https://doi.org/10.48047/AFJBS.6.Si4.2024.560-570

African Journal of Biological Sciences

Evaluation of The Flexural Strengthof Heat-cured Acrylic Resin Modified with Titanium Dioxide/Quercetin-Nanocomposite Particles

Eslam Mahmoud Gomaa[*1], Mahmoud Mohamed Ammar[2], Mostafa Abdelqawy Younis[3], Ahmed Dahy Abogabal[4]

1. Demonstrator of Removable Prosthodontics, Faculty of Dentistry, Assiut University, Egypt.
2. Professor of Removable Prosthodontics, Faculty of Dental Medicine,AL-Azhar University (Assiut), Egypt.
3. Professor of Removable Prosthodontics, Faculty of Dental Medicine, AL-Azhar University (Assiut),Egypt.
4. Lecturer of Dental Biomaterial, Faculty of Dental Medicine,AL-Azhar University (Assiut),Egypt.

Corresponding author: Eslam Mahmoud Gomaa
Email:eslam_gomaa@aun.edu.eg

Article History

Volume 6, Issue Si4, 2024
Received: 25 May 2024
Accepted: 15 June 2024
doi: 10.48047/AFJBS.6.Si4.2024.560-570

ABSTRACT

Objective: evaluation ofthe flexural strength of heat cured acrylic resinthat incorporated with different concentrations of (Titaniumdioxide/Quercetin) nanocomposite particles by comparing with conventional heat cured acrylic resin.

Materials and methods: flexure strength test is applied to a total of twenty specimens thatare divided into four main groups according to the percentage of the added Nano material used, then Scanning of the fractured surface by electron microscope.

Results: Regarding theflexural strengththere was a statistically remarkable decrease for all modified groups compared with the control group.

Conclusion: The concentrationof nano (TiO_2/Quercetin) added to PMMAsignificantly affected the mechanical properties of PMMA.Flexurestrengthhave not significantly improved in the modified groups when compared to the control group.

KEY WORDS:heat cure resin, PMMA, flexure strength, Nano, TiO_2, Quercetin, electronic microscope

INTRODUCTION

Acrylic resin (PMMA) has been widely used in dental field since it developed by Walter in 1936, due to its good characteristics as low cost, ease of construction, polishability, acceptance of repair, excellent aesthetics, and biocompatibility. Despite that, it has some drawbacks such as low surface hardness,insufficient flexural strength, and poor antimicrobial activity that causing denture stomatitis and abutment caries.(1)

