The Effect of Magnesium Oxide Nanoparticles on the Bonding Strength of Soft Denture Liner to the Denture Material

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Introduction: One of the most common problems of the soft denture liners is the deboning from the acrylic denture material. Thus, this study evaluates the effect of magnesium oxide nanoparticles (MgO NPs) on the soft liner deboning from the denture material.

Materials and methods: In this study, two tests were done (Tensile strength and Shear bond strength), for each test two groups were prepared first group (Control, n=5); second group (5 % of MgO NPs impregnated into the soft liner, n=5). Total 40 samples of hot cure acrylic were prepared in dimension of (8.1.2 cm length, width, depth respectively), for tensile bond strength, two acrylic samples where joined vertically with 3 mm thickness soft liner between the two pieces, while for the shear bond strength, two pices of acrylic were joined horizontally with the 3 mm thickness soft liner. The samples placed in distal water for 5 days, Universal testing machine used at crosshead speed of 5 mm/min.

Result: The data showed no statistical difference (Tensile bond strength and Shear bond strength) when 5 % of MgO NPs added into the soft liner. However, when tensile was compared with shear bond strength, higher resistance to tensile was observed compared to the shear strength.

Conclusion: Addition of MgO NPs did not affect the mechanical properties of soft denture liner, accordingly, MgO NPs can be used as antibacterial (as proved by previous studies) without compromising the mechanical properties.

Keywords: Dental Materials, Nanotechnology, Tensile Strength, Shear Strength, Acrylic Resin

1. Introduction

Chair side soft liner material is a soft, silicone based reline material also called as resilient liner which may be soft elastic and resilient material covering all or part of the impression surface of a denture. It usually acts as a cushion between the hard acrylic and the soft tissue surface, thus, providing comfort to the tissues. (Kalamalla et al., 2019).

The choice of a soft liner for clinical use should be based on the material's biocompatibility, mechanical properties and durability in the oral environment. However, soft liners have some problems like, water sorption, dimensional change, growth of microorganisms which causes color change eventually, deboning from the denture surface, and they have low tear resistance as well. Throughout

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years many attempts were made in order to improve the properties of the soft liner, such as improving the attachment of soft liner to acrylic denture material by using different etching solution on the denture material, to increase the roughness. (Khakbaz et al., 2018). Sandblasting procedure also have been used as a method to improve the bonding, which involves spraying a stream of aluminum oxide particles against the acrylic denture surface that intended for bonding under high pressure. (Chung et al., 2008). Despite soft liner benefits, the use of soft denture liners is associated with several problems mainly the colonization by microorganisms and adhesion failure from the denture base, recently, attention was directed toward the incorporation of nanoparticles such as Ag, ZnO, TiO2, and SiO2 into dental materials to improve their properties. (Ansarifard et al., 2021). Form the studies it was stated that the addition of silver nanoparticles (SNPs) in various concentrations improves the antimicrobial properties of both denture base and soft liners. (Ferreira et al., 2022). Addition of low concentrations of nano-SiO2 to acrylic denture base was reported to be a method for enhancing the denture strength. The SNPs' incorporation within the acrylic denture base material was even stated to improve its viscoelastic properties, however, there is limited data about the effect of MgO NPs on the soft denture liner as antimicrobial and as a technique to improve the mechanical properties. (Habibzadeh et al., 2020). Basically, magnesium oxide nanoparticles (MgO NPs) from research exhibited biocidal activity against bacteria and spores (Ravishankar Rai et al., 2011). However, research effort has mainly focused on the use of MgO NPs as antibacterial against certain bacteria (Tang et al., 2014). A number of mechanisms have been proposed, such as the formation of reactive oxygen species (ROS), the interaction of nanoparticles with bacteria, subsequently damaging the bacterial cell (Tang et al., 2014). Accordingly, more studies should be carried out on the activity of MgO NPs towards other microorganism species and their effect if it was impregnated in to the soft liners at different concentration and whether high concentration can improve the mechanical properties or not. Thus, the main aim of this study was to impregnate 5 % MgO NPs in to soft denture liner and to test the mechanical properties (Tensile and Shear bond strength) between modified soft iner (5% MgO nanoparticles) and with acrylic denture material aiming to improve the mechanical properties and to prevent infection and ingrowth of yeast, bacteria into the soft liner. However due to limited time only mechanical properties was tested and compared with control samples.

