Effect of addition of Magnesium Oxide Nanoparticles on surface hardness and tensile bond strength of denture soft liner

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Abstract

Background and objective: This study was aimed to determine the effect of addition of 3% of Magnesium Oxide Nanoparticles (MgONPs) on the surface hardness (SH) and tensile bond strength (TBS) of asilicone based denture liner at various time intervals. Method: The SH and TBS of a silicone denture liner were studied after addition of 3% by weight of MgONPs. A total of 140 samples were constructed. The samples were divided into two main groups, control group and test group to which 3% of MgONPs were added.

Results: The SH of all the samples for both groups was significantly higher after a period of 6 months. For TBS the pattern was reversed in which there was a decrease in the mean of TBS for both control and test groups significantly. Conclusion: The addition of 3%(MgONPs) to Silicone denture liner causes a non-significant effect in the SH but significantly improves TBS.

Keywords: *Soft liner, Nanoparticles, Magnesium Oxide.*

Introduction

The resilient denture lining materials bonded to the removable dentures are usually used to decrease the amount of the forces transmitted to denture supporting tissues.[1] These materials are able to form an absorbing layer on the part of the denture in contact with the oral mucosa and this allows less traumatic transmission of occlusal forces. The result is that wearing the prosthesis becomes more comfortable for the patient.[2]

The resilient liners used for prosthetic purposes are available either as resin based or silicone based. Both types are present in autopolymerized or heatpolymerizedform.[3]

Despite numerous advantages of this material, soft liners have some shortcoming such as high porosity that increases plaque accumulation, colonization of Candida strains and development of denture stomatitis.[4]

Bacterial contamination continues to draw public attention. Generally, antibacterial agents can be categorized as organic or inorganic antibacterial agent. Organic antibacterial agents have low resistance to processing conditions, which limit their applications. As a result, inorganic antibacterial agents have attracted much interest for bacterial control.[5] The main advantages of inorganic antibacterial agents over the organic antibacterial agents, are the improved stability under harsh processing conditions.[6] In medicine, inorganic antibacterial agents such as MgO are used for the relief of heartburn, sore stomach, and for bone regeneration[7,8]. Huang et al. demonstrated that MgONPs had an antibacterial effect they also determined that the antibacterial efficacy increased with decreasing particle size[9].[10]

Material and Method

A total of 140 samples were constructed and divided into two main groups, control (n=70) and test (n=70).

The study was done to evaluate the SH and TBS of

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a silicone denture liner after addition of 3% MgONPs depending on a pilot study which was done earlier in which different concentrations of MgONPs (2%, 3%, 4%, 5% and 6%) by weight were added to the soft liner and evaluated to determine which concentration provide best anti-microbial effect. Also a Scanning electron microscopic (SEM) evaluation was performed to determine the distribution of the (MgONPs).

Preparation of the Samples: Mollosil, which is a silicone based soft denture lining material is supplied in a two- pastes (base and catalyst), it is an auto polymerizing material, the material is mixed manually at ratio 1:1 base/catalyst according to manufacturer instructions. The base and catalyst parts were weighed by digital weight scale. Then the (MgONPs) was weighed and added in small trace amount to the base part of the material at concentration of (3%) by weight, and mixed together for one minute in a circular motion (120 cycles/ minute), after that the catalyst part was added to them and mixed for 30 seconds according to manufacturer instructions all of the samples were made at a constant room temperature 25 °C.

Hardness Test: A total of 70 samples divided into two main groups, control n=35 and test n=35were constructed using abrass mold(diameter 45 mm, 6 mm thickness) according to ASTM: D-2240-5)[11]. The samples were further subdivided into five subgroups (n=7) according to the storage time in distilled water (24 hours, 1 week, 4 weeks, 3 months and 6 months), each subgroup was tested separately because the SH measurement test does not allow reusing the samples.

The SH was measured after 24 hrs, 1 w, 4 w, 3 m and 6 m of aging in distilled water at 37 ± 1 °C. The SH of every sample was measured at five measurement points, that were at least 5 mm away from the edge of each sample and spaced at least 3 mm away from each other's and then the average was taken

The measurements were performed after 5 seconds of loading using a Shore A Digital Durometer under 1 kilogram.

Tensile bond strength test: The TBS was measured according to the ISO standard.[12] 140 Heat-cured Polymethyl methacrylate (PMMA) acrylic plates (25mm X 25mm X 3.5 mm) were prepared(2 plates for each TBS sample).

The surface of acrylic plate coated with adhesive bonding agent supplied by the soft liner material manufacturer. The adhesive was applied to one surface of both acrylic plates simultaneously with a brush, the first acrylic plate was placed on flat floor. A polyethylene O-ring with an internal diameter of 10 mm and a thickness of 3 mm was placed in the middle of the acrylic plate. Next, the test material was poured into the O-ring by the use of disposable syringe to prevent air bubble intrusion. Then, the second acrylic plate was placed over the ring and the testing material.