Compete denture is one of the important dental prosthesesfor completely edentulous patients. It enhances mastication, phonetic problems and aesthetic that improves the psychological condition of the patient.(2)
the fillers size, shape, distribution, and adhesion at the PMMA matrix, hasan important role in the mechanical properties of the PMMA.(3)
Reinforcement of PMMA with metal oxides also improved the physical properties of the material, as well as patients' sensation of hot and cold stimuli that cause better food sensation and healthier oral mucosa. (4)
Recently, incorporation of natural organic substances in denture base acrylic resinimproves inflammation treatment with varying success. (5)
Nanofillers incorporation mostly improve PMMA properties. huge surface area, and homogenous distribution of nanoparticles improving the physical and mechanical characteristics of PMMA compared with pure PMMA. (4)
TiO_2 nanoparticlehas recently been useddue to their high stability, availability, white colour, and low cost. TiO_2 NPs also are chemically inert and non-toxic and have corrosion resistance as well as good hardness and antibacterial activity under a wide microbial spectrum.(6)
It was found that adding TiO_2 nanoparticles has improved flexure strength, hardness, and thermal conductivity of PMMA. As well as increase in impact strength and a significant decrease in water sorption were found upon addition of TiO_2 to PMMA.(4)
On the other hand, other studies found that TiO_2has decreased the flexure strength of denture acrylic resin, that may be due to clustering of the nanoparticles within the resin matrix, that decreasing the mechanical properties of PMMA.(4)
Quercetin, this name comes from Quercus that mean:(oak forest tree), quercetin is found in plants like apples, grapes, onions, and tea as well seeds like nuts, flowers.(7)
Quercetin displays activity against streptococcal membranes as well as Streptococcus-mutans byinhibiting acid production in biofilm. It also showing inhibitory activity against Staphylococcus aureus. (8)
Quercetin also has a good antimicrobial effect against candida that is the causative organism of denture stomatitis (9)
Quercetin is a polyphenolic flavonoid that mainly is found in fruits and vegetables. It also has antioxidant, antiartherogenic, anti-inflammatory, anti-carcinogenic, neuroprotection properties,antibacterial,and antiviral properties. (10)
Titanium surface of implant was coated with quercetin (QUE), the obtained compound (Ti-Que) was found that able to reduce the biofilm formation of Staphylococcus mutants and adhesion compared to the uncoated titanium surface. (11)
Complete dentures are subjected to high flexural stressesmainly during themastication, which cause cyclic deformation of denture base PMMA, resulting in crack propagation and formationthat causedenture fracture. So that , high flexural strength is important to denturesuccess.(12)
Due to the irregular pattern of bone resorption, dentures are supported by uneven alveolar ridges that cause high flexural stressesin denture base material under flexural loading. (13)
According to ISO 20795-1 (international standard of denture basepolymer), the denture base material (PMMA) should has flexural strength not be less than 60 MPa.(14)

Materials and Methods

1.1. Study design.

This Study was designed as an experimental in vitro controlled study. The study was carried out in the removable prosthodontic department - Faculty of Dental Medicine – al Azhar university (Assiut branch).

1.2. Samples grouping

To evaluate the effectiveness of adding TiO2/Quercetin nanoparticles to heat cured PMMA, a total of 20 specimens were divided into four main groups according to the percentage of added nanoparticles (Five samples in each group).

Group 1: Control group –heat cured PMMA.
Group 2: Nanoparticles added to heat cured PMMA by 0.5% of weight.
Group 3: Nanoparticles added to heat cured PMMA by1% of weight.
Group 4: Nanoparticles added to heat cured PMMA by 1.5% of weight.

2.1. Materials

The Materials thathave been used in this study along with relative information (description and manufacturers) are:

- Heat cured poly methyl methacrylate*(Acrostone Dental& medical supplies, Cairo, Egypt).*
- Nanoparticles of Titanium dioxide/Quercetin *(Nano Gate company, Cairo, Egypt)*

2.2. Mixing nanoparticles with PMMA

The dried powder of (Qu loaded TiO_2 NPs) was mixed with PMMA powder at different ratios 0.5%, 1% and 1.5%by weight, typically for 1%, 1 gm of TiO_2/Quercetin NPs mixed with 99 gm of PMMA by meaning of ball mill (Retsch pm 400, Japan, Nano Gate company) for 2 h to get homogenous mixing.

3.1. Samplesfabrication

To fabricate heat cured acrylic resin samples with standard dimensions according to ISOstandards, a virtual design was made with the help of a computer program (Tinkercad, free web app for 3D design, Autodesk)according toISOstandard dimensions and then converted into a stereolithography (.stl) file, which then printed to resin model by 3D printer that shown in **(Fig.1)**.

Resin models of rectangular shape were converted to heat cured PMMA samples for flexural strength test, The resins were processed by the conventional water bath technique in this research.

The specimens were cut out and trimmed to final dimensions, using finishing stones. A digital **calliper** (TMT331501; Total, China) was used to ensure the final dimensions of the specimens**(Fig.2)**.

Fig.1: 3D printed model of the specimens

Fig.2: 3.3mm thickness, 64 mm length and 10 mm width are dimension of flexure strength test and hardness test specimens.

