

# Investigating Tensile Bonding and Other Properties of Yttrium Oxide Nanoparticles Impregnated Heat-Cured Soft-Denture Lining Composite *In Vitro*

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Received : 21-09-21  
Revised : 06-11-21  
Accepted : 18-11-21  
Published : 29-01-22

**ABSTRACT** **Aims:** This study was conducted to assess the effect of the addition of yttrium oxide ( $Y_2O_3$ ) nanoparticles on the tensile bond strength, tear strength, shore A hardness, and surface roughness of soft-denture lining material. **Materials and Methods:**  $Y_2O_3$  NPs with 1.5 and 2 wt.% were added into acrylic-based heat-cured soft-denture liner. A total of 120 specimens were prepared and divided into four groups according to the test to be performed (tensile bond strength, tear strength, surface hardness, and surface roughness). **Results:** There was a highly significant increase in tensile bond strength between the soft liner and the acrylic denture base, tear strength, and hardness at both concentrations as compared to the control group, whereas there was a nonsignificant difference between 1.5wt% of  $Y_2O_3$  nanoparticles and the control group, and between 1.5wt% and 2wt% of  $Y_2O_3$  nanoparticles. But there was a significant difference between 2wt% of  $Y_2O_3$  nanoparticles and the control group. **Conclusion:** The  $Y_2O_3$  nanoparticles impregnated in soft-lining materials increased the mechanical properties of both tensile bonding strength and tear strength. Also, there was a significant increase in hardness but there was no change in surface roughness of acrylic-based denture soft-lining materials.

**KEYWORDS:** Hardness, soft-denture liner, tear strength, tensile bond strength, yttrium oxide nanoparticles

## INTRODUCTION

Resilient liners, which are layered between the denture base and oral mucosa, are composed of plasticized resins or silicone elastomers.<sup>[1]</sup> The resins are heat cured or auto-polymerized.<sup>[2]</sup> Long-term and short-term resilient liners have differences: long-term denture liners remain resilient for 30 days and up to 12 months, whereas short-term liners maintain their desirable properties for 7 days and up to 30 days.<sup>[3]</sup> Resilient denture liners are indicated for patients with sharp atrophied alveolar ridge, patients with thin oral mucosa who could not tolerate denture pressure and patients who have denture that causes pressing or indenture pressure mark.<sup>[4]</sup>

The main drawback of denture liners is the loss of durable bond to denture base material, because the detachment of the liners from denture base is a common clinical problem; a reliable bond between the soft liner and the denture base is required for optimal denture function.<sup>[5]</sup>

The common methods used to evaluate the bonding strength of denture soft liners to denture base materials include peel, shear, and tensile tests.<sup>[6]</sup> Tear resistance test evaluates the ability of material

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**How to cite this article:** Abdul-Baqi HJ, Safi IN, Nima Ahmad A, Fatalla AA. Investigating tensile bonding and other properties of yttrium oxide nanoparticles impregnated heat-cured soft-denture lining composite *in vitro*. J Int Soc Prevent Communit Dent 2022;12:93-99.

Access this article online	
<b>Quick Response Code:</b> 	<b>Website:</b> www.jispcd.org  <b>DOI:</b> 10.4103/jispcd.JISPCD_274_21

to resist tearing forces when subjected to a denture cleaning procedure.<sup>[7]</sup> The hardness test (shore A) is considered one of the nondestructive tests used to determine whether a resilient material can be used as a liner; this test evaluates the reaction force of a tested material to indentation.<sup>[8]</sup> Surface roughness can be an influence of the adhesion of microorganisms; a rougher surface indicates a higher biofilm accumulation.<sup>[9]</sup> Yttrium oxide ( $Y_2O_3$ ) nanoparticles (NPs) are a highly insoluble, thermally stable, and air-stable substance with good chemical stability, resistivity, and breakdown strength.<sup>[10]</sup>

This study aimed to evaluate the mechanical and surface properties of liner materials, namely, tensile bond strength, tear strength, shore A hardness, and surface roughness, after impregnation with  $Y_2O_3$  NPs.

The null hypothesis states that  $Y_2O_3$  NPs do not affect the mechanical and surface properties of denture liners compared with the control group.

## MATERIALS AND METHODS

A pilot study that involves tensile bond strength and surface roughness tests using four  $Y_2O_3$  NPs concentrations (1, 1.5, 2, and 2.5 wt%) was conducted. The  $Y_2O_3$  NPs concentrations of 1.5 and 2 wt.% were chosen because they revealed favorable improvements in tensile strength without affecting the surface properties of the soft-lining materials.