A weight of 1 Kg was placed over the whole assembly, when the material was set the weight was removed, after that, the ring was removed gently by cutting it with a sharp surgical blade. Fig 1

Lastly, the prepared 70 specimens were conditioned in distilled water at 37 ± 1 °C for 24 ± 1 hour, 1 week ±1 °C, 4 weeks ± 1 h, 3 months ± 1 hour and 6 months ± 1 hour.

Figure 1: TBS sample

The specimens were tested using a software programmed universal testing machine. To ensure the specimen assembly pulled at a right angle to the denture base soft liner interfaces a specially designed metal sample holders were used to grasp the specimens to the universal testing machine grip.

The holders have a 3 mm extension lip to ensure adequate grasping and prevent possible movement of the specimens during testing Fig 2.

Then the sample with the holders were secured into the testing device jaws and stretched at constant cross head speed 10 mm/min, the force which caused deboning was recorded.

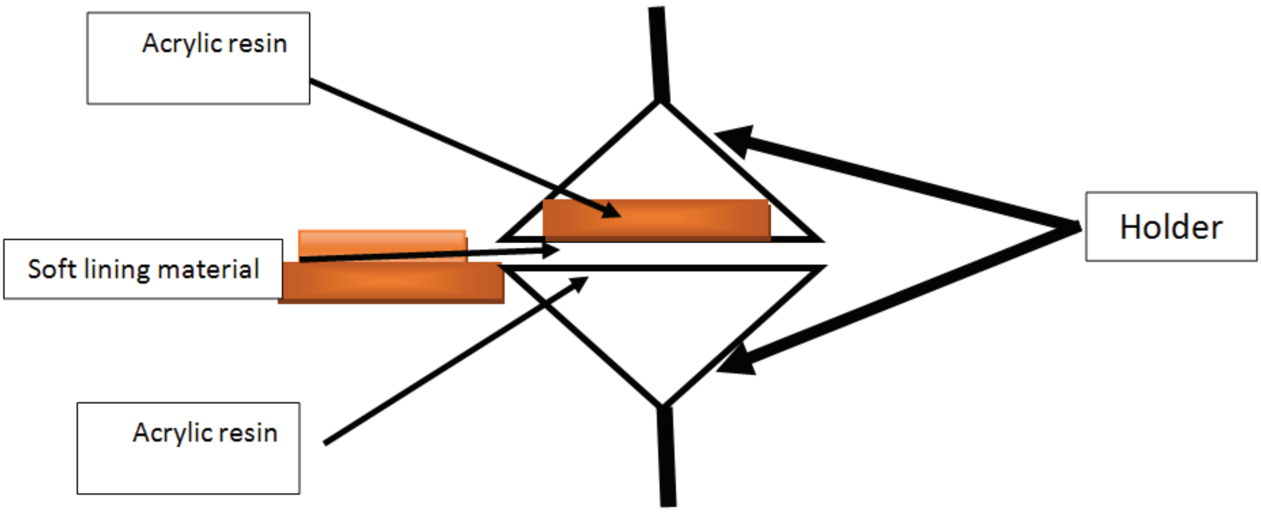

Figure 2: Custom made sample holder

The values of TBS were calculated automatically as the force at debonding divided by a cross-sectional area of interfaceaccording to the following formula:

Tensile strength = F/A (N/mm^2)

F = force of failure. (N)

A = Original surface area of the cross section. (mm^2)

Results and Discussion

The addition of MgONPs to the soft liner resulted in an increase in the mean SH but this increase wasa non-significant for all groups (table.1)

The test group was harder than the control group. This group is likely to have highly cross linked network in combination with the added MgONPs. A material with a very high cross link density produces a very dense and hard material, also adding the fillers which have a very small size and the uniform distribution within the material may increase polymer/filler interactions and therefore reduces the mobility of the polymer chains. Furthermore, as the particle size decreases the number of the boundaries of these particle increases, therefore the dislocation movements by these boundaries may cause an increase in the SH.[13]

The control group showed lower SH value. This may be due to no MgONPs content, therefore increase polymer chain mobility between cross links. The results from the present study is in agreement with Aziz et al as they found the same result for maxillofacial silicon.[14] also agreed with results of other studies on denture soft lining materials.[15,16] furthermore, the increase in silicone SH of the modified group in the present study may be due to continued polymerisation and cross linking of this materials throughout the experiment.[17]Also, may be due to formation of new bonds between the fillers and the polymer chains, or because of reduction in the interstitial spaces in the matrix of the polymer chain. It has been stated that silicone denture lining materials contain no plasticizer but contain filler[18] and absorption of water by the filler could lead to decreased softness.