3.2. Flexural strength test:

Dimension of **64 mm length, 10.0±0.2 mm width and3.3±0.2mm height** to conduct the flexural strength test based on the recommendation of **ISO 20795-1:2013.**(14)

A total of 20 sampleswere tested using a universal testing machine (INSTRON, Dental material lab, Assuit university, Egypt).

A standard three-point load flexural test was used to fracture the specimens,after mounting the specimens in the testing device apparatus with 50 mm distance between two vertical supports, the vertical load was applied midway between the supports with a 5 mm/min crosshead speed until the specimen was fractured, and the maximum load at fracture was recorded with the PCsoftware**(Fig.3)**.

After flexure strength test, features ofthe fractured surfaces of each test group were observedusing field emission scanning electron microscope.

Flexural strength was calculated using the formula:

FS = 3WL/2bd²

$$FS = 3WL/2bd^2$$

FS: flexure strength (MPa)

W: the maximum load before fracture (N)

L: the distance between supports (50 mm)

b: the specimen width (10 mm)

d: the specimen thickness (3.3 mm)

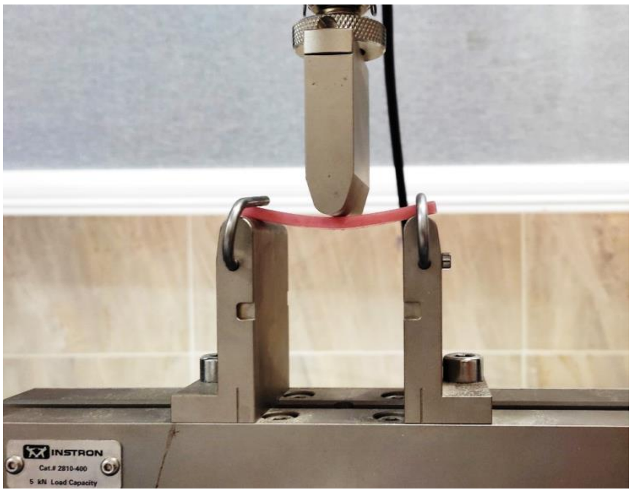


Fig.3: samples under three-point loadingduring flexural strength test

4.1. Electron microscope scanning (SEM)

Fractured surfaces of the specimens of control, 0.5%, 1%, and 1.5% groups after flexure strength test were randomly selected, gold-sputter coated by (JEOL JFC-1100) and observed using scanning electron microscope SEM (JEOL Scanning electron microscope JSM-5400) under magnification of (350x, 1000x)at unit of Electron Microscope Scanning, Assiut University.

The fractured surface of the specimenswas studied toexplainthe failure mechanism. Specimens were mounted onto aluminium stubs and sputter-coated with gold to overcome the non-conductive nature of the material.

Images were taken at different magnifications (350x, 1000x) for better visual inspection, and to determine the nature of the failure.

Smooth surface fields present brittle fracture modes, while a rough appearance presents intermediate (brittle to ductile) fracture modes.

