RESEARCH ARTICLE

Evaluation of flexural and impact strength of heat-cured poly methyl methacrylate and vertex resins after immersion in different disinfection solutions

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Abstract

Objective: To evaluate the flexural and impact strength of heat-cured polymethyl methacrylate and vertex resins after disinfection with alkaline peroxide and sodium hypochlorite solution.

Method: The in-vitro, experimental study was conducted at the Dr Ishrat-ul-Ebad Khan Institute of Oral Health Sciences, Karachi, from June 15, 2019, to May 31, 2020, and comprised samples of polymethyl methacrylate and vertex rapid simplified resins that were fabricated using custom metal moulds. The samples were divided into three groups based on the immersion medium: distilled water (control group), alkaline peroxide, and sodium hypochlorite. An immersion time of 6 hours was chosen to simulate one day, thereby three months of continuous immersion represented one year. The samples were then subjected to a 3-point bending test and the Pendulum Impact test to evaluate their flexural and impact strength, respectively. Data was analysed using SPSS 21.

Results: There were 90 samples each of polymethyl methacrylate and vertex rapid simplified resins. There was a significant difference in the mean values of impact strength between polymethyl methacrylate and vertex rapid simplified resins following immersion in the disinfectants ($p<0.05$). However, no significant difference was observed in flexural strength among the groups subjected to immersions in alkaline peroxide and sodium hypochlorite solutions ($p>0.05$).

Conclusion: The immersion in denture cleansers led to an enhancement in both flexural and impact strength for vertex resin simplified resins compared to conventional polymethyl methacrylate denture base materials.

Keywords: Denture base materials, Mechanical properties, Disinfectants, Impact strength, Flexural strength.

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Introduction

Polymethyl methacrylate (PMMA) has been employed as a removable denture base material since 1946 due to its favourable characteristics, low cost and ease of manipulation.[1,2] With time, advancements in PMMA have led to the development of acrylic resins with rapid curing properties, reducing prosthesis fabrication time. Vertex rapid simplified (VRS), a rapid-cure acrylic, is an example of this advancement.[3]

The mechanical properties of acrylic resins are pivotal for the success of prosthodontic treatments, demanding attributes such as resilience and strength to endure impacts.[4] VRS, a heat-cure denture base material for complete and partial dentures, stands out with its pressing technique and rapid 20-minute polymerisation cycle. A notable feature is its porosity-free nature due to the presence of a low concentration of benzoyl peroxide and dimethyl-p-toluidine.[5] Maintaining hygiene is critical for the longevity of prosthesis, emphasising hygiene practices, disinfectants and cleaning solutions. Denture base materials' interaction with cleansers necessitates the assessment of physical strength after immersion in cleaning agents.[6] Irrespective of the denture base, prioritising oral and denture hygiene is critical in preventing issues like bad breath, staining, plaque accumulation and calculus formation. Effective disinfection methods (mechanical or chemical) must ensure oral and denture hygiene without compromising the base's mechanical and physical properties. Various cleansing agents are known to influence the mechanical properties of the acrylic denture base diversely.[6,7]

Flexural strength serves as an indicator of resistance to breakage under functional loads during mastication, making it a significant determinant of denture longevity.[8]

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Some studies have also highlighted the substantial influence of material constituents on flexural strength.[9,10] It was noted that as long as the denture base constituents remain unchanged, the flexural strength remains consistent, predominantly relying on the strength of the polymers. In a study, PMMA was subjected to various curing techniques and durations, revealing noteworthy impact on flexural strength.[11] Furthermore, it has been demonstrated that while longer curing cycles required more time, they resulted in increased flexural strength in the denture base material when compared to shorter cycles.[12]

Immersion of denture base materials in different cleansers has varying effects on their mechanical properties. Impact and flexural strength of both PMMA and VRS can be influenced after exposure to sodium hypochlorite (SH) and alkaline peroxide (AP) solutions. The choice of appropriate denture cleansers is crucial in maintaining both the oral health and mechanical integrity of denture base materials. Understanding the effects of different cleansers on the mechanical properties of these materials can aid in making informed decisions regarding denture care. SH and AP are disinfectant solutions that are commonly used as denture cleansers, but their impact on heat-cure acrylic (HA) and vertex resin (VR) dentures remains unclear. The current study was planned to fill the gap in literature by investigating the effect of SH and AP disinfectant solutions on the impact and flexural strength of PMMA and VRS.