Composites of the soft-lining materials (Vertex Soft, Vertex Dental, Netherlands) and  $Y_2O_3$  NPs (US Research Nanomaterials, Houston, TX, USA) were prepared by adding the measured nano- $Y_2O_3$  to monomers. A probe sonication apparatus (Soniprep 150, Highland, UK; 120 W, 60kHz) was used for 3 min to achieve a good distribution of NPs within the monomer. The monomer with  $Y_2O_3$  NPs was immediately mixed with soft-lining powder to minimize the chance of particle aggregation.

Fourier-transform infrared spectroscopy (FTIR) (Tensor 27, München, Germany) was performed to investigate the chemical interaction between  $Y_2O_3$  NPs and poly(ethyl methacrylate) (PEMA).

Scanning electron microscopy (SEM) (AIS2300, Anestron Advanced, Peabody, MA, USA) was performed to investigate the dispersion of  $Y_2O_3$  NPs within the matrix of PEMA, and energy-dispersive spectrum (EDS) was performed to obtain the atomic and weight percentages of the composition of the nanocomposite.

The tested specimens were fabricated to assess tensile bonding strength (10 specimens for the control group and 10 specimens each for the liners with 1.5 and 2.5

wt.%  $Y_2O_3$  NPs). Bond strength was tested using a universal testing machine (WDW-20, Larger Technology Co., Ltd., Quanzhou, China) with a crosshead speed of 5 mm/min. The maximum load needed for failure was registered to determine the bond strength of the specimens. The following equation was applied:

$$\text{Bond strength (N/mm}^2\text{)} = F/A,$$

where  $F$  is the maximum load at failure (N) and  $A$  is the cross-sectional area of the sample ( $\text{mm}^2$ ).<sup>[11]</sup>

Acrylic blocks 10 mm  $\times$  10 mm  $\times$  83 mm width, depth, and length, respectively, were prepared according to the manufacturer's instructions. Then, the acrylic blocks were positioned in the mold with 3 mm space in between blocks to be filled with the required amount of soft-lining materials, which were cured according to the manufacturer's instructions.

Thirty testing specimens were prepared according to the literature to test the tear strength.<sup>[12]</sup> A universal testing machine with a crosshead speed of 500 mm/min was used to measure the force per unit thickness needed to tear initiation. Tear strength was determined as follows:

$$\text{Tear strength} = F/D,$$

where  $F$  is the maximum force required to the break sample (N) and  $D$  is the medium thickness of each sample (mm).

Thirty specimens with 3 mm thickness and 30 mm diameter were prepared for shore A hardness testing. All specimens were immersed in distilled water and kept in an incubator for 48 h at 37°C before testing. A shore A durometer (Time Instruments TH200, Shandong, China) was used to evaluate the hardness of the lining materials. Five readings were performed for each sample. The contact time was 5 s following each penetration, and the average was considered the test value.

Thirty specimens (65 mm  $\times$  10 mm  $\times$  2.5 mm) were prepared for roughness testing. The specimens were immersed in distilled water for 24 h at 37°C before testing. A profilometer device (TIME, TIME3200/3202 (TR200), Shandong, China) was used. Three measurements were performed for each sample, and the average value was calculated.

The results were statistically analyzed by interpreting the mean, standard deviation, and bar chart plotting; in addition to one-way analysis of variance (ANOVA) table with multiple-comparison Bonferroni's test applied.

## RESULTS

The FTIR results revealed that  $Y_2O_3$  NPs (1.5 and 2 wt.%) and the acrylic soft-denture lining materials had no chemical interaction or reaction [Figure 1].

The SEM images of the control and experimental groups reveal a uniform distribution of  $Y_2O_3$  NPs within the matrix [Figure 2].

The EDS diagram indicates the incorporation of  $Y_2O_3$  NPs into the matrix of the soft-lining materials, as shown in Figure 3.

Tensile bonding strength increased with the addition of 1.5 and 2 wt.%  $Y_2O_3$  NPs compared with the control group. One-way ANOVA table revealed a highly remarkable difference among control and experimental groups, with multiple-comparison analysis by Bonferroni test the experimental groups and the control revealed highly significant differences ( $P < 0.05$ ), but no substantial difference was found between both experimental groups ( $P > 0.05$ ) as shown in Figure 4.

