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Effect of Montmorillonite Incorporation on Shear Bond Strength and Surface Hardness of Acrylic Base Soft Lining Material (An in Vitro Study)

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Research Article

History

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ABSTRACT

Objective: One problem with the soft lining material is that it detaches from the acrylic base of dentures after a particular time period. So, the aim of this work was to evaluate how adding montmorillonite nano clay would affect the soft lining material's shear bond strength and surface hardness.
Materials and Methods*:* The heat-cured acrylic denture material for the control group, polymer reinforced with (0.25%, 0.5% by wt.) of montmorillonite nanoparticles(MMNTPs) for experimental groups was used in this study. For the shear bond strength test 60 blocks of acrylic-based material were constructed, each pair connected with soft lining material, the other 30 specimens for the surface hardness tests were carried out to be tested with a shore A durometer. The data were statistically examined using the One-Way ANOVA test and Bonferroni multiple comparisons test.
Results: 0.5% by weight MMTNPS should significantly increase in both shear bonding strength and surface hardness of soft lining material.
Conclusions*:* MMTNPs were remarkably successful in improving the strength of the shear connection between acrylic and soft liners.

Key words*:* Montmorillonite, Nanoparticles, Soft Lining Material, Shear Bond Strength, Surface Hardness.

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Introduction

Soft liners are extremely useful in dental procedures due to their rheological properties, the function of which is to absorb impact stress, lessen and spread out the stress on supporting tissues from dentures, and improve the intaglio denture's appearance. For patients being treated for the atrophic ridge, bruxism, xerostomia, or bone undercuts, these liners are clinically useful.[1]

One of the most common requirements for denture liners is that they must bind well enough to polymethylmethacrylate to prevent early breakage during use. However, using soft lining materials has a number of drawbacks, the main one being the lack of a strong attachment to the denture foundation.[2,3]

Denture base and liner materials debonding provide a platform for microbial growth resulting in the development of plaque and calculi. So, soft liners often need to be checked and replaced on a regular basis.[4] These issues have since been resolved with a number of improvements and techniques that enhance bonding of soft liners. These techniques consist of adding nanoparticles like glass fiber and zirconia silver nanoparticles with alumina. One of the nanomaterials used in polymers is MMTNPs, which has great biocompatibility and aesthetics.[5,6]

The 2:1 phyllosilicate mineral montmorillonite (MMT) is the most popular layered silicate mineral nano clay utilized in nanocomposite manufacturing. MMTNPs is an off-white powder that shouldn't have a negative impact on the denture base's aesthetics. According to reports, the material is biocompatible and has good physical and mechanical qualities.[6,7]

The chemistry of the nano clay, its dispersal, polymer reactivity, and process conditions all influence the efficiency of nano clay in improving the properties of nanocomposite materials. Clay exfoliation at less than 5% by weight improves nanocomposite properties significantly.[8]

Most nanoparticles have distinct features that make t hem useful in a wide range of biomedical applications, le ading to the production of amazingly effective diagnostic and therapeutic tools.

Furthermore, nanoparticles might be used in pharma ceutical delivery systems to lessen the negative effects th at are usually associated with standard drug use.[9]

Because of its multiple applications, nanotechnology has had an influence on all aspects of life in recent years and is interconnected with many other scientific areas.[10]

In this study, (MMTNPs) had been incorporated to acrylic soft lining material in amounts of 0.25%wt and 0.5%wt, along with control specimens, to enhance the strength of shear bonds.

The null hypothesis H_0 was that the incorporation of montmorillonite has no effect on soft lining material.

Table 1. The results of shear bonding strength test in pilot study.

Sample	Control	0.25%	0.5 %	0.75%	1%	1.5%
1	12	17	17	18	22	22
2	14	15	16	21	19	24
3	12	14	18	19	21	20
Mean	12.6	15.3	17	19.3	20.6	22

Table 2: The results of surface hardness test in pilot study.

Sample	Control	0.25%	0.5%	0.75%	1%	1.5%
1	66.2	68.2	70	71.4	78.3	76.8
2	67.4	68	68.8	72	77	77.5
3	65.4	67.4	69.2	71.8	76.3	78.5
Mean	66.3	67.8	69.3	71.7	77.2	77.6

Material and Methods

Ethical approval

The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional regional), the study protocol was reviewed and approved by an ethical committee of the College of Dentistry, University of Baghdad according to the document number (741 in 1-12-2022).

Pilot study: A pilot study to assess the effect of various MMTNPs percentages on the soft lining material's shear bond strength and surface hardness was conducted. MMTNPs were used in three samples for each percentage of 0%, 0.25%, 0.5%, 0.75%, 1%, and 1.5% by weight. According to the result, the MMTNPs percentages of 0.25 and 0.5 wt.% were chosen because they had a considerable improvement in shear bond strength as presented in table 1 and 2.