4.2. SEM analysis displayed:

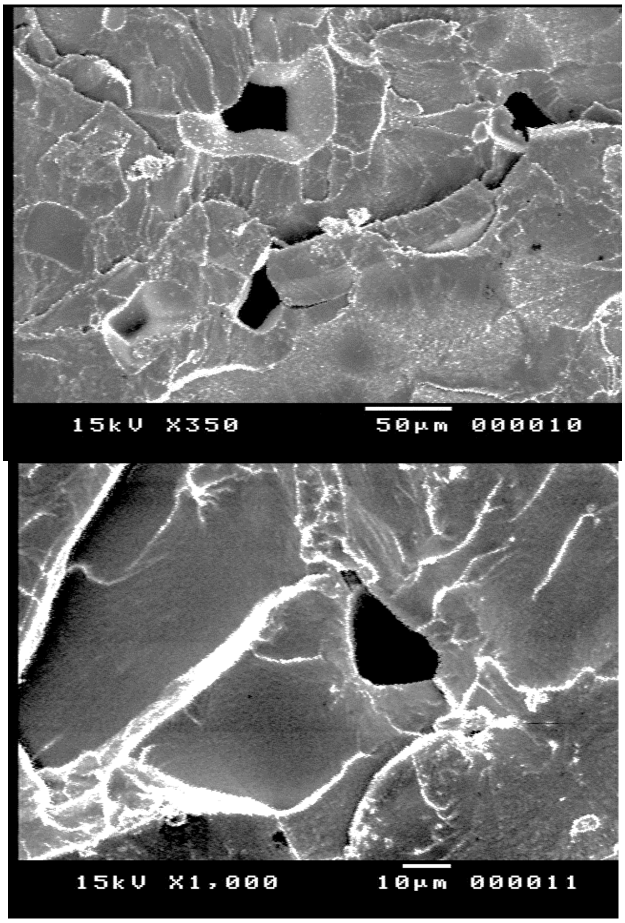


Fig.4:*control sample scanned image by electron microscope at 350x and 1000x*

shows a compact morphology containing broad scattered voids with irregular compact surface and show flake or sheetlike structure of certain thickness.

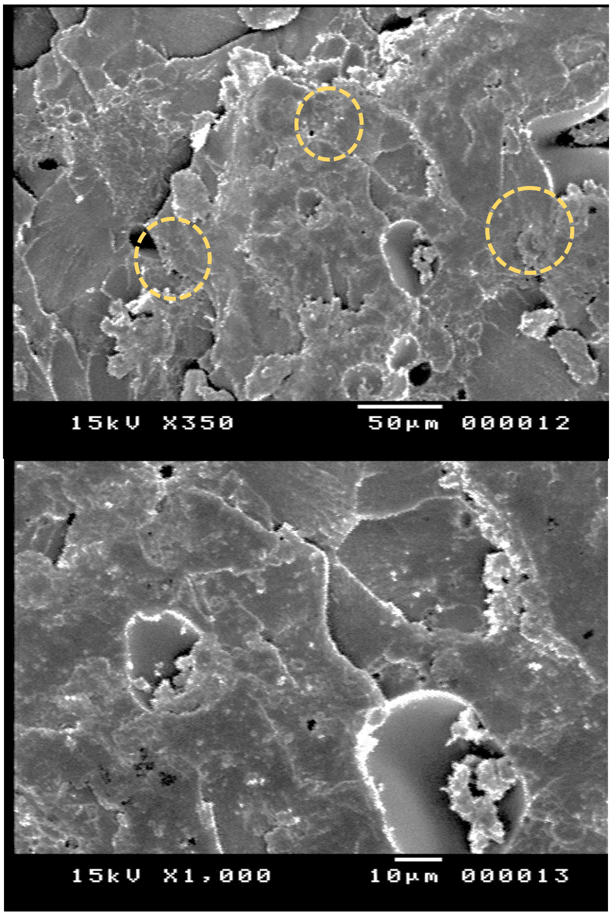
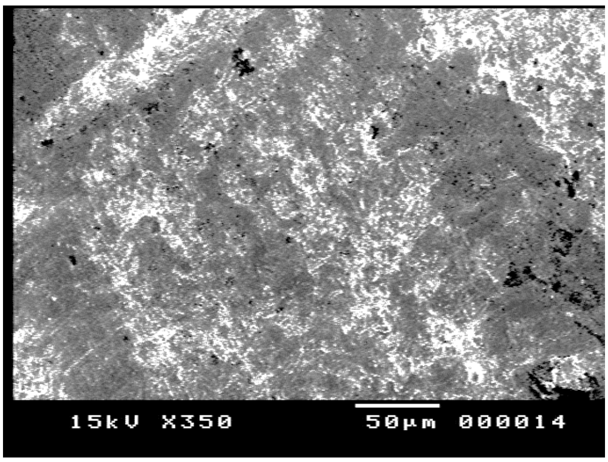


