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The Effects of Magnesium Oxide Nanoparticles Addition on Flexural Strength of Cold-cured Acrylic Resin material

Nooralhuda Waadullah Al-Taee *[1], Ahmed Asim Al -Ali [2]

[1, 2] Department of Prosthodontic, College of Dentistry, University of Mosul., Iraq

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***Correspondence:**
Nooralhuda W Al-Taee

E-mail:
nooralhudaw.altaee
@uomosul.edu.iq

Abstract

Aims: This study investigates the effects of the addition of magnesium oxide Nanoparticles (MgO NPs) with size (50 nm) on the flexural strength of cold-cured acrylic resin. **Materials and methods**: Forty acrylic specimens were made, which divided into four groups (10 specimens for each group) which were control group (pure acrylic without addition), group of acrylic specimens containing 1.25% MgO NPs, group of acrylic specimens containing 2.5%MgO NPs, and a group of acrylic specimens containing 5%MgO NPs, the flexural test was performed using the universal testing machine, FTIR test performed using (BRUKER LASER CLASS 1). The statistical analysis was done by using SPSS program including descriptive statistics, ANOVA, and the Duncan´s test at $p \leq 0.05$. **Results**: The Maximum mean of flexural strength belong to the group with 1.25% of MgO NPs,the minimum mean of flexural strength belongs to a group with 5% MgO NPs. **Conclusion**: The addition of MgO NPs affected the flexural strength of the cold-cured acrylic resin, it improved the flexural strength at low concentration but decreased it at higher concentratios.

الخلاصة

الأهداف: تبحث هذه الدراسة فى تاثير إضافة جزيئات أكسيد المغنيسيوم النانوية بحجم (٥٠ نـانومتر) علـى مقاومـة الانحنـاء لراتنج الأكريليک المعالج بالبرودة. **المواد وطرائق العمل**: تم عمـل أربعين عينـة أكريليـک ، والتـى تـم تقسيمها إلـى أربـع مجموعات (١٠ عينات لكل مجموعة) والتى كانت عبارة عن مجموعة تحكم (أكريليک خالص بـدون إضـافة) ، ومجموعـة عينات أكريليک تحتـوى علـى ١,٢٥٪ أكسـيد المغنيسـيوم النـانوى، مجموعـة عينـات أكريليـک تحتـوى علـى ٢,٥٪ أكسـيد المغنيسيوم النـانوى ، مجموعـة عينـات أكريليـک تحتـوى علـى ٥٪ أكسـيد المغنيسـيوم النـانوى، تـم إجـراء اختبـار الانحنـاء باستخدام آلة الاختبار الشاملة ، وتم إجراء اختبار فورييه" لتحويل طيف الأشعة تحت الحمـراء باسـتخدام جهـاز (BRUKER LASER CLASS 1). تم إجراء التحليل الإحصائى باستخدام برنـامج SPSS بما فى ذلک الإحصاء الوصفى ، انوفا ، واختبـار دنكن عند ٠,٠٥ p ≥. **النتائج**: ينتمى الحـد الأقصـى لمتوسط قـوة الانحنـاء إلـى مجموعـة ذات تركيـز ١,٢٥٪ مـن اكسـيد المغنيسـيوم النـانوى ، والحـد الأدنـى لمتوسـط قـوة الانحنـاء ينتمـى إلـى المجموعـة بنسـبة ٥٪ مـن اكسـيد المغنيسـيوم النانوى.**الاستنتاجات**: إضافة جزيئات اكسيد المغنيسيوم النانوى أثرت على قوة الانحناء لراتنج الأكريليـک المعـالج بـالبرودة ، حيث حسنت قوة الانحناء عند التركيز المنخفض لكنها قللت من قوة الانحناء عند التراكيز العالية

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INTRODUCTION

One of the fated conditions in the prosthodontic is the breakage of the denture that is made of heat-cured polymethylmethacrylate. There are many causes for such a situation which is either in the patient's mouth due to occlusal load or impact failure due to accidental fall of the denture [1,2]. Construction of a new denture is not always reasonable,its costly and time wasting, so denture repair is the desired option[3].

The most commonly used materials to restore broken heat-cured denture base are heat-cured acrylic, light cured acrylic, and cold-cured acrylic, although diverse materials were used for repairing broken denture base made of polymethyl methacrylate resin (PMMA), the repaired site still be the weakest area that is liable to refracture [4]. Heat-polymerized acrylic resin materials have better mechanical properties compared with light and cold-cured acrylic resins [5]. Nevertheless, they require laboratory packing and flasking processes, which are not only time - wasting but also associated with the hazard of denture deterioration by heat [6].

The ample utilization of cold-cured acrylic resin in prosthodontics is mainly connected to its simple processing at room temperature, need less time, and need less equipments. Some implementations of cold-cured acrylic resin involve interim removable prostheses, maxillofacial prostheses, orthodontic removable appliances, and implant-supported fixed interim prostheses [7].

