Dentistry 3000

Vol 14, No 2 (2026)
ISSN 2167-8677 (online)
DOI 10.5195/d3000/2026.1446

Addition of Silver-Zinc-Potassium Polyacrylate into Polymethyl-methacrylate Dentures

Yas Mohammed Musadaq[1], Abdulrahman Taha Elbaram[2], Hassan T.S. Shatub[3], Rihab Amer Kareem[1], Ahmed Ghaith Ahmed[1]
[1]*College of Dentistry, Ibn Sina University, Iraq*
[2]*Dijlah University, Iraq*
[3]*Al-Hikma University College, Iraq*

Open Access
Citation: Musadaq YM et al. (2026) Addition of Silver-Zinc-Potassium Polyacrylate into Polymethyl-methacrylate Dentures. Dentistry 3000. 1:a001 doi:10.5195/d3000.2026.1446
Received: June 12, 2026
Accepted: June 14, 2026
Published: July 22, 2026

Email: rihab.amer@ibnsina.edu.iq

Abstract

The study was undertaken to assess the effect of addition of a silver–zinc–potassium polyacrylate (Ag–Zn–KPA) composite filler to PMMA denture base materials on their mechanical properties, antimicrobial activity and water sorption behavior. Specimens of PMMA were modified with different concentrations (0%, 1%, 2.5% and 5 wt%) of Ag–Zn–KPA composite. Flexural strength, impact resistance, surface hardness and water sorption tests according to ISO 20795-1 standards were performed for mechanical performance characterization. Antimicrobial activity was assessed by colony-forming unit (CFU) counts and inhibition zone against Candida albicans and Streptococcus mutans. Statistical comparisons were conducted with one-way ANOVA and Tukey post-hoc tests ($\alpha = 0.05$). The incorporation of Ag–Zn–KPA exhibited significantly higher flexural strength and surface. hardness and higher antibacterial activity than PMMA resin ($p < 0.05$). The 2.5 wt% formulation provided the best combination of enhanced mechanical performance with controlled water sorption. The Ag–Zn–KPA-modi fi ed PMMA revealed a promising multifunctionality, showing mechanical durability, antimicrobial resistance and functional water retention. This composite system could represent an interesting and potentially clinically relevant improvement of denture base materials.

Introduction

Polymethyl methacrylate (PMMA) has been the material of choice for removable denture bases for several decades due to its acceptable esthetics, favorable processing properties, and cost effectiveness. However, despite these benefits, PMMA possesses intrinsic disadvantages such as low flexural and impact strength, fatigue failure susceptibility and rapid microbial adhesion and biofilm formation on its surface. These drawbacks can jeopardize prosthesis durability and result in various oral inflammatory conditions like denture stomatitis [1]. The inherent absence of antimicrobial properties, water sorption and surface roughness significantly affect microbial colonization on PMMA surfaces. The adhesion of Candida albicans and oral streptococci to acrylic resin dentures is a known phenomenon and continues to be an important clinical problem, especially in elderly or immunocompromised patients [2]. Thus, various strategies involving material modification have been designed to address these drawbacks [3]. PMMA reinforcement based on nanotechnology has been proposed as a viable solution [3,4]. Silver nanoparticles (AgNPs) have exhibited broad-spectrum antimicrobial activity which might be through ion release, lipoperoxidation and nucleic acid replication interference [5,6]. ZnO accused of metal and metal oxide antimicrobial effectiveness, as well as their reinforcing activity together with satisfactory esthetic properties (i.e. ZnO discussed in more detail below due to white opaque structure) [3,7]. At the same time, there has been some focus on functional polymers which include potassium polyacrylate for their super absorbent and moisture absorbing–retaining–releasing properties [8]. Such polymers can also be infused in denture bases for sufficient hydration of the mucosa and increased patient comfort, particularly in patients with xerostomia [9]. However, increased water sorption can negatively affect the dimensional stability and mechanical properties of polymers 50565 which requires optimal formulation for the hybrid organic-

Vol 14, No 2 (2026) DOI 10.5195/d3000/2026.1446

inorganic polymer to be effective. Previous investigations by Kareem and colleagues demonstrated the feasibility of incorporating composite fillers and nano-scale additives into dental materials to improve mechanical performance and biological behavior [10,11]. Building on these findings, the present study integrates silver and zinc ions within a potassium polyacrylate matrix and evaluates its effect when incorporated into PMMA denture base materials.
The aim of this study was to evaluate the mechanical, antimicrobial and water sorption properties of silver–zinc–potassium polyacrylate composite modified PMMA denture base materials.