Fig.5:*(0.5%) scanned image by electron microscope at 350x and 1000x*

shows a compact morphology with diminutive pores preoccupied by nanomaterials *(yellow circles).*



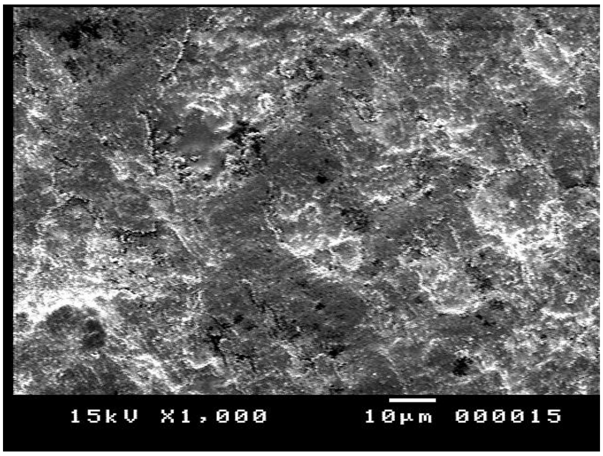


Fig.6:*(1%) scanned image by electron microscope at 350x and 1000x*

shows a smooth surface resulting from the role of nanoparticles filling the voids.

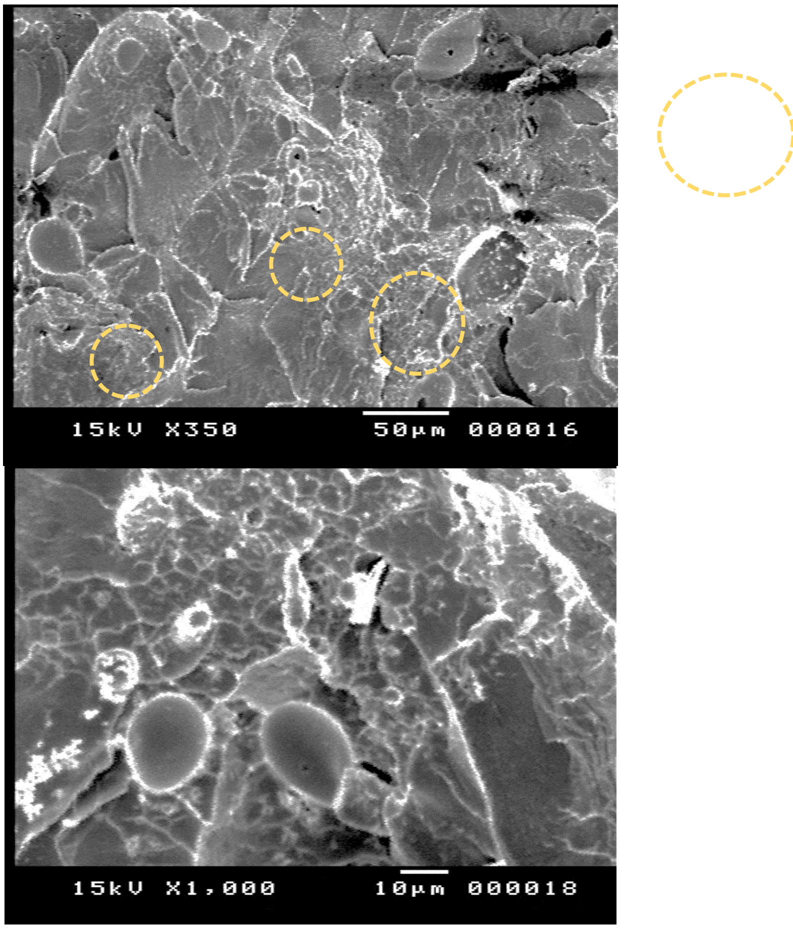


Fig.7:*(1.5%) scanned image by electron microscope at 350x and 1000x*

shows loosely attached clusters of nanoparticles on the surface of specimens. the distribution of the nanoparticles was not uniform, and the fillers tended toward agglomeration ***(yellow circles)***.