Figure 5 shows that the addition of  $Y_2O_3$  NPs (1.5 and 2 wt.%) substantially increased the tear strength of the

liner compared with the control group. ANOVA table revealed a significant difference ( $P = 0.002$ ). Multiple-comparison test by Bonferroni shows significant differences between control group and 2wt.% experimental group ( $P < 0.05$ ).

The liner with 2 wt.%  $Y_2O_3$  NPs showed the greatest mean surface hardness value among the tested liners, as shown in Figure 6. The hardness of the liners with 1.5 and 2 wt.%  $Y_2O_3$  NPs had a considerably higher hardness value than the control group. ANOVA table shows a significant difference ( $P < 0.001$ ). Bonferroni's multiple-comparison test revealed that similar results obtained with tensile bond strength applied for the surface hardness test.

The liner with a higher  $Y_2O_3$  NPs concentration (2 wt.%) had a higher roughness value than the other liners. Its surface roughness was remarkably different compared with that of the control but was not remarkably different compared with the liner with 1.5 wt.%  $Y_2O_3$  NPs. ANOVA table revealed that highly significant differences among all groups further multiple comparisons by Bonferroni's test show that

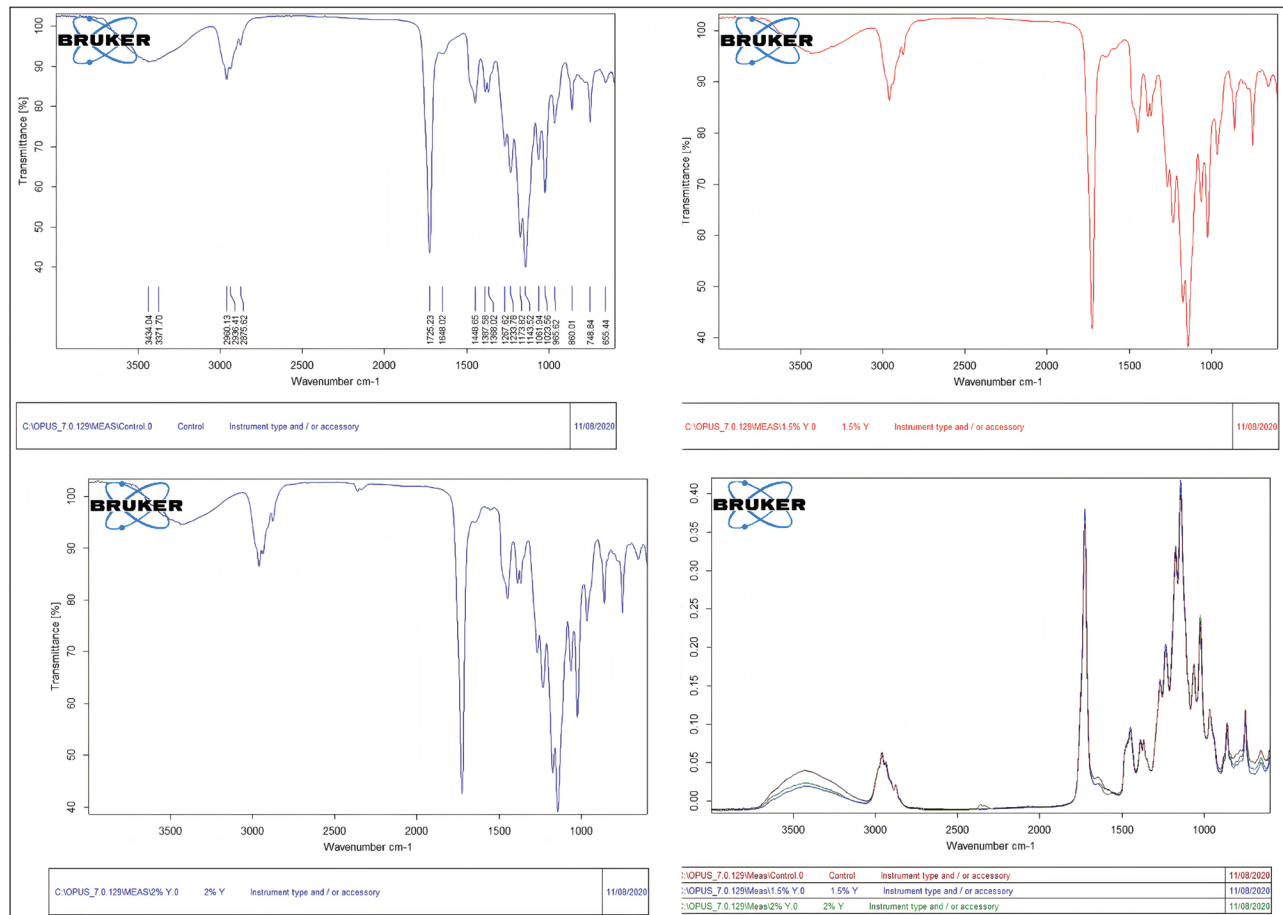
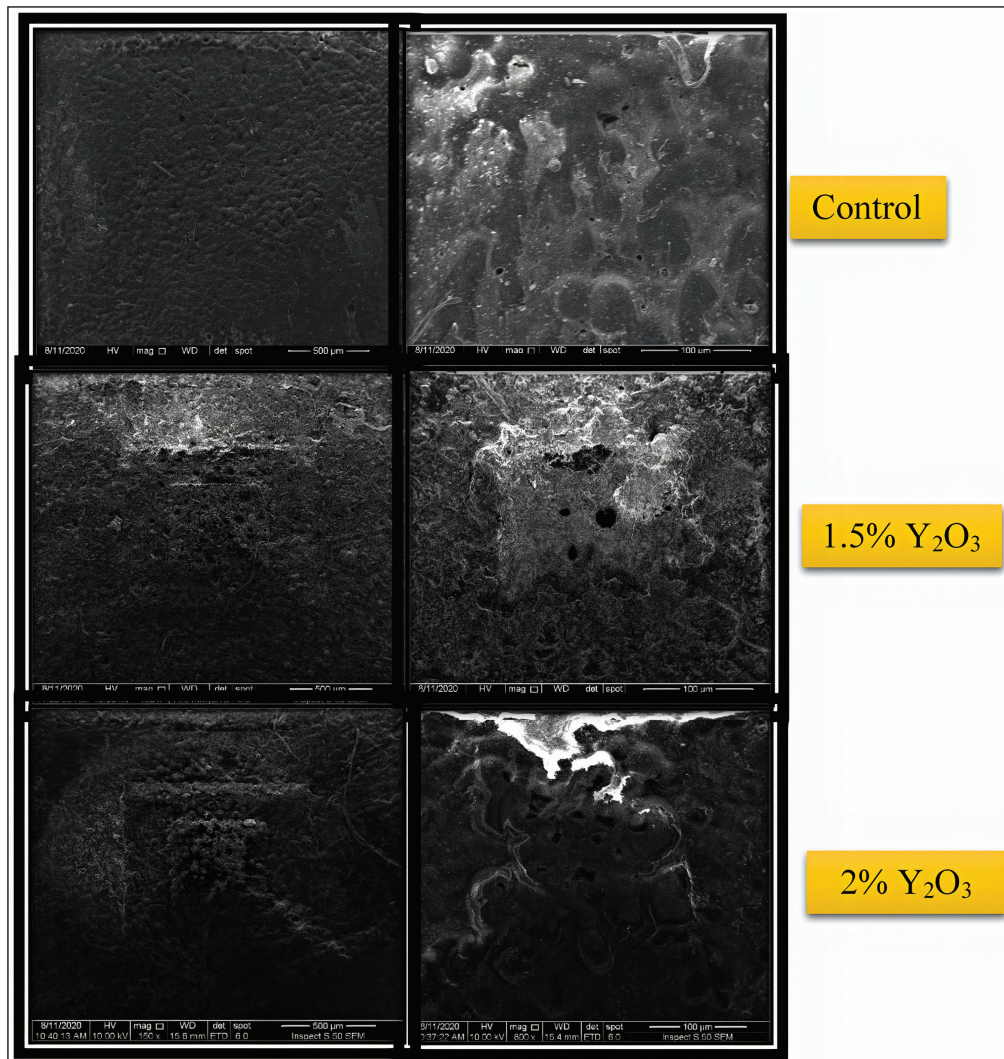


Figure 1: Fourier-transform infrared spectroscopy (FTIR) analysis





**Figure 2:** Scanning electron microscopy (SEM) analysis

similar results of tensile bond strength and surface hardness test [Figure 7].