Table 1: The mean and standard deviation (SD) of SH at different time intervals

	24h	1 week	4 weeks	3 months	6 months
Control	20.57 (0.97)^{A,a}	21.28 (0.85)^{B,b}	25.21 (0.90)^{C,c}	28.14 (1.18)^{D,d}	30.57 (1.30)^{E,e}
Test	20.71 (0.85)^{A,a}	21.35 (0.89)^{B,b}	25.28 (0.56)^{C,c}	28.21 (1.07)^{D,d}	30.64 (1.37)^{E,e}
Total n=70	14	14	14	14	14

Note: Groups with the same uppercase superscript letters for each row and lowercase superscript letters for each column are not significantly different at the $p < 0.05$ level.

Aging process showed a significant effect on the SH of the material for both control and modified group, this result is in line with previous studies.[15,17,19,20] this increase in the SHcould be due to the gradual leaching of the soluble contents from the materials when undergoes aging for a long periods of time [21]

The TBS value among different studies vary occasionally owing to using different testing variables, the chemical formula of the tested materialsinfluences the results[22] Also, the different specimen treatment method such as conditioning or storage before testing need to be standardized[5,23] Finally, the TBS values differ according to the specimen fixation method, alignment of loading points, and crosshead speed.[24]

The TBS (table. 2) in this study were dropped from 1.087 MPa after 1 day to 0.446 MPa after six months for control group and 1.097 MPa to 0.462 MPa for test group respectively. Minami et al.[25] obtained similar range valuesfor another brand of silicone denture liner, using similar tensile test specimen assembly.

In this study, it was observed that within the same group, different soft liners showed difference TBS values. This was in agreement with the results obtained in other studies where similar test standardization was used in which their studies showed different TBS results for similar chemically silicone lining materials.[22,24]

The lowest TBS values were shown by control group which was statistically significant when compared to test group at all period intervals.

This increase in the TBS for the modified group may be due to the low concentration and a very small size of MgONPs used which may have led to less tendency for agglomeration with in the matrix, or possibly the added MgONPs may have been increased the surface area of adhesion between the acrylic resin and the soft denture lining material.[26]

On the other hand, the present study disagrees with the results of Sampaio[27] when found that there is no difference in the TBS after sealant application to the tissue conditioner, this could be explanted by the use of different material formula, shape and size of the specimens or testing parameter in each study.

Table 2: The mean and SD of TBS at different time intervals

	24h	1 week	4 weeks	3 months	6 months
Control	1.087 (0.004)^{A,a}	1.031 (0.003)^{B,b}	0.987 (0.005)^{C,c}	0.682 (0.006)^{D,d}	0.446 (0.004)^{E,e}
Test	1.097 (0.002)^{A,b}	1.046 (0.003)^{B,c}	1.003 (0.005)^{C,d}	1.003 (0.005)^{D,e}	0.462 (0.002)^{E,f}

Note: Groups with the same uppercase superscript letters for each row and lowercase superscript letters for each column are not significantly different at the $p < 0.05$ level.

Regarding the effect of aging, it was found that there is a negative relation between the storage time and the TBS for both groups, this finding is similar to previous studies.[19,27,28] This reduction in the TBS could be due to swelling and formation of the stress at the acrylic-liner bond interface, or changing the viscoelastic properties of the soft lining materials after immersion[29]thus the material become stiffer and able to transmit more external loads to the bond site[30].

Finally, the SEM revealeda homogenous distribution without any agglomeration of the MgONPs within the matrix of the tested material, also the EDX revealed the presence ofaccurate concentration of MgONPs in the test group. figure 3,and4 shows the SEM of control and modified samples.