The research evaluated the shear bonding strength and surface hardness of a heat-curable acrylic-based soft liner (Moon Star, Turkey) before and after the incorporation of MMTNPs (SIGMA-ALDRICH, USA), (Figure 3) showed some of material used in the study.

Shear bond strength test

I. Specimens preparation: Sixty specific acrylic blocks with dimentions which is not ISO but its suitable for testing device (length, width, and thickness: 75mm, 25mm, and 5mm respectively) with a stopper of approximately 3 mm were created to assess the shear bond strength test.[11]

The above-given dimensions were used to build plastic blocks (made in Iraq), (Figure 4/A) that would later be replicated in acrylic. To facilitate duplicating, laboratory silicone putty (Labosil, Spain) was employed (Figure 4/C). As instructed by the producers, heat-cured acrylic (SpofaDental, Czech) was combined at (2.2 gm to 1ml). To ensure fair distribution of the material, the silicone molds with acrylic was packed and cured.[12] After cooling the acrylic samples were removed and refined as presented in (Figure 4/D, E). An acrylic sample is layered on top of another, with space between for soft lining material to be applied (Figure 4/F, G).[13]

II. Soft liner application: The soft liner (Moon Star, Turkey) was used and as directed by the producer, 10g of powder and 7.8 ml of monomer were blended in a dry, clean glass beaker. The beaker was then tightly sealed it took around fifteen minutes to get to the dough stage., the material had been gradually added into the spaces between each pair of blocks. Once the spaces were overloaded, it was packed and cured. After cooling the specimens were retrieved as presented in (Figure 4/H, I) and placed in a container with distilled water for 48h.[13]

III. Incorporation of MMTNPs: For test specimens, MMTNPs powder at two distinct concentrations (0.25% and 0.5% by weight) was included in the liner monomer. By using a probe sonication instrument (Soniprep-150, England) (120W, 60 kHz) for three minutes, the nanoparticles are broken up into individual nanoparticles and spread out evenly throughout the monomer. to lessen the likelihood of aggregation of MMTNPs it was immediately mixed with soft liner powder.[14]

A universal testing equipment (WDW-20, Laree Technology Co., Ltd., China) 0.50 mm/min cross-head speed with a maximum 100 kg load capacity for the load cell was used for testing. The maximal force of failure is represented by readings taken from the machine. strength was estimated by dividing the maximal force at which a bond would break by the area of its cross-section of each sample. Bonding strength (N/mm2) = maximal load/cross-sectional area = F/A.[15]

The specimens of soft liner for surface hardness tests were fabricated with parameters of (65mm,10 mm, and 2.5mm) in length, width, and thickness respectively.[16] All the samples were submerged in distilled water and stored for 48 hours at 37°C Before evaluation to remove excess monomer. A shore A durometer (Time groupTH200, China) hardness test was performed on the lining materials. Each sample has undergone five separate analyses. After each penetration, there was a 5-second contact period, and the mean of these times was used for the result of the test, as presented in (Figure 5).[17]

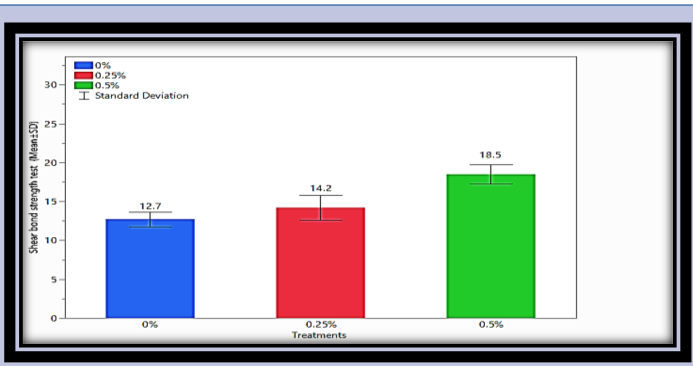

Figure 1. Bar chart representation the mean values and standard deviation of shear bond strength test (MPa) result among the studied groups. MPa: Megapascal

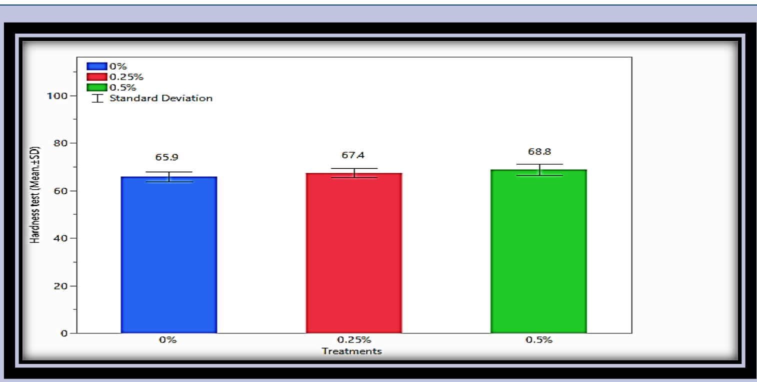

Figure 2. Bar chart representation the mean values of shore A hardness test result