## DISCUSSION

The effect of  $Y_2O_3$  modification on the mechanical and surface properties of soft, acrylic-based denture lining materials was investigated. Denture liners are supposed to increase patients' denture acceptance throughout functional stress distribution. Many problems are correlated to soft liners, such as poor bond strength to denture base and poor tearing strength.<sup>[13]</sup>

Soft-denture lining materials should have excellent adhesion to the denture base, because failure of adhesion could lead to functional and hygienic problems.<sup>[14]</sup> Bond adhesion to denture base was remarkably improved by the incorporation of 1.5 and 2 wt.%  $Y_2O_3$  NPs, which could be attributed to the van der Waals force between nanofillers and the polymer.<sup>[15]</sup>

According to Jacobsen *et al.*,<sup>[16]</sup> the penetration of soft-lining materials is inversely proportional to the viscosity of liners. This relationship could explain the influence of  $Y_2O_3$  NPs on the flowability of lining materials. The increase in stiffness will permit the easy adaptation of the lining materials to the denture base and provide good contact for the molecules of chemically similar polymers across the interface with acrylic resin.<sup>[17,18]</sup>

The highly remarkable increase in the durability and marginal integrity of lining materials with the addition of 1.5 and 2 wt.%  $Y_2O_3$  NPs may be attributed to the interfacial bonding by the formation of van der Waals forces between nanofillers and the polymer, which increase the resistance of polymer chains to rupture under tearing forces.<sup>[15]</sup> When tearing is propagated, nanofillers inside the polymer matrix scatter the strain energy near the tips of the growing cracks; therefore,