- The nanoparticles appeared as bright points in the acrylic resin matrix.
- Void formation shown in **Fig.4** may be due to entrapped air and moisture, incomplete wetting of the fillers by the resin, difficulty of obtaining good adhesion between fillers and the resin matrix and the fact that nanoparticles act as an interfering factor in the integrity of the polymer matrix.
- Microporosities may be resulting from an inadequate polymer monomer ratio, distinct stages of the mass during the packing process, and inadequate pressure on the mass inside the flask during the polymerization procedure.
- Although the nanoparticles were in the nanoscale, the electron microscope images showed that some nanoparticleshad some agglomeration and were still in the nanoscale.
- This agglomeration may be due to the tendency of nanoparticles to decrease their contact surface with PMMA. Good distribution of nanoparticles in PMMA matrix help improving the nanocomposite properties.

Results

One WAY ANOVA showed a significant difference between tested groups at p=0.002. The highest flexure strength resulted for control which was insignificantly higher than 0.5% concentration only and significant with other tested groups.

Table (1): Descriptive statistics of flexure strength test results showing mean values, standard deviations, and statistical significance**.**

Groups	Mean	Sd	Range		P – value
			Min	Max	
Group 1 (control)	**99.81**	**5.69**	**93.1**	**108.3**	**<0.001***
Group 2 (0.5%wt Nano)	**93.42**	**7.84**	**85.7**	**106.2**	
Group 3 (1%wt Nano)	**82.44**	**5.35**	**77.3**	**91.1**	
Group 4 (1.5%wt Nano)	**75.76**	**4.01**	**71.3**	**79.7**	

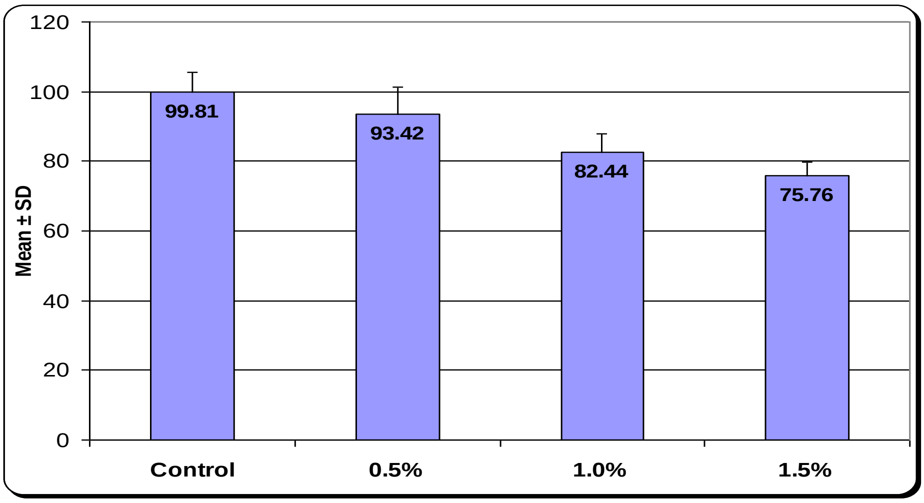


Fig.8: Column chart showing flexure strength mean values and standard deviation fornano modified groups compared to control group.