It was proclaimed that the strength of cold-cured acrylic is only 80% of heat cure polymer [8], it was confirmed by researches performed on flexural strength and impact strength of cold-cured acrylic compared to heat-cured resin [9,10]. The PMMA is not typical in every aspect, although it has some good properties, PMMA has poor surface and mechanical characteristics and poor antimicrobial effects [11].

The typical repair materials should substitute the shortage in the mechanical and physical characteristics of heat cure denture base material [12]. So trials to enhance the repairing conditions still going, either by changing the design of the broken joint, treating the broken surface with various materials, or strengthen the repaired materials with diverse fillers [4,13]. Different fillers, metallic oxides, and carbon graphite fibers are integrated into the matrix of PMMA to reduce these problems and to enhance the mechanical properties of the PMMA [14,15]. Nanomaterials have contributed to advanced implementations in nanomedicine and biomedical sciences due to their remarkable physical and chemical properties, among different types of nanoparticles, are metal oxides that are valuable not only because of the diversity of their physical and chemical properties but also because of their antibacterial properties [16].

The strength, ductility, antimicrobial effects, and aesthetic merits of PMMA have been enhanced by the incorporation of nanoparticles[17].

Among the known metal oxide nanoparticles, magnesium oxide (MgO) has been widely studied because of its novel applications in areas such as electronics, adsorption, catalysis, ceramics, petrochemical products, coatings, detection and remediation of chemical waste and warfare agents, and many other fields [18].

According to our knowledge, no study investigated the effect of MgO NPs addition on the flexural strength of cold - cured acrylic resin.

This research aimed to study the influence of MgO NPs addition at different concentrations on the flexural strength of cold - cured acrylic resin material.

MATERIALS AND METHODS

Sampling:

Total number of specimens were forty which divided into four groups,10 specimens for each one which were (control, 1.25%MgO NPs, 2.5%MgO NPs and 5%MgO NPs), This study was done at the college of dentistry and technical institute at the University of Mosul. Approval of study was from the Scientific Research Committee / Department of Prosthodontics / College of Dentistry (UoM.Dent / DM. L.43/21)

The preparation of the specimens for mechanical test:

The specimens were prepared by cutting the hard plastic sheet by laser machine according to the dimensions of specimen specified for flexural strength test which were (65×10×2.5) ±0.03mm (length, width, and thickness respectively), according to ADA Specification no.12, 1975)[19].

Investing plastic models:

The molds for preparation of acrylic specimens were prepared by investing the plastic models with previous dimensions in dental stone by using metal flasks as shown in Figure (1),the dental stone (synarock/Germany)was mixed following manufacturer´s instructions,then the stone mixture was poured in lower half of flask, good vibration using vibrator machine,then models were placed,then after the setting of stone was completed, a separating medium(Imiseal / Turkey) was applied over the set stone then allow it to set then upper half of flask was applied over the lower half then filled with stone,after setting of stone occurred,the two halves of the flasks were opened and hard elastic models were removed,after drying a separating medium was applied to both halves of the flask[20] .weighing the nanoparticles MgO (US Research Nanomaterials.,Inc/ USA) with the selected percentage of (1.25%, 2.5% and 5% of Nano MgO),weighing of the acrylic resin powder and monomer liquid

(Imicryl/ Turkey) , ratio was made according to the manufacturer's instructions which were (24gm of powder :10gm of monomers),the nanoparticles were added to monomer ,then placed in ultrasonic device to ensure homogenous mixing and avoiding aggregation of nanoparticles,then acrylic powder was mixed with(monomer/nano) suspension , when reached to dough stage, placed it into molds(over filled) then place the upper half of flask then the flask was put under the hydrulic press between 1250-2000 pounds and left under the press for 15 min[21]. After setting, the specimens were removed for finishing and polishing, then all the specimens were immersed in distilled water at 37°C for 48 hours before being tested [22].

Figure (1): Investing plastic model in dental stone

Flexural Strength Measurement Test:

The test was achieved by using a three-point bending tester on the universal testing machine as shown in Figure (2). The device was equipped with central loading press and two supports, the distance between two support was 50mm, the test was done with a crosshead speed of 5mm/min. The test specimen was placed at each end of the two struts with the loading head applied centrally between the struts, and the specimen deflected until breakage occurred [23]. The flexural strength was calculated according to the formula: $\mathbf{S = 3PI/ 2bd^2}$[24].

S =transverse strength (N/mm2),**P** =maximum force exerted on specimen(N),**I**=distance between support(mm),**b**=width of specimen(mm),**d** =depth of specimen.