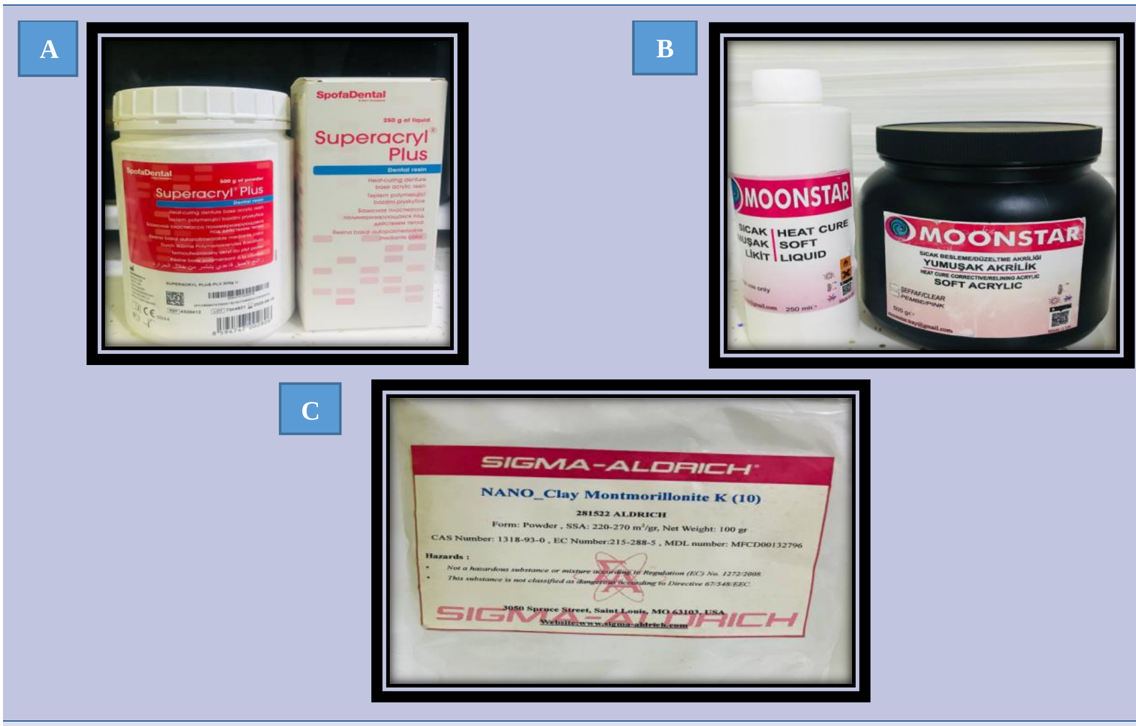

Figure 3. A, Heat cure acrylic based material. B, Heat cure acrylic based soft liner. C, : Montmorillonite K10 nanaparticles.