Materials and Methods

The in-vitro, experimental study was conducted at the Dr Ishrat-ul-Ebad Khan Institute of Oral Health Sciences (DIKIOHS), Karachi, from June 15, 2019, to May 31, 2020. After approval from the ethics review board of the Dow University of Health Sciences (DUHS), Karachi, the sample size was estimated using PASS version 11.[13] The impact strength of PMMA when immersed in Clinsodent disinfectant has been reported to be 0.86±0.235 compared to 0.96±0.247 when immersed in Clanden disinfectant.[14] These values were used alongside 95% confidence interval (CI) and 80% power. The sample was raised using non-probability purposive sampling technique. The samples of conventional HA (Stellon QC-20, Fabnos International, Pakistan) and VRS (Vertex rapid simplified, Holland) resins were prepared using three-piece custom metal moulds. For flexural strength, a stainless-steel (SS) metal mould with dimensions 65mm x 10mm x 2.5mm was used as per the American Dental Association (ADA) specifications[15] to prepare the samples (Figure 1). For impact strength, an SS metal mould of dimensions 80mm x 10mm x 4mm as per ADA specifications[15] was used to prepare the samples (Figure 2). The process of packing and curing was performed in the DIKIOHS prosthodontics laboratory, according to manufacturers' instructions for both PMMA and VRS samples.

For both PMMA and VRS, acrylic powder was weighed using electronic scale (Model no. JA303P, Pioway Medical Lab Equipment Co., Ltd, China) with the precision of 0.0001g. Monomer liquid was measured using a calibrated measuring cylinder. Further, 22g powder was mixed with 10ml monomer liquid in a 2:1 ratio in a silicon bowl until a doughy consistency was achieved. Cold mould seal was applied to the SS mould and left to dry. The mixture was then kneaded and packed into the mould. After closing, a pressure of 3500psi was applied on the mould using hydraulic bench press (Mestra, Mfg no. 030350, US) to allow excess material to flow out of the mould, which was then removed with a sharp knife (Figure 3). The mould assembly was then placed in a digital acrylic curing unit (Acrydig 12, Manfredi, Torino, Italy) for polymerisation. For PMMA, the curing involved processing the PMMA at 74°C for 8 hours, followed by terminal boil at 100°C for one hour. For VRS, polymerisation involved rapid heating of the packed dough in boiling water for 20 minutes, and the water was boiled at 100°C.

After completion of the polymerisation cycle, the metal moulds were cooled for 30 minutes at room temperature and then placed under running water for 15 minutes. After careful deflasking from the mould, the finishing of the samples was done using acrylic trimming bur and 120-grit sandpaper (Figure 4). Polishing was performed using pumice and polishing cake. The dimensions of the specimens were rechecked with a digital vernier caliper (Model no. 1108-300, Insize, Pakistan) with an accuracy of 0.01mm.[15] Samples that were fractured or porous were excluded.

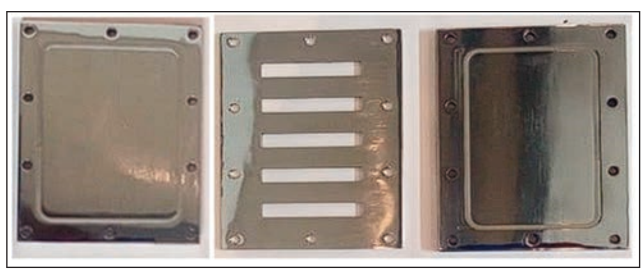

Figure-1: A three-piece stainless steel mould for flexural strength.

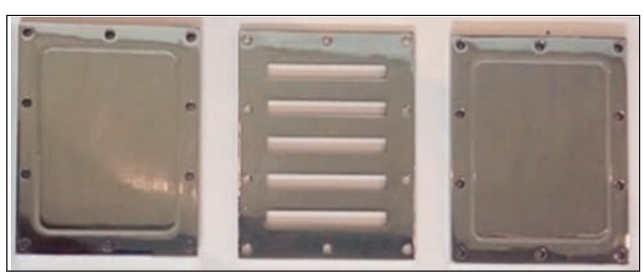

Figure-2: A three-piece stainless steel mould for impact strength.