2. Materials and Methods

This study aims to improve bonding strength of soft denture liner to heat cure acrylic (ACRILICO VERACRIL) through addition of nanoparticles. In this study 5 % MgO NPs (size 20mm, purity 99+% Nano powder, code: U53310, US) was added (Impregnated) into soft liner (Proclinic Expert). Two main groups were prepared; first for the tensile strength test, each samples made of two heat cure acrylic joined vertically by soft denture liner. Second group, were prepared for shear bond strength, each samples made of two heat cure acrylic joined horizontally by soft denture liner. Both groups were subdivided into two groups (control samples and modified samples). Universal testing machine was used for both tests (DRK101S, Electronic, computerized, China) at crosshead speed of 5 mm/min until deboning. The data were shown in Mpa unit. The data were analyzed using (Stat graph version 5.1) with one-way ANOVA ($p<0.05$), Excel sheet was used for bar graph.

2.1 Preparation of the Heat Cure Acrylic

The heat cure acrylic block samples were prepared in dimensions of (8.1.2 cm Length, width, depth respectively), first wax sheet prepared with above dimensions. In order to prepare mold for the samples, a box was prepared and then plaster was inserted into the box, the plaster was distributed evenly in the tray by using vibrator to avoid air bubbles. Before setting of the plaster, the wax blocks where immersed into the plaster until only the surface was exposed. Then the samples where left until the plaster was cured. Afterwards the Vaseline was used on the surface of the plaster except the wax. Then second layer of plaster was poured into the box and left to be cured for one day as shown in (Figure 1A). After curing of the plaster, the box was inserted into a boiling water for 15 minutes for wax elimination. Then the two layers of plaster was separated leaving the place of wax block empty to be filled with heat cure acrylic (Figure 1B). The heat cure acrylic was prepared and placed into the space that was occupied by the wax. Afterword the second half of box was closed and pressure was applied by using clamp flask to close it firmly, then was inserted into the boiling water until complete curing. After that the acrylic was removed for finished and polished.

2.2 Tensile Bond Strength Samples Preparation

For the tensile strength test 5 replicas of acrylic samples were used, each sample consist of two acrylic pieces, the first acrylic piece was stabilized on the wax sheet then the other acrylic piece was also stabilized vertically on the wax sheet with space between them (3mm) for the soft liner material as shown in (Figure 2A). The border was sealed by wax to prevent leakage of the material. Bonding solution was applied to the acrylic samples. For the control samples, the soft liner material was mixed on a glass slab using spatula then packed precisely into the 3mm space. Once the soft liner cured the wax on the border was removed (Figure 2B). For the modified samples, the soft liner was mixed on glass slab then weighted with digital scale. Afterwards 5 % of MgO NPs was mixed with soft liner vigorously for 1 minute with the use of spatula then added into the 3 mm space.

2.3 Shear Bond Strength Sample Preparation

Similarly, to tensile strength test 5 replicas of acrylic samples were used. Each sample consists of two acrylic pieces, the first acrylic piece was stabilized on the wax sheet then the other acrylic piece was also stabilized horizontally on the wax sheet with space between them (3mm) for the soft liner material as shown in (Figure 2C). Bonding solution was applied to the acrylic samples. For the control samples, the soft liner material was mixed on a glass slab using spatula then packed accurately into the 3mm space. Once the soft liner cured the wax on the border was removed (Figure 2D). For the modified samples, the soft liner was mixed on glass slab then weighted with digital scale. Afterwards 5 % of MgO NPs was mixed with soft liner vigorously for 1 minute with the use of spatula and inserted into the 3 mm space. Once the samples were prepared, they were left in distal water for five days then a test was performed by universal testing machine.

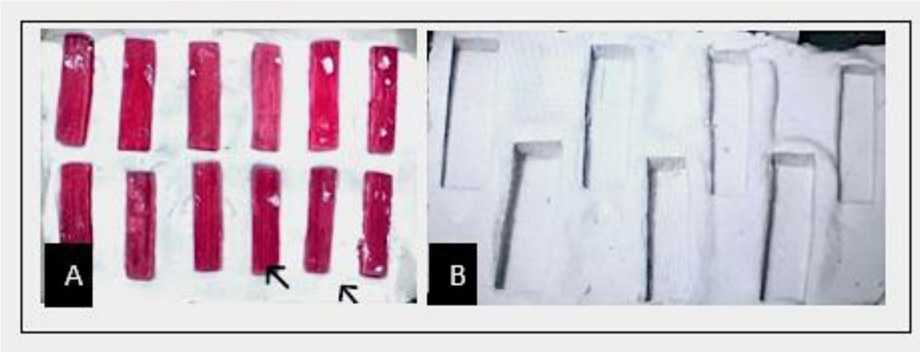

Figure 1: A) Wax sheet blocks immersed into box of plaster as a first layer. The arrows show plaster and wax samples fully embedded in the plaster except the superficial layer. B) After wax elimination box cleansed and ready for heat cure acrylic insertion.