Discussion

different materials have been used for construction of denture base, but polymethyl methacrylate (PMMA) still used for more than 80 years. PMMA has several advantages as ease of manipulation and repair, accurate fit, ease of polishing, aesthetic appearance, and stability in the oral environment. However, PMMA also has disadvantages, aslow hardness and poor wear resistance..[15]

Literature has found that reinforcement by nanoparticles of Titanium dioxide brings new optical, physical and mechanicalproperties atsmall TiO2 concentrations, which makes PMMA-TiO2 nanocomposites a promising new material.[16]

Moreover, TiO2 nanoparticles have been used as additives to biomaterials to improve antimicrobial properties.[16]

Quercetin exists in many vegetables and fruits including apples, tea, onions, red grapes, and tomatoes as it is the most abundant flavonoid. Quercetin has good against wide spectrum of bacteria, such as Staphylococcus aureus, Escherichia coli and Pseudomonas aeruginosa.[17]

Previous studies demonstrated that quercetincouldaffectthe bacterial cell surface properties to decrease biofilm formation.As well as, it may be beneficial to decrease periodontal tissue destruction by inhibiting activity of P. gingivalis.[17]

As nanoparticles have a high surface energy, uniform distribution at the polymer matrix can be difficult challenge, due to its tendencyto aggregation. [18]

The results of this study showed a not significant decrease in flexural strength by adding (0.5% TiO2/Quercetin nanocomposite) to PMMA resin and significant decrease in the other groups from control.

Denture base is subjected to compressive, tensile, and shear stresses during function, and fractures may develop due to repeated masticatory force. Increase in flexural strength is required to prevent the fracture of denture resulting from long term use or heavy occlusion..[15]

The concentration of nanoparticles was inversely proportional to the flexural strength of PMMA, It was noted that all the groups showed flexural strength more than the minimum requirement of flexural strength for denture base according to the ISO specification i.e., 65 MPa. [19]

Incorporated nanoparticles can also aggregate and agglomerate, that creating a stress concentrationcentreand lead to poor mechanical properties.[19]
On the other hand,higher concentrations of nanoparticles may cause agglomeration, cluster formations, and loss of homogeneity.[20]
As well as, Residual monomers may act as a plasticizer, and negatively influence the mechanical properties of thedenture base PMMA.[21]
The surface of the nanoparticles must be modified with coupling agents, which creates a strong bond with the resin matrix. A silane coupling agent is required to fix the fillers in the resin matrix[18]
A silane coupling agent is required to retain fillers in the resin matrix and to form chemical bonds with inorganic fillers and organic matrix .[18]

Conclusion
Based on the findings of this in vitro study, the following conclusions indicate that: The flexural resistance property did not improve in the modified groups when compared to the control group.

Recommendation
The authors recommend further studies assessing the use of different acrylic resins, different concentration ofloading the nanomaterial, adding nanofillers to PMMA using silane coupling agent.

limitations
The flat surface of the tested specimens, which did not mimic the actual denture anatomy completely but would allow for comparison with previous reports.

References
1. Chen R, Han Z, Huang Z, Karki J, Wang C, Zhu B, et al. Antibacterial activity, cytotoxicity and mechanical behavior of nano-enhanced denture base resin with different kinds of inorganic antibacterial agents. Dental materials journal. 2017;36(6):693-9.
2. Kamonkhantikul K, Arksornnukit M, Takahashi H. Antifungal, optical, and mechanical properties of polymethylmethacrylate material incorporated with silanized zinc oxide nanoparticles. International Journal of Nanomedicine. 2017;12:2353.
3. Fayad MI, Alwafy GM, Abdelrahim RA, Abuhelal O. Effect of Incorporation of Henna and Silver-nanoparticles on Surface Properties of PMMA Acrylic Resin. Al-Azhar Assiut Dental Journal. 2020;3(2):129-37.
4. Gad MM, Fouda SM, Al-Harbi FA, Näpänkangas R, Raustia A. PMMA denture base material enhancement: a review of fiber, filler, and nanofiller addition. International journal of nanomedicine. 2017;12:3801.
5. An S, Judge R, Wong R, Arzmi M, Palamara J, Dashper S. Incorporation of the microencapsulated antimicrobial agent phytoncide into denture base resin. Australian Dental Journal. 2018;63(3):302-11.
6. Ataol AS, Ergun G, Abdulrazzaq Naji S, Behroozibakhsh M, Jafarzadeh Kashi TS, Eslami H, et al. Effects of incorporation of 2.5 and 5 wt% TiO2 nanotubes on fracture toughness, flexural strength, and microhardness of denture base poly methyl methacrylate (PMMA). The journal of advanced prosthodontics. 2018;10(2):113-21.