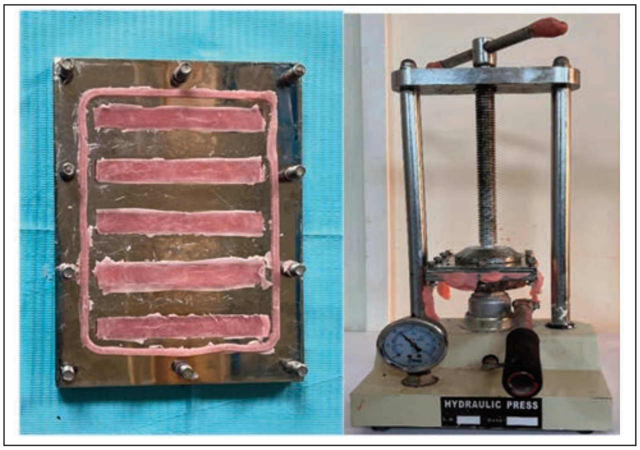

Figure-3: Packing and pressing of resins in metal moulds.

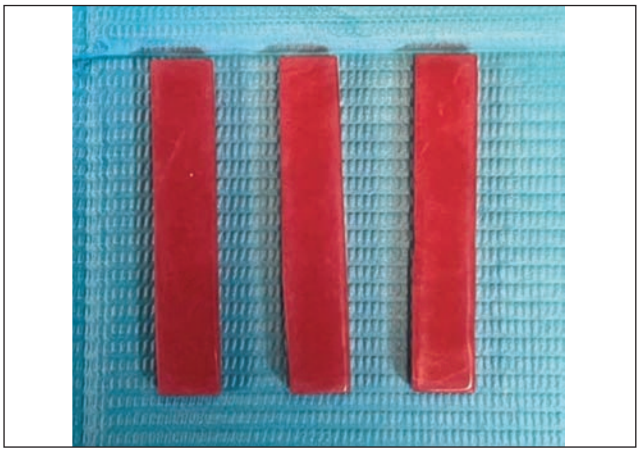

Figure-4: The samples after curing and polishing.

The samples were divided into two main groups: group A comprising conventional HA resin samples, and group B having VRS samples. Each group was further divided into three subgroups based on the immersion medium selected for storage. Groups A1 and B1 were control groups stored in distilled water (DW); groups A2 and B2 were immersed in 1% (138.7±1.1 mmol/L) AP for storage; and groups A3 and B3 were immersed in 0.5% SH. Half the samples in each subgroup were used for the testing of flexural and impact strength each. Immersion time of six hours represented one day, and three months of continuous immersion represented one year. The storage temperature was maintained at the ideal room temperature of 23±2°C that was monitored using a thermostat.

Following immersion in their respective cleansing agents, the samples underwent testing for both impact and flexural strength using the RESIL impact-testing machine (Ceast-Resil impactor, Type 6967000, Serial #18711, Italy) and the Universal testing machine (Instron, Model no. 4301, Serial # H 11853, UK) respectively, at the Plastic and Polymer Department of the Pakistan Council of Scientific and Industrial Research (PCSIR) laboratories in Karachi.

For impact strength assessment, the test specimens were positioned on the machine's platform. A pendulum with a 2J testing capacity and an impact speed of 3.46m/s was used. Energy absorbed at the point of fracture was gauged using a calibrated scale. The impact strength was determined using the formula: Impact strength = e / (Wt), where was the energy absorbed by the specimen upon fracturing, W was the cross-sectional area and t was the thickness of the specimen.

For flexural strength determination, the specimens were loaded individually onto a custom jig fixed in the machine. The samples were placed on a support beam with a 50mm span, and a load was applied until fracture. The fracture load was noted, and the flexural strength was calculated using the formula: $\sigma = 3FL / (2bd^2)$ in which F was the fracture load, L was the distance between supports, b was the specimen's width, and d was the specimen's thickness.

Data was analysed using SPSS 21. Mean±standard deviation and 95% CIs were reported for flexural strength and impact strength for each group. Shapiro-Wilk test was applied to assess data normality. Two-way analysis of variance (ANOVA) was used to determine if there were significant differences in flexural strength and impact strength between PMMA and VRS after immersion in the disinfectants. Post-hoc Tukey's test was conducted for pairwise comparisons to identify specific differences among the groups. $P \leq 0.05$ was considered significant.