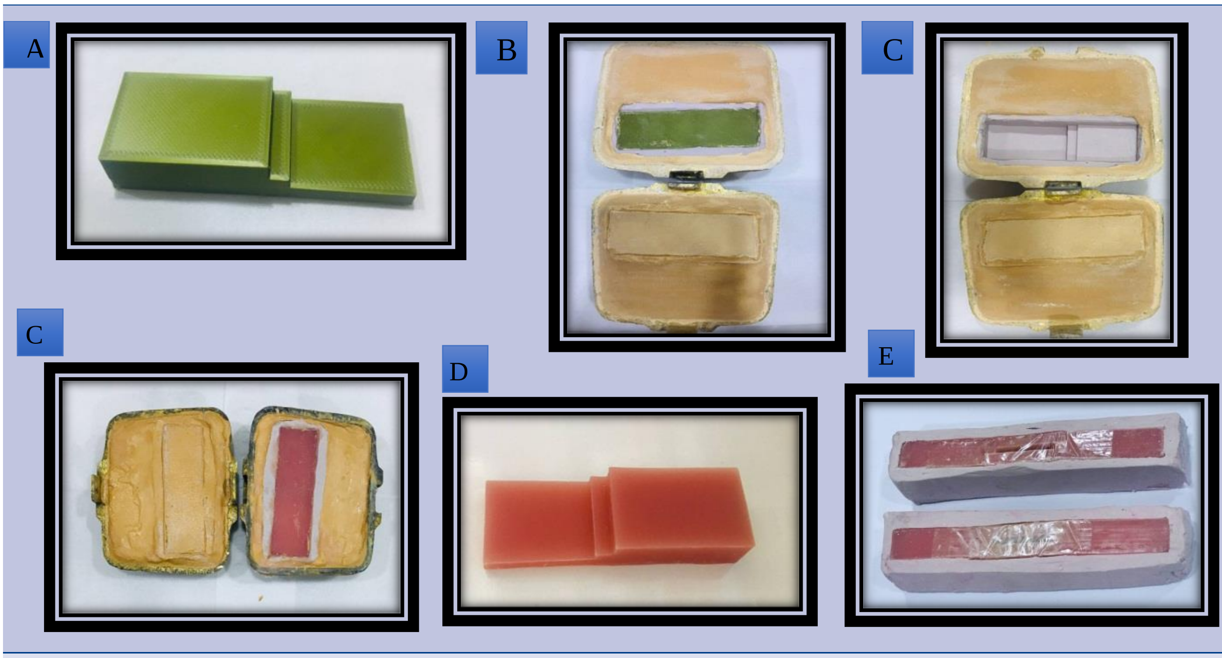

Figure 4: Shear bond strength specimens preparation. A, plastic mold. B, plastic mold placed in silicone and in stone. C, block removed. D, flask after curing. E, acrylic specimen after finishing. F, acrylic blocks invested in silicone. G, specimens invested in stone. H, specimens after curing. I, final specimens.

Figure 5: Surface hardness specimens ready for testing.

Table 3. One-way ANOVA test result of shear bond strength.

Analysis of Variance						
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	Significant
Between Groups	2	181.26	90.63			
Within Groups	27	44.20	1.63	55.36	<.0001*	HS
C. Total	29	225.46				

DF: Degree of freedom, HS; Highly significant

Table 4. One-way ANOVA Table for hardness test results.

Analysis of Variance						
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	Significant
Between Groups	2	42.71267	21.3563			
Within Groups	27	130.72100	4.8415	4.4111	0.0220*	S
C. Total	29	173.43367				

S:Significant

Results

Shear bond strength

The maximum value was obtained in a group containing (0.5%) wt. MMTNPs with (18.5) MPa, followed by a group containing (0.25%)wt. MMT with (14.2) MPa, while the lowest value of (12.7) MPa was obtained in the control group (Figure 1).

Statistical analysis using one way ANOVA test for shear bond strength showed a statistically highly significant difference among all studied groups (P. <0.01) as shown in (Table 3).

In dental treatment, soft lining materials are frequently adapted to reshape surfaces of dentures that are with an interface with the oral mucosa. They offer shock absorption that helps to distribute and reduce the functional forces. However, the primary drawback of soft liner materials is their tendency to separate from the denture base over time.[18]

This research was done to assess the soft liner's shear bond strength following the addition of MMTNPs in various concentrations and how that affected surface hardness.

The findings of this investigation revealed a significant rise in the average shear bond strength in 0.5% MMTNPS addition into soft liner compared to the two other groups. It is anticipated that the hydrogen bonds and the van der Waals interaction that form between the nanofiller and polymer will enhance the rigidity and shear strength of the material, in addition, the MMTNPs function as fillers by occluding voids between soft liner particles and improving the surface area for denture base material adherence, more importantly; the size of the sample used (25 mm long by 25 mm wide) is considered to be large, this might be used in the improvement of bonding.[19]

Hardness is among the most crucial characteristics of materials for soft denture liner since it reduces the effect of absorption.[20]

In this investigation, the distribution of MMTNPs throughout the matrix may be responsible for the rise in hardness. The particles cluster inside the voids of the soft lining matrix also as interparticle distance decreases and the bonding strength between particles increases, which in turn causes an increase in hardness.[21]

Hardness is directly related with nanoparticle concentration, as the concentration of MMTNPs increased the hardness increase and vice versa. with a low concentration (0.25% MMTNPs) resulting in a minimal effect related to a low number of networks, even so, there is no boundary to the spectrum of Shore a hardness values that can be used for therapeutic purposes.[22]

The study is limited by in vitro environment so we cannot generalized the result to the clinical situations.

Conclusions

Within the limit of this study, the following findings were obtained: after addition of 0.25% and 0.5% of

Surface hardness test

Maximum value (68.8) was obtained in 0.5% weight followed by the group containing 0.25% weight with (67.4), while lowest value of (65.9) was obtained in control group (Figure 2).

One-way ANOVA table for hardness test results showed significant difference between all tested groups (Table 4).

Discussion

MMTNPs into acrylic based heat cured soft denture lining material:

1-Incorporation of 0.5% MMTNPs into heat-cured acrylic-based soft denture liner material. showed a significant improvement in shear bonding strength in both concentration (0.25% and 0.5%) which a highly important improvement.

2-There was a significant increase in surface hardness of soft lining material in 0.5% MMTNPs but with 0.25% there was an acceptable value of hardness.

Acknowledgements

Non.

Conflicts of Interest Statement

Non.

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