Materials and Methodos

Commercial heat-cured polymethyl methacrylate resin was utilized as a base material. Synthesis and ion loading of potassium polyacrylate using silver nitrate, zinc acetate, acrylic acid monomer, potassium hydroxide, ammonium persulfate and N,N-methylenebisacrylamide.
Potassium polyacrylate was prepared by free-radical polymerization of potassium hydroxide-neutralized acrylic acid. The reaction mixture was cross-linked with N,N-methylenebisacrylamide and initiated by ammonium persulfate at controlled thermal conditions. The hydrogel produced was washed and dried to get the fine granules of polymer.
Soaking of the hydrated potassium polyacrylate hydrogel was performed in aqueous solutions of $AgNO_3$ and $Zn(CH_3COO)_2$ to absorb the ions. The composite was completely rinsed and dried in a vacuum oven for 24 h to afford the Ag–Zn–KPA powder.
PMMA was separated into four subgroups: control (0%), 1%, 2.5% and 5 wt% Ag–Zn–KPA. The powder was homogeneous mixed with PMMA polymer powder before the addition of a monomer. The specimens were processed within the same conventional heat-curing cycle and kept in distilled water at 37°C for 48 hours before performing testing.
Three-point bending test was conducted for the determination of flexural strength. Resistance to impact, hardness of surface, and water sorption were tested as per ISO 20795-1 specifications.
Antifungal disc-shaped samples were tested against Candida albicans and Streptococcus mutans. The antimicrobial effectiveness was evaluated by employing CFU reduction and inhibition zones.
Data were analyzed by one-way ANOVA followed by Tukey post-hoc tests. Statistical significance level was given at $p < 0.05$.

Results

The study's findings showed that the significance of mechanical behavior, antimicrobial performance and water sorption characteristics was associated with Ag–Zn–KPA preparation in PMMA denture base materials. Depending on the quantity of included composite filler, these consequences were varied.
Table 1. Flexural strength of PMMA/Ag–Zn–KPA composites.

Group	Ag–Zn–KPA (wt%)	Flexural Strength (MPa)
Control	0%	82.4 ± 3.1
Group B	1%	91.6 ± 2.8
Group C	2.5%	99.2 ± 3.4
Group D	5%	94.8 ± 3.9

The values for flexural strength (Table 1) indicated a statistically significant difference in all the Ag–Zn–KPA-modified groups when compared to the control PMMA ($p < 0.05$). Increasing filler% above 2.5 wt% shows a decrease in flexural strength due to the poor dispersion within PMMA matrix, as overloading prevents full integration of the filler and matrix as well reducing flexibility of polymer. The 5 wt% group exhibited higher values than the control yet slightly decreased compared to the other two at 2.5 wt%, possibly due to particle agglomeration at higher filler loadings.
Table 2. Elastic modulus of PMMA/Ag–Zn–KPA composites.

Group	Ag–Zn–KPA (wt%)	Elastic Modulus (GPa)
Control	0%	2.10 ± 0.15
Group B	1%	2.38 ± 0.12
Group C	2.5%	2.71 ± 0.18
Group D	5%	2.53 ± 0.21

The trend of elastic modulus (Table 2) was like that of flexural strength, where it increased dramatically up to 2.5 wt% Ag–Zn–KPA content. The composites with this modification show improved rigidity and load-bearing characteristics more than pure PMMA.
Table 3. Impact strength of PMMA/Ag–Zn–KPA composites.

Group	Ag–Zn–KPA (wt%)	Impact Strength (kJ/m²)
Control	0%	6.4 ± 0.6
Group B	1%	7.8 ± 0.5
Group C	2.5%	9.1 ± 0.7
Group D	5%	8.3 ± 0.8

Impact strength (Table 3) was significantly improved compared with unmodified PMMA for all modified groups ($p < 0.05$). Of the samples tested, the 2.5 wt% group showed the highest resistance to a sudden load applied by impact, suggesting high effectiveness of energy dissipation throughout the composite structure.
Table 4. Vickers surface hardness of PMMA/Ag–Zn–KPA composites.