Results

Of the 180 samples, 90(50%) each were in groups A and B; 30(33.3%) each in the A1, A2, B1, B2, A3 and B3 subgroups. Of them, 15(50%) each were used to assess flexural and impact strength. In groups A1 and B1, the mean impact strength of PMMA was 20.4+2.35kJ/m^2 compared to VRS's 21.9+1.37kJ/m^2. In groups A2 and B2, the mean impact strength of VSR was 26.9+1.64kJ/m^2 compared to PMMA's 23.3+1.54kJ/m^2. In groups A3 and B3, the mean impact strength of PMMA was 18.7+1.13kJ/m^2 compared to 22.2+1.44kJ/m^2 for VSR ($p<0.05$) (Table 1).

Table-1: Impact strength comparison of heat cure acrylic and vertex resins under different immersion conditions.

Group	Mean±SD (kJ/m^2)	95% CI (kJ/m^2)	MSE (*p*-value)	Effect size
HA-DW (A1)	20.4±2.35	18.3 - 21.2	2.03 (0.007**)	11.1%
HA-AP (A2)	23.3±1.54	20.9 - 25.2		
HA-SH (A3)	18.7±1.13	16.6 - 20.0		
VRS-DW (B1)	21.9±1.37	19.7 - 23.6		
VRS-AP (B2)	26.9±1.64	23.8 - 28.8		
VRS-SH (B3)	22.2±1.44	19.9 - 24.0		

**Significant at 1%, HA: Heat-cure acrylic, VRS: Vertex resin simplified, DW: Distilled water, AP: Alkaline peroxide, SH: Sodium hypochlorite.

A1 and B1 DW; A2 and B2 AP; A3 and B3 SH

There was a significant difference (p=0.007) in the impact strength when different materials and their immersion in disinfectants were compared. The effect size was 11.1%, indicating that 11.1% of the observed differences in impact strength could be attributed to variations in the materials used, and not to the effect of disinfectants.

Significant differences were observed, especially when comparing A2 with A1 groups (p<0.001) and B2 groups (p<0.001) (Table 2).

Table-2: Impact strength comparison of heat cure acrylic and vertex resins under different immersion conditions.

Comparisons	Mean Difference	*p*-value
A		
A2 v/s A1	2.91	<0.001**
A2 v/s B1	-1.42	0.081
A2 v/s B2	3.6	<0.001**
A2 v/s B3	-4.66	<0.001**
B		
B2 v/s A3	8.25	<0.001**
B2 v/s B1	5.02	<0.001**
B2 v/s B3	-4.74	<0.001**

**Significant at 1%, A: Heat-cure acrylic, B: Vertex resin, A1and B1: Control groups, A2 and B2: Alkaline peroxide groups, A3 and B3: Sodium hypochlorite groups.

Table-3: Comparison of mean differences of flexural strength of HA and VR in different solutions.

Group	Mean±SD MPa	95% CI MPa	MSE	p-value	Effect size
HA-DW (A1)	82.4±4.84	73.85 - 88.30	09.73	<0.001	81%
HA-AP (A2)	59.8±3.90	52.78 - 63.8			
HA-SH (A3)	62.0±4.11	55.51 - 67.1			
VR-DW (B1)	53.3±3.53	47.68 - 57.63			
VR-AP (B2)	68.5±4.54	61.28 - 74.08			
VR-SH (B3)	63.4±4.26	56.69 - 68.53			

VR: Vertex resin, HA: Heat-cure acrylic, DW: Distilled water, AP: Alkaline peroxide, SH: Sodium hypochlorite, CI: Confidence interval, MPa: Mega Pascal, SD: Standard deviation, MSE: Mean squared error.

Table-4: Pairwise comparison of flexural strength among groups based on disinfectants and materials used.

Comparisons	Mean Difference	*p*-value*
A1		
A1 vs A2	-23.42	<0.001**
A1 vs A3	-20.36	<0.001**
A1 vs B1	-29.12	<0.001**
A1 vs B2	-13.9	<0.001**
A1 vs B3	-19.04	<0.001**
B2		
B2 vs A2	9.52	<0.001**
B2 vs A3	6.46	0.001
B2 vs B1	15.22	<0.001**
B2 vs B3	-5.14	0.015

**Significant at 1%, A1and B1: Control groups, A2 and B2: Alkaline peroxide groups, A3 and B3: Sodium hypochlorite groups; *Post-hoc Tukey test was used.

There were significant differences in flexural strength among materials immersed in different solutions (p<0.001) (Table 3).