Figure (2): Universal testing machine

FTIR (Fourier transform infrared):

This test is used to shows if there is any chemical change in acrylic chemical composition after the addition of MgO nanoparticles [25]. FTIR with transmittance mode was used to characterize the existence of specific chemical groups in the tested catheter samples. FTIR measurements were carried out on ALPHA PLATINUM-ATR Spectrometer (BRUKER LASER CLASS 1, Germany) a versatile Attenuated Total Reflectance (ATR) sampling accessory with a diamond crystal plate. Spectra were recorded in the spectral range of 400–4000cm $^{-1}$. Each specimen was placed on a diamond crystal table to be in direct contact with the internal reflection element (IRE) ([26], each specimen placed for 32 sec to provide an accurate reading.

RESULTS

The statistical analysis: Descripitive statistic, the test of normality, Inference statistic (ANOVA and Duncan´s test) were done by using spss program version (19). In the test of normality, the results of Shapero test were not significant with normal distribution at ($P \geq 0.05$), so we can use parametric tests.

Flexural strength test:

Descriptive statistics which include (mean and standard deviation) of four groups which were (control,1.25%,2.5%, and 5%) were presented in table (1), the group of 1.25% MgO NPs had maximum flexural strength value while the other groups showed a reduction in the flexural strength with minimum value was in the group modified with 5% MgO NPs.

Analysis of variance (ANOVA) was presented in table (2), which showed that there was a significant difference between all groups at $P \leq 0.05$.

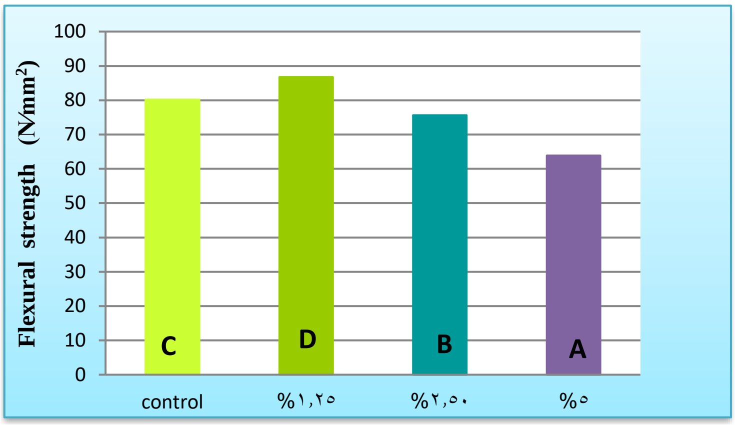
Duncan´s multiple analysis range test of control group and groups contained MgO nanoparticles at different concentrations was presented in Figure(3), it showed a significant increase in the flexural strength in the group contained MgO nanoparticles at 1.25% compared to the control group while the other groups which were 2.5% and 5% showed a significant decrease in the flexural strength compared to the control group, also a significant difference in flexural strength was found between all modified groups(1.25%,2.5%, and 5%).

Table (1): Showed mean and standard deviations of flexural strength test.

Groups	N	Mean(N⁄mm^2)	Std. Deviation
Control	10	80.17	3.325
1.25% MgO NPs	10	86.76	3.450
2.5% MgO NPs	10	75.63	2.525
5% MgO NPs	10	63.87	3.102

Table(2): Analysis of variance (ANOVA) of flexural strength.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2789.641	3	929.880	95.452	.000
Within Groups	350.707	36	9.742		
Total	3140.348	39			



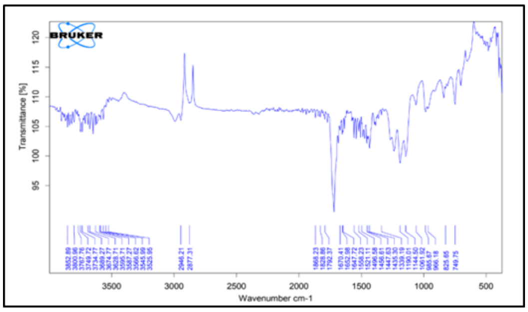
Figure(3): Showed Duncan´s multiple analysis range test of flexural strength test.

*Different letters means significant difference at P ≤ 0.05.

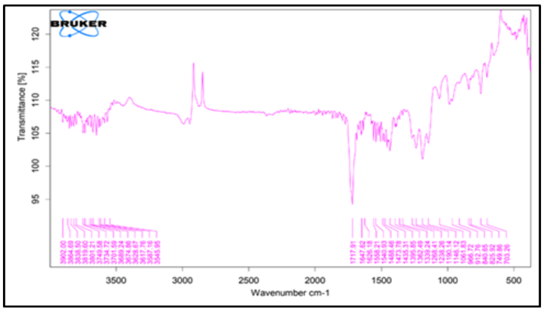
FTIR (Fourier Transform Infrared):

Figure (4 A), demonstrated the infrared spectrum of the control group of cold-cured acrylic which showed main bands identifying the vibrational spectrum, two main absorbance peaks appeared which were nearly at 1718 cm $^{-1}$ which represents C=O absorbance peak, other absorbance peak appeared at 2950 cm^{-1} which represents C-H [27].