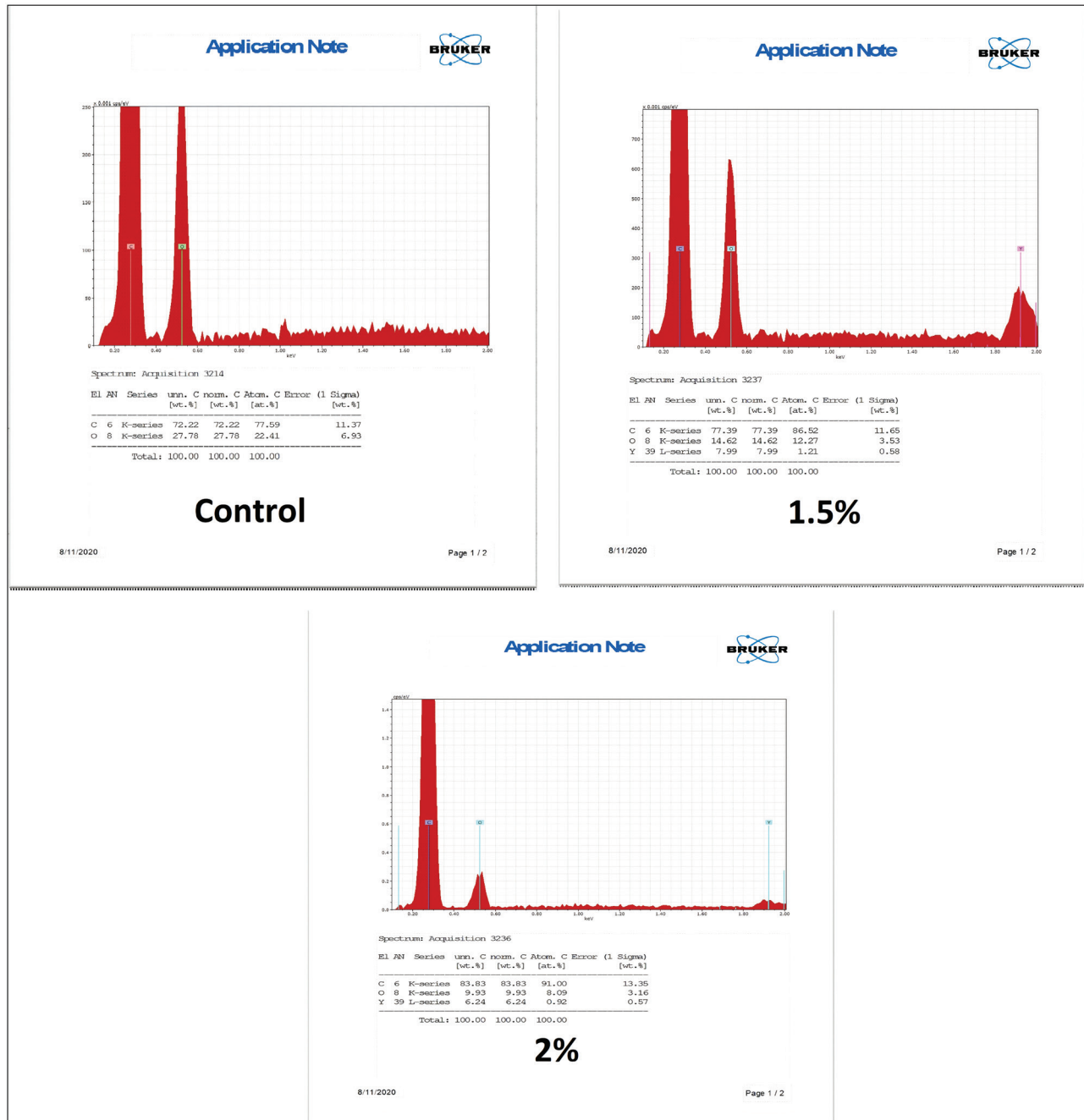


Figure 3: Energy-dispersive spectrum (EDS) analysis

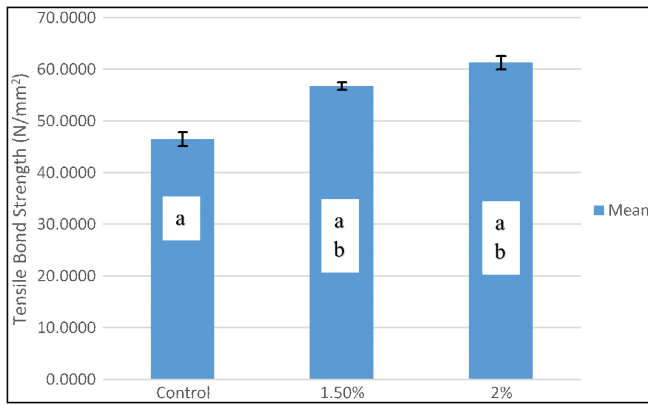
a large force will be required to break the polymer matrix.<sup>[19]</sup>

The remarkable increase in tear strength was directly proportional to the nanofiller concentration because the fine size of the fillers produced a greater interfacial bonding along with good dispersion and homogeneity in the bonds.<sup>[20,21]</sup>

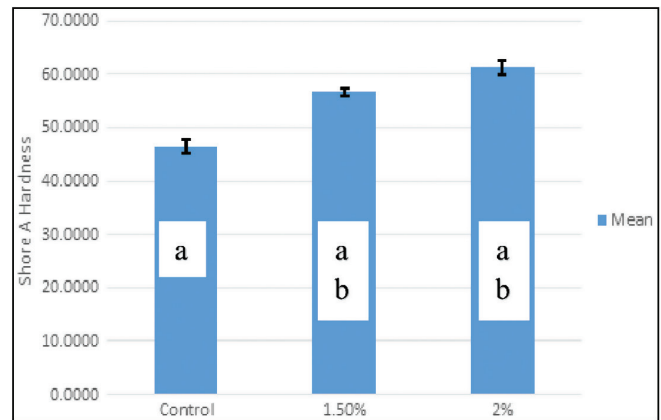
One of the most important properties of soft-denture lining materials is hardness because it lessens the impact of absorption.<sup>[22,23]</sup> In this study,  $Y_2O_3$  NP

concentration was directly proportional to the hardness of the liner. The increase in hardness may be attributed to the NP distribution within the matrix. A decrease in interparticle distance with the increase in the bonding strength between particles makes the particles cluster together within the spaces of the soft-lining matrix and subsequently leads to an increase in hardness.<sup>[8,24-26]</sup>

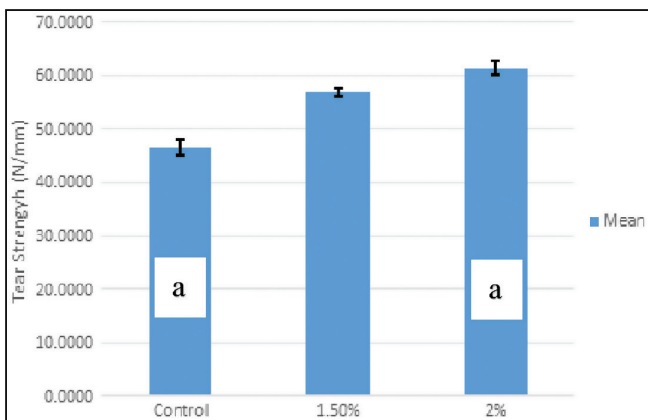
Surface roughness is an important characteristic of denture lining materials because it affects the adhesion of microorganisms and the development of pathogenic