Comparison of flexural strength among different groups based on the disinfectants used and the choice of material also showed significant differences (Table 4).

Discussion

The strength and longevity of denture base materials directly correlate with the quality of life and satisfaction of the denture-wearers. Chemical disinfection has been routinely used to maintain denture hygiene and prevent cross-contamination.[16] Dentures that exhibit superior impact and flexural strength not only enhance patient comfort, but also reduce the need for repairs and replacements. Denture cleansers may affect the surface roughness as well as the impact strength and flexural strength of prosthesis which may lead to prosthesis failure. Therefore, understanding the mechanical properties of these materials and the effects of disinfectants on them is crucial in ensuring the long-term success of denture prosthesis.[17-19]

The current study aimed at assessing the impact strength and flexural strength of two dental materials, PMMA, represented by HA, and VRS, after immersion in various denture cleansers, including DW, AP and SH.

Results showed that both the material type and the disinfectants significantly influenced the impact and flexural strength of the denture base. These results are supported by an earlier study.[20] These findings have important implications for denture prosthesis design and the selection of appropriate disinfectants for denture maintenance.

The current results found significant variations in impact strength when the two materials were exposed to different disinfectants. Similar results have been reported earlier,[21] emphasising the influence of both the material and the disinfectant on the impact strength. A recent study demonstrated that the choice of disinfectant significantly affected the impact strength of the materials, and cleansing agents containing alcohol decreased the impact strength.[22]

Ragher M et al. reported decrease in flexural strength of PMMA when immersed in two different denture cleansers. The flexural strength was highest for PMMA in DW.[23] These results support the current findings in this regard. Davi LR et al. also reported similar results,[24] while Arruda et al. highlighted that material selection plays a pivotal role in the impact strength of dental prostheses.[25] Furthermore, it has been advised to limit the use of solutions containing alcohol as acrylic denture cleansers due to their negative effect on impact strength of acrylic.[21]

The 1.1% effect size observed in the current study indicated that 11.1% of the impact strength variation could be attributed to material and disinfectant selection, and aligned with the overall trend observed in recent studies,[13,21] highlighting that while material and disinfectant choices are significant factors, they do not account for the entirety of the observed variations in impact strength. Other uncontrolled variables, such as processing techniques, manufacturing quality, and wear and tear, may also contribute to these differences as discussed in a study by Ragher M et al.[14]

The significant impact of the disinfectant factor, as indicated by the effect size of 69%, highlighted the importance of selecting the appropriate disinfectant for denture maintenance. AP appears to be the most effective disinfectant, significantly improving the impact strength of both materials. In contrast, SH had a detrimental effect on HA, and to a lesser extent on VRS. This was also observed in a study by Gad et al.[26]

Flexural strength of the denture base materials is a vital mechanical property for denture base materials. To resist fracture or deformation under flexural forces, the denture base should have sufficient flexural strength.[27,28] The current results showed that HA exhibited superior flexural strength compared to VRS when immersed in DW, while the situation reversed when the materials were immersed in AP. Flexural strength decreased for both materials when immersed in SH, with VR maintaining a slight advantage. The effect size for material and disinfectant on the change of flexural strength was substantial (81%), highlighting the considerable influence of both factors.

Comparing the two materials, HA displayed a lower mean impact strength compared to VR with a 52% effect size. In contrast, for flexural strength, HA had a higher mean strength compared to VRS with a 36% effect size. These results suggested that while VR could excel in impact strength, HA demonstrated an advantage in flexural strength.

The comparison of different disinfectants for HA showed that DW tended to yield higher mean flexural strength compared to AP and SH, although the differences were not statistically significant.

The current study has several limitations. First, it focused on only one type of each material, and results may vary with other brands. Additionally, the immersion times in disinfectants were uniform; clinical scenarios might involve varying immersion durations. The study also did not consider factors such as temperature, mechanical stress, or multiple disinfectant cycles, which could affect material properties.

The study's strengths include the use of standardised testing methods and statistical analysis, providing robust results. The examination of two critical mechanical properties, impact and flexural strength, after various immersion conditions, adds valuable insights into the dental material literature.

To build upon this research, future studies should explore the long-term effects of exposure of different as well as new disinfectants on denture base materials while considering factors like temperature, repeated disinfection and mechanical stress. Studies may also create an environment to simulate oral conditions to evaluate the properties. Additionally, investigating the impact of different disinfectants on other mechanical, physical and aesthetic properties of denture base materials could provide a comprehensive understanding of material behaviour in clinical settings.