7. David AVA, Arulmoli R, Parasuraman SJPr. Overviews of biological importance of quercetin: A bioactive flavonoid. Pharmacognosy reviews. 2016;10(20):84.
8. Gutiérrez-Venegas G, Gómez-Mora JA, Meraz-Rodríguez MA, Flores-Sánchez MA, Ortiz-Miranda LFJH. Effect of flavonoids on antimicrobial activity of microorganisms present in dental plaque. Heliyon. 2019;5(12):e03013.
9. Corega C, Vaida L, Festila D, Rigoni G, Albanese M, D'Agostino A, et al. The benefits of Quercitin for dentistry and maxillofacial surgery: a systematic review. Minerva stomatologica. 2014.
10. Jaisinghani RN. Antibacterial properties of quercetin. Microbiology research. 2017;8(1):6877.
11. Gomez-Florit M, Pacha-Olivenza MA, Fernández-Calderón MC, Córdoba A, González-Martín ML, Monjo M, et al. Quercitrin-nanocoated titanium surfaces favour gingival cells against oral bacteria. Scientific reports. 2016;6(1):22444.
12. Arslan M, Murat S, Alp G, Zaimoglu A. Evaluation of flexural strength and surface properties of prepolymerized CAD/CAM PMMA-based polymers used for digital 3D complete dentures. Int J Comput Dent. 2018;21(1):31-40.
13. Gad MM, Fouda SM, ArRejaie AS, Al-Thobity AM. Comparative effect of different polymerization techniques on the flexural and surface properties of acrylic denture bases. Journal of Prosthodontics. 2019;28(4):458-65.
14. ISO 20795-1:2013; Dentistry—Base Polymers—Part 1: Denture Base Polymers. International Organization for Standardization: London, UK, 2013.
15. Al-Mahdy Y, Eltayeb H. The Effect of Nano-ZrO2 and nano-Al2O3 reinforcement on flexural and impact strength of repaired acrylic denture base. Al-Azhar Dental Journal for Girls. 2018;5(1):89-100.
16. Mansour MM, Al-Nassr MS, Shon AA, Fayad MI, Abd-Allah R. EFFECT OF TITANIUM DIOXIDE NANOPARTICLES ON MECHANI-CAL PROPERTIES OF DENTURE BASE RESIN: AN IN VITRO STUDY. Al-Azhar J Dent Sci. 2017;20:261-5.
17. He Z, Zhang X, Song Z, Li L, Chang H, Li S, et al. Quercetin inhibits virulence properties of Porphyromas gingivalis in periodontal disease. Scientific reports. 2020;10(1):18313.
18. Zidan S, Silikas N, Al-Nasrawi S, Haider J, Alshabib A, Alshame A, et al. Chemical characterisation of silanised zirconia nanoparticles and their effects on the properties of PMMA-zirconia nanocomposites. Materials. 2021;14(12):3212.
19. Raj V, Bhat V, John N, Shetty A, Joseph S, Kuriakose R, et al. Assessment of Flexural Strength and Cytotoxicity of Heat Cure Denture Base Resin Modified with Titanium Dioxide Nanoparticles: An In Vitro Study. The Journal of Contemporary Dental Practice. 2021;22(9):1025-9.
20. Abualsaud R, Aleraky DM, Akhtar S, Khan SQ, Gad MM. Antifungal activity of denture base resin containing nanozirconia: In vitro assessment of candida albicans biofilm. The Scientific World Journal. 2021;2021.
21. Karci M, Demir N, Yazman S. Evaluation of flexural strength of different denture base materials reinforced with different nanoparticles. Journal of Prosthodontics. 2019;28(5):572-9.