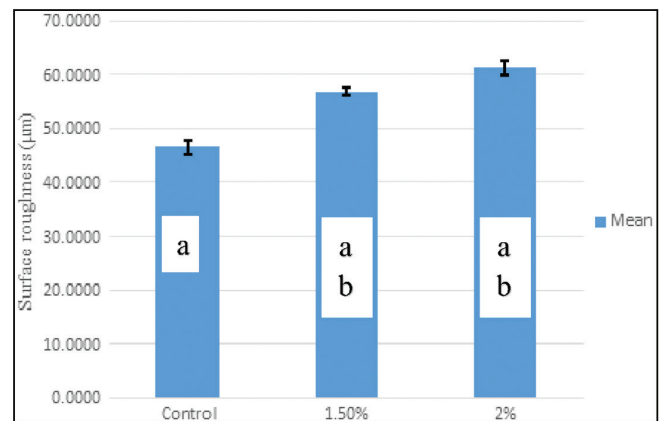
**Figure 4:** Bar chart representation for tensile bonding strength test for all groups (bars with similar letters represent a significant difference when  $P < 0.05$ )



**Figure 6:** Bar chart representation for shore A hardness test for all groups (bars with similar letters represent a significant difference when  $P < 0.05$ )



**Figure 5:** Bar chart representation for tear strength test for all groups (bars with similar letters represent a significant difference when  $P < 0.05$ )



**Figure 7:** Bar chart representation for surface roughness test for all groups (bars with similar letters represent a significant difference when  $P < 0.05$ )

diseases, such as denture stomatitis, as a result of interference with proper oral hygiene maintenance.<sup>[8,25-27]</sup>

In this study, the addition of  $Y_2O_3$  NP resulted in an unremarkable increase in surface roughness. The small concentration of  $Y_2O_3$  NPs impregnated in the soft liners resulted in the good dispersion of NPs within matrix and caused a nonsubstantial increase in surface roughness.<sup>[21,28,29]</sup>

## CONCLUSION

Within the limitations of this study, it is concluded that the addition of  $Y_2O_3$  NPs into the soft-lining materials increased the tensile bond strength, tear strength, and hardness but not the surface roughness of soft, acrylic-based denture lining materials.

## RESEARCH APPLICABILITY

According to the obtained results, the characterizations and properties of prepared heat-cured soft-denture lining composite make it suitable and applicable

to clinical practice as modified soft-denture lining material.

## RESEARCH LIMITATION

This study did not investigate the biological test. Any researcher cannot gamble and introduce modified material depending on testing mechanical or physical properties. A plan should be applied for testing the biological properties to support the results of our study.

## ACKNOWLEDGMENT

Nil.

## FINANCIAL SUPPORT AND SPONSORSHIP

Nil.

## CONFLICTS OF INTEREST

There are no conflicts of interest.



**AUTHORS CONTRIBUTIONS**

Authors equally contributed to the paper.

**ETHICAL POLICY AND INSTITUTIONAL REVIEW BOARD STATEMENT**

Not applicable.

**PATIENT DECLARATION OF CONSENT**

Not applicable.

**DATA AVAILABILITY STATEMENT**

The data that support the study results are available from the corresponding author (Prof. Dr. Abdalbaseet A Fatalla, e-mail: abdalbasit@codental.uobaghdad.edu.iq) on request.