The current study highlighted the significant impact of both the choice of material and disinfectant on the mechanical properties of denture base materials. Choosing the appropriate disinfectant is crucial for maintaining denture integrity and the choice of material should be based on the specific mechanical properties required for a given clinical application, as has been shown earlier by Alkaltham et al.[29]

Conclusion

VRS and HA exhibited maximum impact strength after immersion in AP solution. Additionally, VRS showed increased flexural strength when immersed in AP, whereas PMMA showed highest flexural strength after immersion in DW. Notably, VR consistently demonstrated higher impact strength levels when subjected to denture cleansers compared to PMMA.

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References

1. Kiran A, Amin F, Lone MA, Moheet IA, Lone MM, Mahmood S, et al. Influence of processing techniques on microhardness and impact strength of conventional and reinforced heat cured acrylic resin: a comparative study. Mater Plast. 2021;58:239-46. doi:10.37358/MP.21.3.5517
2. Ghoveizi R, Tavakolizadeh S, Raftarifarimani A, Barzanji A, Afshari Z. Comparative study of flexural strength of four acrylic resins before and after thermocycling process. J Dent Sch. 2018;36:95-8.
3. Aarts JM, van Vuuren WA, Withy KE, Choi JE, Waddell NJ. A pilot study on the influence of two reinforcing materials (glass fibre mesh and

electro-spun nylon nano fibres) on the flexural strength of a heat-cured poly(methyl methacrylate) denture base resin. N Z Dent J. 2017;113:11-5.

