.000	S	0.021	S
Group IV	Group V	0.000	S	0.053	NS

S: Significant at P ≤ 0.05, NS: Non-significant at P >0.05

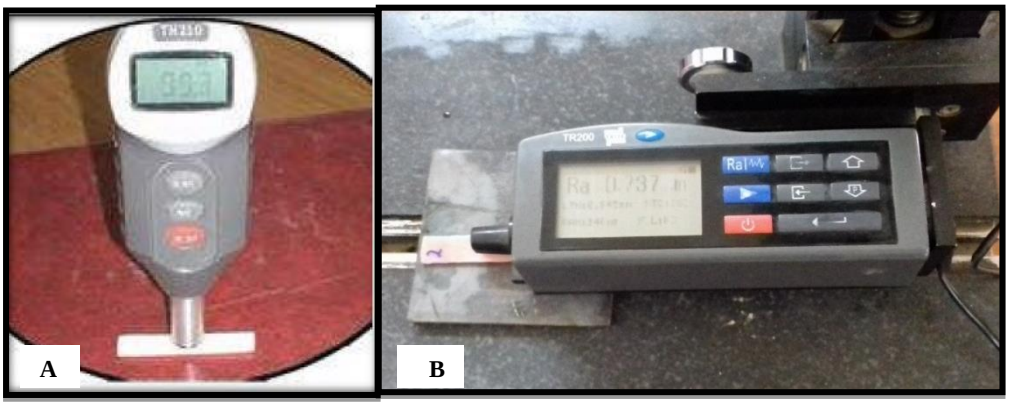

Figure (1): A. Surface hardness test, B.Surface roughness test.

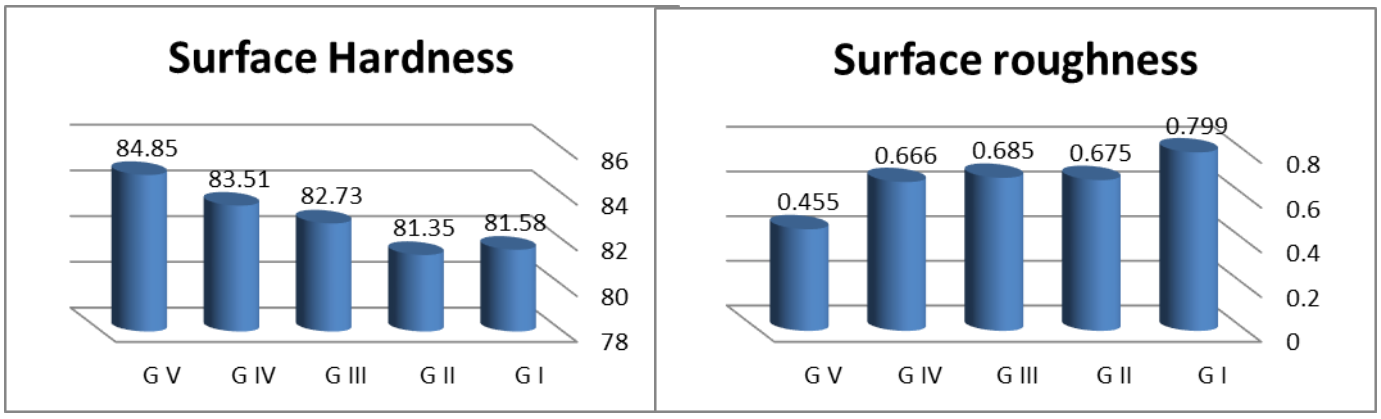

Figure (2): Bar chart showed the surface hardness and surface roughness for all groups.