Group	Ag–Zn–KPA (wt%)	Vickers Hardness (HV)
Control	0%	18.6 ± 1.2
Group B	1%	21.9 ± 1.4
Group C	2.5%	24.7 ± 1.6
Group D	5%	25.1 ± 1.9

Vol 14, No 2 (2026) DOI 10.5195/d3000/2026.1446

The increase in Ag–Zn–KPA concentration progressively increased surface hardness (Table 4). The significantly higher hardness values indicate superior resistance to surface wear and abrasion, thus more clinically relevant concerning denture maintenance in long-term usage.

Table 5. Water sorption of PMMA/Ag–Zn–KPA composites.

Group	Ag–Zn–KPA (wt%)	Water Sorption (μg/mm³)
Control	0%	21.3 ± 1.2
Group B	1%	23.1 ± 1.4
Group C	2.5%	25.7 ± 1.6
Group D	5%	31.4 ± 2.1

The amounts of water sorption (Table 5) increased in a dependent manner as the concentration of Ag–Zn–KPA was increased. Although 5 wt% group caused the highest water gain, 1 and 2.5 wt% groups gave values in clinically acceptable ranges. Without causing dimensional dislocation, the moderate water absorption at 2.5 wt% could be favorable to keep up sufficiency of surface hydration in denture–mucosa interface.

Table 6. CFU% reduction.

Group	*Candida albicans* (%)	*Streptococcus mutans* (%)
Control	0	0
Group B (1%)	45 ± 6	39 ± 5
Group C (2.5%)	72 ± 7	68 ± 6
Group D (5%)	78 ± 8	74 ± 7

All Ag–Zn–KPA-modified PMMA samples shown statistically significant antimicrobial effect compared with the control group ($p < 0.001$) (Table 6). The 5 wt% showed the highest reduction for all microbial counts; nevertheless, the antimicrobial efficacy of the 2.5 wt% group with superior mechanical balance can be used as found in this study.

In conclusion, the addition of Ag–Zn–KPA to PMMA denture base materials led to:

• Incredible enhancement in flexural and impact strength

• Enhanced hardness and stiffness on the surface

• Concentration-dependent antimicrobial activity

• Development of gradual water sorption at medium filler levels

In all the concentration of Ag–Zn–KPA mixture, 2.5 wt% ag–zn–kpa formulation showed consistently positive synergy in mechanical performance, antimicrobial activity and functional water holding capacity.

Discussion

Determining flexural strength is one of the most significant mechanical properties for denture base materials, given that dentures undergo complicated bending stresses during mastication and parafunctional activities [1,3,7]. In the present study, the addition of Ag–Zn–KPA has significantly improved flexural strength and elastic modulus ($p < 0.05$) for all three experimental groups in relative to non-modified PMMA with the highest values obtained at 2.5 wt% concentration.

Impact strength is the used restriction of denture base material when living under shock forces, such as accidental dropping of dentures or extreme occlusal loading are done [1,10]. The current finding showed significant improvements in impact strength for all Ag–Zn–KPA-modified groups as compared to control PMMA and the 2.5 wt% group again demonstrated optimal result.

Clinically, enhanced impact strength is significant because denture fracture continues to be one of the most prevalent reasons for prosthetic failure, especially among older patients and those with compromised neuromuscular control [12,13].

Surface hardness has a close association with wear resistance, surface integrity as well as long-term esthetic stability of denture bases [14]. The Vickers hardness values gradually increased with an increase in Ag–Zn–KPA concentration, thus demonstrating their ability for better resistance to indentation and abrasion on the surface of the composite.

One finding of this research is the ability to provide mechanical reinforcement while providing integrated activity without compromising performance. Addition of antimicrobial agents into PMMA has traditionally associated with a decline in mechanical properties [14]. In contrast, application of optimized concentration from present composite system at suitable concentration augmented strength and toughness along with bioactivity.