4. Pantea M, Ciocoiu RC, Greabu M, Totan AR, Imre M, Tancu AMC, et al. Compressive and flexural strength of 3D-printed and conventional resins designated for interim fixed dental prostheses: an in vitro comparison. Materials. 2022;15:3075. doi:10.3390/ma15093075
5. Amin F, Rehman A, Abbas M. Microhardness of heat cure acrylic resin after treatment with disinfectants. J Pak Med Assoc. 2015;65:834-7.
6. Cakmak G, Donmez MB, Akay C, Atalay S, Silva de Paula M, Schimmel M, et al. Effect of simulated brushing and disinfection on the surface roughness and color stability of CAD-CAM denture base materials. J Mech Behav Biomed Mater. 2022;134:105390. doi:10.1016/ j.jmbbm. 2022.105390
7. Procopio ALF, da Silva RA, Maciel JG, Sugio CYC, Soares S, Urban VM, et al. Antimicrobial and cytotoxic effects of denture base acrylic resin impregnated with cleaning agents after long-term immersion. Toxicol In Vitro. 2018;52:8-13. doi:10.1016/j.tiv.2018.06.016
8. Alhotan A, Yates J, Zidan S, Haider J, Silikas N. Flexural strength and hardness of filler-reinforced PMMA targeted for denture base application. Materials. 2021;14:2659. doi:10.3390/ma14102659
9. Perea-Lowery L, Minja IK, Lassila L, Ramakrishnaiah R, Vallittu PK. Assessment of CAD-CAM polymers for digitally fabricated complete dentures. J Prosthet Dent. 2021;125:175-81. doi:10.1016/j.prosdent. 2019.12.019
10. Al-Dwairi ZN, Tahboub KY, Baba NZ, Goodacre CJ. A comparison of the flexural and impact strengths and flexural modulus of CAD/CAM and conventional heat-cured polymethyl methacrylate. J Prosthodont. 2020;29:341-9. doi:10.1111/jopr.13124
11. Al-Dobaei EG, Badr NA, Abdel-Hamid DM. The effect of curing techniques of denture base resins on strength characteristics under different loading modes. Egypt Dent J. 2012;58:3927-37.
12. Kanchanavasita W, Jongtamgpiti T, Wonglamsam A, Nagaviroj N. Flexural strength of three denture base materials in different curing procedures. M Dent J. 2017;37:273-80.
13. Hintze J. (2011) Passll. Ness
14. Ragher M, Prabhu UM, Ittigi JP, Naik R, Mahesh CS, Pradeep MR. Efficacy of denture cleansers on impact strength of heat polymerized acrylic resins. J Pharm Bioallied Sci. 2017;9:S241-5. doi:10.4103/jpbs. JPBS_176_17
15. Salman TA, Khalaf HA. The influence of adding of modified ZrO2-TiO2 nanoparticles on certain physical and mechanical properties of heat polymerized acrylic resin. J Bagh Coll Dent. 2015;27:33-9.
16. Zhang K, Zhang S, Shi Y, Zhang L, Fu B. Effects of disinfectants on physical properties of denture base resins: a systematic review and meta-analysis. J Prosthet Dent. 2024;131:841-58. doi:10.1016/ j.prosdent.2023.02.020
17. Rocha MM, Carvalho AM, Coimbra FCT, de Arruda CNF, Oliveira VC, Macedo AP, et al. Complete denture hygiene solutions: antibiofilm activity and effects on physical and mechanical properties of acrylic resin. J Appl Oral Sci. 2021;29:e20200948. doi:10.1590/1678-7757-2020-0948
18. Fotovat F, Abbasi S, Nikanjam S, Alafchi B, Baghiat M. Effects of various disinfectants on surface roughness and color stability of thermoset and 3D-printed acrylic resin. Eur J Transl Myol. 2024;34:11701. doi:10.4081/ejtm.2024.11701
19. Al-Hussien HJA. Effect of immersion in chemical solution on the mechanical and physical properties for composite material reinforced by nano alumina particles. Iraqi J Sci. 2015;57:1952-63.
20. Amin F, Qadir F, Akram S. Impact strength of acrylic resins after storage in denture cleansers. Pak Oral Dent J. 2014;34:735-8.
21. Rasheed ZN, Hussain SM. Impact strength behaviour of PMMA denture base through addition of different nanoparticles after immersion in some nutrition liquids. Iraqi J Phys. 2019;17:40-50.
22. Ahmad AS. Denture cleanser's effect on impact strength of heat cured acrylic. Iraqi Dent J. 2015;37:1-5.
23. Ragher M, Vinayakumar G, Patil S, Chatterjee A, Mallikarjuna DM, Dandekeri S, et al. Variations in flexural strength of heat-polymerized acrylic resin after the usage of denture cleansers. J Contemp Dent Pract. 2016;17:322-6. doi:10.5005/jp-journals-10024-1854
24. Davi LR, Peracini A, Ribeiro NQ, Soares RB, da Silva CHL, Paranhos HFO, et al. Effect of the physical properties of acrylic resin of overnight immersion in sodium hypochlorite solution. Gerodontology. 2010;27:297-302. doi:10.1111/j.1741-2358.2009. 00349.x
25. Arruda CN, Sorgini DB, Oliveira VC, Macedo AP, Lovato CH, Paranhos HFO. Effects of denture cleansers on heat-polymerized acrylic resin: a five-year simulated period of use. Braz Dent J. 2015;26:404-8. doi:10.1590/0103-6440201300220
26. Gad MM, Abualsaud R, Fouda SM, Rahoma A, Al-Thobity AM, Khan SQ, et al. Effects of denture cleansers on the flexural strength of PMMA denture base resin modified with ZrO2 nanoparticles. J Prosthodont. 2021;30:235-44. doi:10.1111/jopr.13253
27. Fouda SM, Gad MM, Ellakany P, Al Ghamdi MA, Khan SQ, Akhtar S, et al. Flexural properties, impact strength, and hardness of nanodiamond-modified PMMA denture base resin. Int J Biomater. 2022;2022:6583084. doi:10.1155/2022/6583084
28. Asopa V, Suresh S, Khandelwal M, Sharma V, Asopa SS, Kaira LS. A comparative evaluation of properties of zirconia reinforced high impact acrylic resin with that of high impact acrylic resin. Saudi J Dent Res. 2015;6:146-51. doi:10.1016/j.sjdr.2015.02.002
29. Alkaltham NS, Aldhafiri RA, Al-Thobity AM, Alramadan H, Aljubran H, Ateeq IS, et al. Effect of denture disinfectants on the mechanical performance of 3D-printed denture base materials. Polymers (Basel). 2023;15:1175. doi:10.3390/polym15051175

Author Contribution:

ZS: Concept, design and data acquisition.
MAL: Drafting and revision.
BJ: Data analysis and interpretation.
MKH: Data collection, statistical analysis and results.
MZK: Drafting, literature search and writing the discussion.
Z & AI: Methodology, preparation of the samples, curing procedures and final approval.