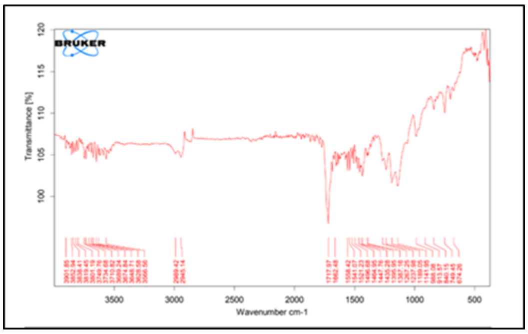
FTIR figures(4B to 4D) results charts revealed that there were no changes in the absorption bands between control group and groups modified with MgO nanoparticles at different concentration, that means there were no chemical changes occurred after addition of MgO nanoparticles.



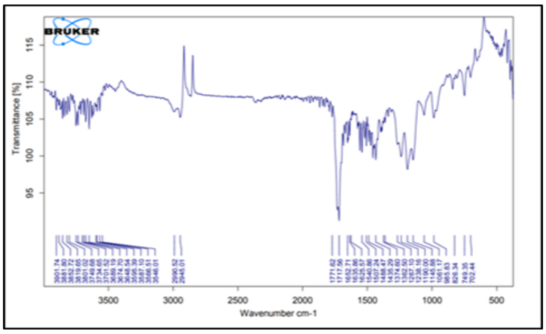
(A) Control (without additive)



(B) 1.25% MgO NPs



(C) 2.5% MgO NPs



(D) 5% MgO NPs

Figure(4): FTIR of cold- cured acrylic specimen (A)control and acrylic modified with MgO NPs at (B) 1.25% (C) 2.5% and (D) 5% .

DISCUSION

Flexural strength of denture base resin is considered the primary mode of clinical failure [28], the results obtained from this study showed that there was an effect of magnesium oxide nanoparticles(MgO NPs) addition at different concentrations on the flexural strength of cold-cured acrylic resin, it showed an increase in the flexural strength of cold-cured acrylic resin with the addition of 1.25% of MgO NPs, this is maybe due to the ability of MgO NPs to stop spreading of crack inside acrylic nanocomposite, additionally may be due to the good adhesion between the acrylic matrix and nanoparticles and this agree with Salih *et al*. [29], while its disagree with Shakir and Abbas,[30] who added 1.5% of MgO NPs to hot -cured acrylic denture base and showed a reduction in flexural strength at this concentration. Proper distribution of the nanoparticles allows them to enter between linear chains of the polymer, so nanoparticle restricted mobility of polymer chains which lead to an improvement in flexural strength [31]. At a concentration of 2.5% and 5% which are higher than 1.25%, there was a reduction in flexural strength value this may be due to formation areas of agglomeration of nanoparticles (NPs) within the polymer matrix, which act as weak point(stress concentration point) due to poor bonding between nanoparticles and polymer matrix or may lead to pores formation within the composite and this agrees with Kul *et al*.[32] and Omer and Ikram, [33].

As we can see, the concentration of the nanoparticles (NPs) definitely had an important role in jeopardizing the mechanical strength of acrylic resin. This agrees with Ghaffari *et al*.[34] research that showed a lowering in strength with increasing in concentration of NPs. Also, other studies had identified an inverse relationship between raising the NPs concentration and strength [31].

Karci *et al*.[35] performed a study on the addition of different nanoparticles(SiO_2, Al_2O_3, TiO_2) at different percentage 1, 3, and 5 wt%, they proved that increase in the concentration of nanoparticles added to acrylic denture base above 1% showed a reduction in flexural strength due to agglomeration of nanoparticles. This study also agrees with Hameed and Abdul Rahman,[36] who added ZrO_2 NPs to acrylic and they showed a reduction in flexural strength at higher concentration, they concluded that too many fillers lead to separation of PMMA chains and weak force between these chains lead to a reduction in fracture resistance and the mechanical characteristics of the polymer, also a decrease in flexural strength at higher concentration is due to clumping(agglomeration) of modified nano-ZrO_2 fillers, nanoparticles tend to reduce their surface area by agglomeration, the agglomerated mass cannot supply any enhancement in the mechanical properties, instead, they act as micrometer-sized flaws in the matrix and often cause deterioration of properties.

CONCLUSION

The addition of MgO nanoparticles influenced the flexural strength of cold-cured acrylic resin. At the low concentration of MgO NPs (1.25%), there was a significant increase in the flexural strength, but at high concentrations (2.5% and 5%) of MgO NPs, there was a significant reduction in the flexural strength value.

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