**REFERENCES**

1. Hashem MI. Advances in soft denture liners: An update. *J Contemp Dent Pract* 2015;16:314-8.
2. Chladek G, Źmudzki J, Kasperski J. Long-term soft denture lining materials. *Materials (Basel)* 2014;7:5816-42.
3. Kreve S, Dos Reis AC. Denture liners: A systematic review relative to adhesion and mechanical properties. *Sci World J* 2019;2019:6913080.
4. Kawano F, Dootz ER, Koran A 3rd, Craig RG. Comparison of bond strength of six soft denture liners to denture base resin. *J Prosthet Dent* 1992;68:368-71.
5. Mohad A, Fatalla AA. The effectiveness of aluminum potassium sulfate micro-particles addition into soft denture lining material on tensile strength and peel bond strength of soft denture lining material. *J Bagh Coll Dent* 2019;31:51-8.
6. Naik AV, Jabade JL. Comparison of tensile bond strength of resilient soft liners to denture base resins. *J Indian Prosthodont Soc* 2005;5:86.
7. Oguz S, Mutluay MM, Dogan OM, Bek B. Effect of thermocycling on tensile strength and tear resistance of four soft denture liners. *Dent Mater J* 2007;26:296-302.
8. Herla M, Boening K, Meissner H, Walczak K. Mechanical and surface properties of resilient denture liners modified with chitosan salts. *Materials* 2019;12:3518.
9. Abuzar MA, Bellur S, Duong N, Kim BB, Lu P, Palfreyman N, *et al.* Evaluating surface roughness of a polyamide denture base material in comparison with poly (methyl methacrylate). *J Oral Sci* 2010;52:577-81.
10. Jollet F, Noguera C, Thromat N, Gautier M, Duraud JP. Electronic structure of yttrium oxide. *Phys Rev B Condens Matter* 1990;42:7587-95.
11. American Society for Testing and Materials (ASTM). Standard test method for tensile properties of plastics. Designation D882-01. In: *Annual Book of ASTM Standards*. Philadelphia, PA: ASTM; 1986.
12. ASTM International. Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers. West Conshohocken, PA: ASTM International; 2012.
13. Tugut F, Akin H, Mutaf B, Akin GE, Ozdemir AK. Strength of the bond between a silicone lining material and denture resin after er:Yag laser treatments with different pulse durations and levels of energy. *Lasers Med Sci* 2012;27:281-5.
14. Gundogdu M, Yesil Duymus Z, Alkurt M. Effect of surface treatments on the bond strength of soft denture lining materials to an acrylic resin denture base. *J Prosthet Dent* 2014;112:964-71.
15. Sun L, Gibson RF, Gordaninejad F, Suhr J. Energy absorption capability of nanocomposites: A review. *Compos Sci Technol* 2009;69:2392-409.
16. Jacobsen NL, Mitchell DL, Johnson DL, Holt RA. Lased and sandblasted denture base surface preparations affecting resilient liner bonding. *J Prosthet Dent* 1997;78:153-8.
17. Tugut F, Coskun ME, Dogan DO, Kirmali O, Akin H. Tensile bond strength between soft liners and two chemically different denture base materials: Effect of thermocycling. *J Prosthodont* 2016;25:319-23.
18. Lassila LV, Mutluay MM, Tezvergil-Mutluay A, Vallittu PK. Bond strength of soft liners to fiber-reinforced denture-base resin. *J Prosthodont* 2010;19:620-4.
19. Shakir DA, Abdul-Ameer FM. Effect of nano-titanium oxide addition on some mechanical properties of silicone elastomers for maxillofacial prostheses. *J Taibah Univ Med Sci* 2018;13:281-90.
20. Mishra S, Shimpi NG. Studies on mechanical, thermal, and flame retarding properties of polybutadiene rubber (PBR) nanocomposites. *Polym Plast Technol Eng* 2007;47:72-81.
21. Hasan WY, Ali MM. Evaluation of thermal conductivity and some other properties of heat cured denture soft liner reinforced by halloysite nanotubes. *Biomed Pharm J* 2018;11:1491-500.
22. Pisani MX, da Silva CH, Paranhos HF, Souza RF, Macedo AP. Evaluation of experimental cleanser solution of *Ricinus communis*: Effect on soft denture liner properties. *Gerodontology* 2012;29:e179-85.
23. Huddar DA, Hombesh MN, Sandhyarani B, Chandu GS, Nanjannawar GS, Shetty R. Effect of denture cleanser on weight, surface roughness and tensile bond strength of two resilient denture liners. *J Contemp Dent Pract* 2012;13:607-11.
24. Haider YM, Abdullah ZS, Fatalla AA, Jani GH, Mokhtar N. Corrigendum to "evaluation of some mechanical properties of a maxillofacial silicon elastomer reinforced with polyester powder". *Int J Dent* 2020;2020:7187159.
25. Urban VM, Lima TF, Bueno MG, Giannini M, Arioli Filho JN, de Almeida AL, *et al.* Effect of the addition of antimicrobial agents on shore A hardness and roughness of soft lining materials. *J Prosthodont* 2015;24:207-14.
26. Fatalla A, Husham G, Abdullah Z. The effect of addition of combination of plasma treated polyester and polyamide fibers on surface roughness and some mechanical properties of heat cured acrylic resin. *J Bagh Coll Dent* 2018;30:12-6.
27. Yankova M, Yordanov B, Dimova-Gabrovska M, Apostolov N. Resilient lining materials for removable dentures: Types, composition and technology. *J IMAB-Ann Proc Sci Pap* 2019;25:2632-9.
28. Kreve S, Oliveira VC, Bachmann L, Alves OL, Dos Reis AC. Influence of AgVO<sub>3</sub> incorporation on antimicrobial properties, hardness, roughness and adhesion of a soft denture liner. *Sci Rep* 2019;9:1-9.
29. Keskin S, Usanmaz A. Hydroxylterminated poly (urethane acrylate) as a soft liner in dental applications: Synthesis and characterization. *J Appl Polym Sci* 2010;117:458-66.