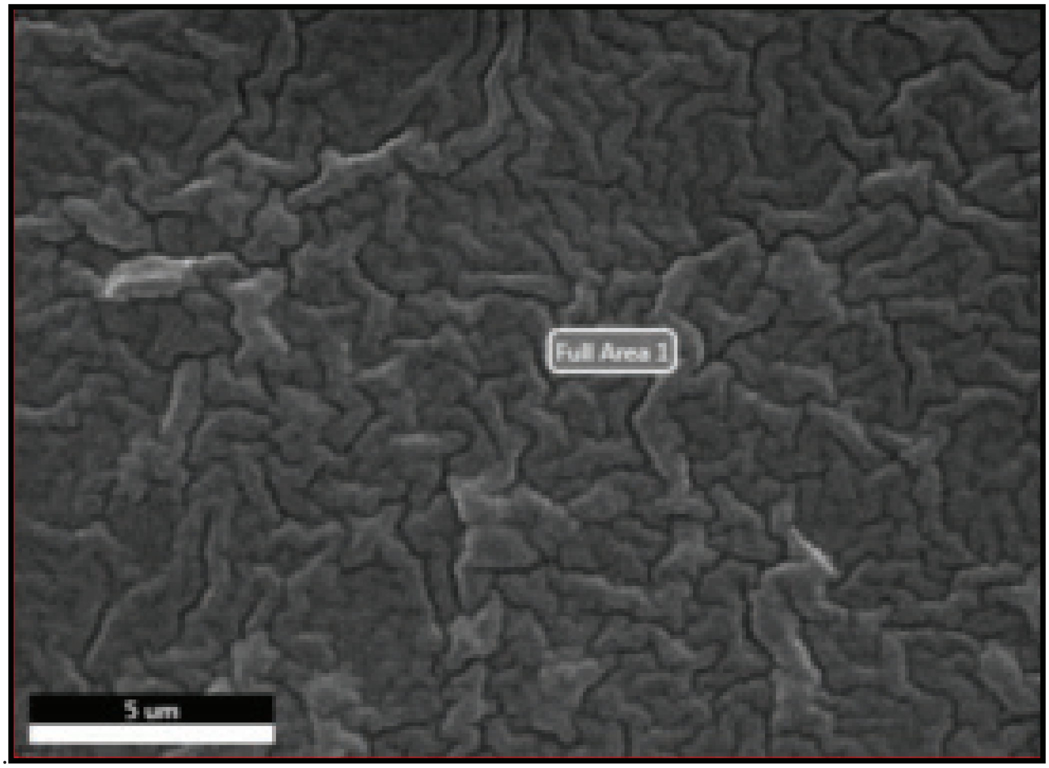

Figure 3: SEM control sample

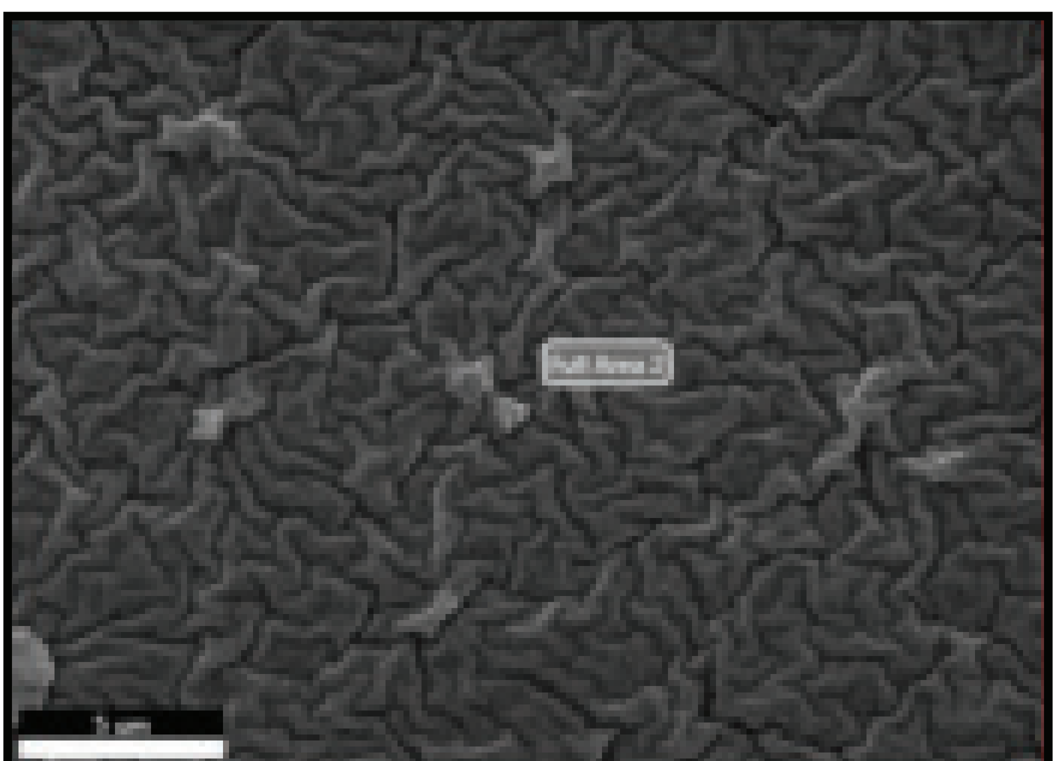

Figure 4: SEM modified sample

Conclusion

Addition of 3% MgONPs to Siliconedenture liner causes a non-significant effect in the SH, but significantly improves TBS.

Ethical Clearance: The Research Ethical Committee at scientific research by ethical approval of both MOH and MOHSER in Iraq

Conflict of Interest: Non

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