Conclusion

As per the findings of this in vitro study as a limitation, the inclusion of silver–zinc–potassium polyacrylate within PMMA denture base materials improved both mechanical strength and antibacterial activity. Thus, 2.5 wt% presented the best balance of performance and water sorption indicating that this formulation may be suitable for clinical use.

Study Limitations

In this in vitro study, evaluation and not accounting for long-term thermal cycling, fatigue loading, or in vivo biological responses. Future studies should include clinical trials, and long-term aging simulations.

References

1. Zafar, M. S. (2020). Prosthodontic applications of polymethyl methacrylate (PMMA): An update. *Polymers, 12*(10), 2299. https://doi.org/10.3390/polym12102299

2. Kareem, R. A., & Naji, G. A.-H. (2021). Preparation and characterization of natural rice husk-derived silica and eggshell-derived calcium carbonate composite as a coating material. *Pakistan Journal of Medical and Health Sciences, 15*(1), 237–240.

3. Matijaković Mlinarić N, Zore A, Veselinović V, Dolić O, Trtić N, Štukelj R, et al. Antimicrobial activity of poly(methyl methacrylate) doped with CuO and ZnO nanoparticles. ACS Omega. 2025;10(13):13060–13072. doi:10.1021/acsomega.4c10170.

4. Gligorijević N, Mihajlov-Krstev T, Kostić M, Nikolić L, Stanković N, Nikolić V, et al. Antimicrobial properties of silver-modified denture base resins. Nanomaterials (Basel). 2022;12(14):2453. doi:10.3390/nano12142453.

5. Long YM, Hu LG, Yan XT, Zhao XC, Zhou QF, Cai Y, et al. Surface ligand controls silver ion release of nanosilver and its antibacterial activity against Escherichia coli. Int J Nanomedicine. 2017;12:3193–3206. doi:10.2147/IJN.S132327.

6. Adeyemi OS, Shittu EO, Akpor OB, Rotimi D, Batiha GES. Silver nanoparticles restrict microbial growth by promoting oxidative stress and DNA damage. EXCLI J. 2020;19:492–500. doi:10.17179/excli2020-1244.

7. Vikram S, Chander NG. Effect of zinc oxide nanoparticles on the flexural strength of polymethylmethacrylate denture base resin. Eur Oral Res. 2020;54(1):31–35. doi:10.26650/eor.20200063.

8. Szemők GE, Balázs L, Tarnawa Á, Klátyik S, Kovács GP, Kende Z. Effects of superabsorbent

polymers on growth and pigment allocation in Chlorella vulgaris. Plants. 2025;14(19):2962. doi:10.3390/plants14192962 .

9. Łysik D, Niewęgłowska J, Mystkowska J. From salivary dysfunction to prosthetic challenges in xerostomia and denture retention with oral gels. Materials. 2025;18(13):3141. doi:10.3390/ma18133141.

10. Kareem S, Moudhaffer M. The effect of zirconium silicate nanopowder reinforcement on some mechanical and physical properties of heat-cured poly(methyl methacrylate) denture base materials. J Bagh Coll Dent. 2015;27(4):37–43.

11. Noori AJ, Kareem FA. The effect of magnesium oxide nanoparticles on the antibacterial and antibiofilm properties of glass-ionomer cement. Heliyon. 2019;5(10):e02568. doi:10.1016/j.heliyon.2019.e02568.

12. Iwasaki M, Iida T, Ishii Y, Yamakawa Y, Honda-Sakaki M, Iwata Y, et al. Effects of reinforcement materials and mechanical retention on the flexural strength and deflection of repaired denture base resin. Cureus. 2025;17(11):e97722. doi:10.7759/cureus.97722.

13. Haralur SB. Clinical strategies for complete denture rehabilitation in a patient with Parkinson disease and reduced neuromuscular control. Case Rep Dent. 2015;2015:352878. doi:10.1155/2015/352878.

14. Alqutaibi AY, Baik A, Almuzaini SA, Farghal AE, Alnazzawi AA, Borzangy S, et al. Polymeric denture base materials: a review. Polymers (Basel). 2023;15(15):3258. doi:10.3390/polym15153258.