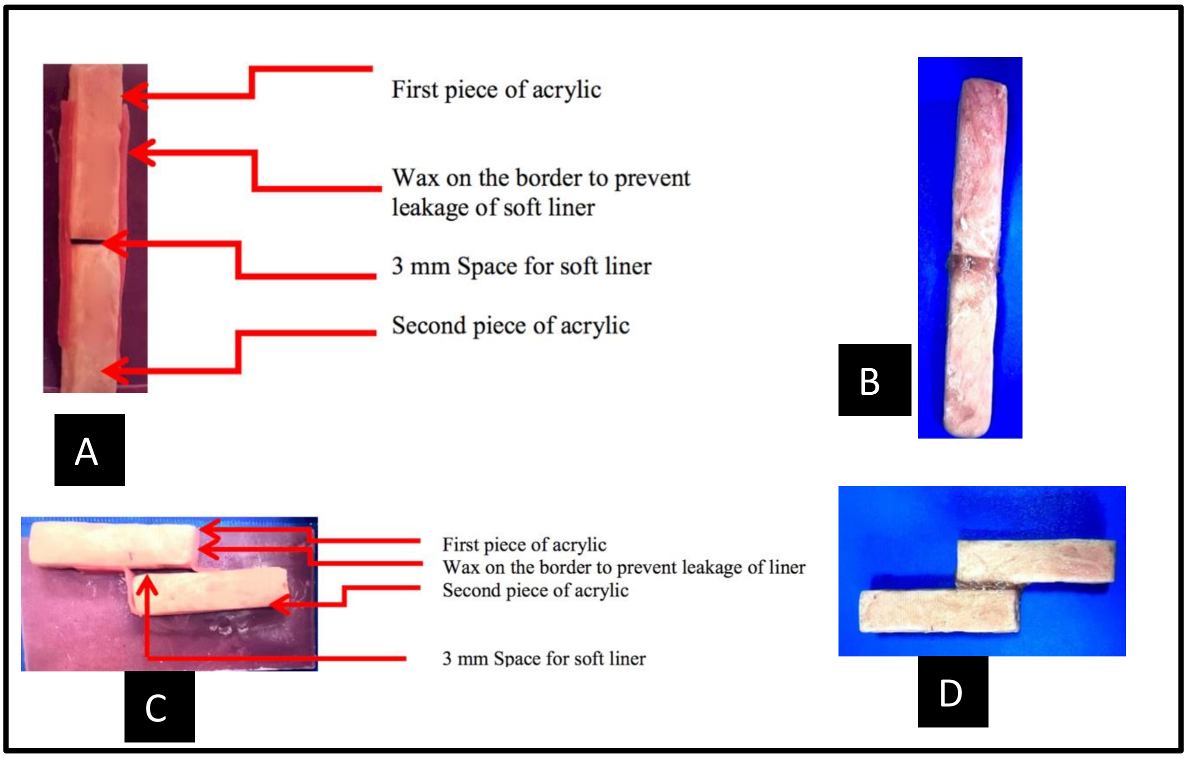

Figure 2: A) Two pieces of acrylic samples were stabilized on the wax sheet vertically with space for the soft liner. The border was sealed with wax sheet. B) Final sample for tensile strength. C) Two pieces of acrylic samples were stabilized on the wax sheet horizontally with 3 mm space for the soft liner. The border was sealed with wax sheet. D) Final sample for shear bond strength

3. Result

3.1 Tensile Bond Strength Test

The tensile strength in the present study showed that there is a statistically non-significant difference between control samples and when the samples were impregnated with 5 % MgO NPs, as shown in (Table 3). The mean value for the tensile group after storage in distal water for 5 days was (2.837 MPa), while when the samples were modified with 5% MgO NPs the mean value was (2.751 MPa), the statistical analysis (ONE WAY ANOVA, p=0.001) showed no statistical difference between their two groups.

3.2 Shear Bond Strength Test

The shear bond strength was recorded for both tested groups (control and modified samples). The result showed that there was no statistical difference between these two groups. The mean value for the shear bond strength after storage in distal water for 5 days was (1.201 MPa), while when the samples were modified with 5% MgO NPs the mean value was (1.240 MPa). The statistical analysis (ONE WAY ANOVA) showed no statistical difference between the two groups. Data were shown in (Table 3).

3.3 Comparing Tensile and Shear Bond Strength

This study showed significant statistical difference between the tensile bond strength of soft liner to a denture base material and the shear bond strength. The mean value of tensile strength for control samples where (2.837 MPa) while, shear bond strength for control samples was (1.201 MPa) (ONE WAY ANOVA). Furthermore, the mean value of tensile strength for modified samples where (2.751 MPa) while, shear bond strength for modified samples was (1.240 MPa) (ONE WAY ANOVA). As shown in (Figure 3).

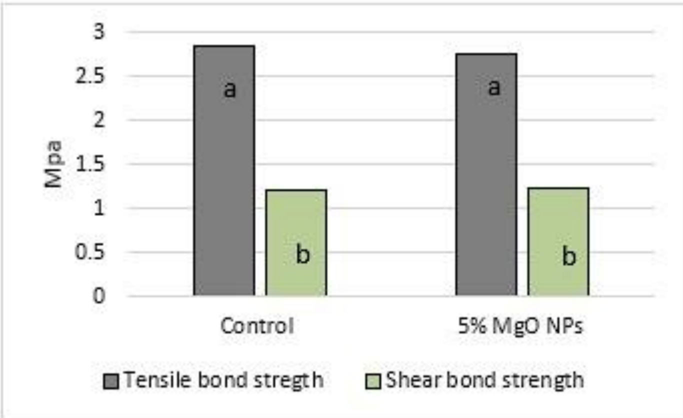

Figure 3: Tensile and shear bond strength of control and impregnated samples with 5 % MgO NPs, unit in MPa (ONE WAY NOVA)

Table 1: Tensile and shear bond strength of control and impregnated samples with 5 % MgO NPs, Unit MPa

Tests	**Control**	**5% MgO NPs**
Tensile strength	2.902 a	2.606 a
	3.001 a	2.772 a
	2.789 a	2.598 a
	2.197 a	2.909 a
	3.299 a	2.872 a
Test	**Control**	**5% MgO NPs**
Shear bond strength	1.098 b	1.029 b
	1.224 b	1.096 b
	1.389 b	1.367 b
	1.099 b	0.989 b
	1.198 b	1.722 b

4. Discussion

Soft liners must present permanent resiliency over extended period of time, however, with time soft liners may debond from the denture base material. Furthermore, mechanical properties also may be compromised with time. Additionally, accumulation and colonization of microorganism on the surface of soft liners may occur (Ahmed et al., 2018). Thus this study aimed to improve the mechanical properties and prevent the accumulation of microorganism on the surface with the use of MgONPs. In this study the addition of 5 % MgO NPs in to soft liner showed no statistical improvement in the tensile strength. The explanation of this finding is perhaps due to the factors which affects the curing system like (crosslink density, molecular weight of the polymer and concentration of filler, interaction of polymer and fillers) which were al the same for both groups. That is why no difference was observed for control and modified with nanoparticles samples. This finding is in agreement with the result obtained by (Meran et al., 2020). That study showed that addition of 3 % MgO NPs to silicone did not cause any significant change in mechanical properties, due to the fact that the addition of nanoparticles into samples had no chemical changes when they analyzed it by FTRI test. This finding could be explained as that the nanoparticles only changed the geometry of polymer network not the chemical properties of the liner. Moreover, the particle size of nanoparticles used in this study was (20 nm) which could cause no contribution in inter and intra macromolecular chains space. Thus, no separation of the chain and weakening of the force between them was observed.

Furthermore, due to the small size of nanoparticles used in this study obviously better fill in the space between chains and less tendency for aggregation will occur. Additionally, shear bond test was also evaluated after addition of nanoparticles to improve the short comes of soft liner properties. When control and modified samples where compared same results was observed as tensile test. Which indicating that nanoparticles did not change the mechanical properties and the addition of powder caused to difference in the samples bonding to acrylic. The results of the present study showed that tensile strength of soft liners to a denture base resin was higher than shear strength. These findings indicate that the adhesive interface was less resistant to shear loading than to tensile loading. It has been reported that the bonding between resilient lining materials and denture base materials is affected by aging in water, the nature of the denture base material and the temperature. Resilient denture liners immersed in water leach out plasticizers and absorb water. These two mechanisms affect the denture compliance and dimensional stability. The material becomes brittle and the external load is transferred to the interface (Najjar et al., 2021).

In the present study, the samples were placed in water for about 5 days before testing them. This outcome may be attributed to material's aging and water sorption at the interface between the soft liners and denture base material. The study by Dohiem et al. (2022) demonstrated that the decrease in bond strength may be attributed to swelling and stress concentration at the bonding interface or to changes in the viscoelatic properties of the lining material.

5. Conclusion

The results of the mechanical testing of soft lining materials are important and help determining which materials have the better resistance under tensile or shear loading. In general, it was observed that the mechanical properties of the liner underwent no degradation after addition of 5% MgONPs. However, when tensile deboning was compared with shear bond strength for all tested groups, the shear bond was decreased, indication that the soft liner cannot withstand shearing stress.

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