Journal of Techniques, ISSN: 2708-8383, Vol. 5, No. 2, 2023, Pages 134-140
DOI: https://doi.org/10.51173/jt.v5i2.1358

JOURNAL OF TECHNIQUES

Journal homepage: http://journal.mtu.edu.iq

RESEARCH ARTICLE - MEDICAL TECHNIQUES

Evaluation of Flexure Strength of Heat Cure Acrylic Resin Reinforcement with Nano Al2O3 After Polishing with Different Abrasive Materials

Nihad AlFuraiji[1*], Wafaa Atallah[1], Syed Saad B Qasim[2]

[1] College of Health & Medical Technology - Baghdad, Middle Technical University, Baghdad, Iraq

[2] Department of Bio Clinical Sciences, Faculty of Dentistry, Kuwait University, Safat 13110, Kuwait

[*] Corresponding author E-mail: nihad.hassan@mtu.edu.iq

Article Info.

Article history:

Received
21 March 2023

Accepted
18 May 2023

Publishing
30 June 2023

Abstract

Composites with Nano fillers reinforced by polymer structures are gaining popularity in the field of prosthodontic. Composite materials are being developed to meet the needs of patients, such as heat cure acrylic resins, that used so much in the field of prosthodontic.
To evaluate the flexure strength of heat-cure acrylic resin reinforcement with Nano aluminum oxide (Al2O3) after polishing with various abrasive materials.
A total of seventy rectangular specimens of heat cure acrylic resin with dimensions (65 mm length x 10 mm diameter x 3 mm thickness) Samples were separated into main seven groups classifications based on the addition of Nano Al2O3 and surface's polishing with different abrasive materials. Each group have (10) specimens.
The highest mean value of flexure strength was obtained in group (B) (87, while the lowest value was obtained in group (F) (56.9).
It concluded that the flexure strength was decreased in groups (F and G) of heat-cured resin polished with diamond, while it was increased in groups (B and C) polished with pumice, followed by the control group(A), and then by groups (D and E) that polished with colloidal.

Publisher: Middle Technical University

Keywords: Heat-Cure Acrylic; Abrasive Polishing Materials; Aluminum; Nano Fillers; Flexure Strength; Dental Composites.

1. Introduction

Acrylic resins were the most often utilized materials in the manufacture of denture bases. They were popular because of their attractive aesthetics, simplicity of handling, strong heat conductivity, minimal permeability to oral fluids, and color stability. These materials have intrinsic drawbacks, such as fatigue fracture when subjected to intra-oral stresses and the inability to sustain extra-oral impact forces. Inadequate transverse, impact, flexural, and fatigue strengths can all cause to fracture. Current advances in the realm of dental materials, as well as the creation of newer and more unique denture base materials, have allowed acrylic denture base resins to overcome some of these drawbacks. [1]. The polymethylmethacrylate (PMMA) resin was a regularly used prosthetic material, and the primary drawback of acrylic material is its poor flexural strength and surface hardness; hence, strengthening the PMMA resin with additional materials may strengthen the acrylic material [2]. Polymethyl methacrylate was a common substance used in prosthetic dentistry (PMMA). Since its debut to Due to its ease of manufacturing, low cost, light weight, and color-matching abilities, it has been utilized well for denture bases in dentistry. Acrylic resin denture founding materials, on the flip hand, have poor durability and fatigue resistance [1]. Ceramic particles have been used in many dental materials and have been proved to be biodegradable while also increasing mechanical qualities. Furthermore, the ceramic powder's white color is not likely to affect with aesthetic appeal [2]. Nevertheless, reinforcing procedures should have little effect on the mechanical characteristics of denture materials. Aluminum oxide nanoparticles are one of the components utilized to improve the characteristics of acrylic composites polymers [3]. Nanoparticles of Al2O3 (99.9% Al2O3) Aluminum oxide, often known as (alumina), is a very inexpensive and frequently used ceramic material. Aluminum oxide was delivered in the form of (Nano-particles), with exceptional size, shape, and purity (99.9%). The strong ionic bonding structure of aluminum oxides contributes to its high rigidity, hardness, strength wear resistance, and thermal conductivity [4]. Aluminum oxide (Al2O3) powder was employed for the development of the physical qualities of high-impact acrylic resin. Consequently, studied the flexural strength (FS) effects of Al2O3 at two distinct ratios [5]. The major analytical technique for denture base material modifications, strengthening, revisions, and concentration was determined as flexural strength. The National Bureau of Standards in the United States of America initiated bending testing on acrylic denture bases [6]. Hand polishing methods use diamond suspensions that get smaller and smaller, followed by a colloidal silica solution. Traditionally, dental prostheses have been manually shined on a lathe at the dentistry lab, with pumice as the insulation material. Although diamond suspension offers mechanical power on the polished specimen surface, colloidal silica produces dispersion as well as chemical-mechanical (CMP) acts by combining mechanics abrasive and chemical surface interaction [6]. Colloidal silica is the optimum polishing media for lowering beneath and surface deterioration in ceramics, and it is also a suitable transitional polishing grit following diamond

Nomenclature & Symbols			
Al_2O_3	Aluminium Oxide	PMMA	Polymethylmethacrylate Resin
F	Fracture Load	E_f	Flexural Modulus
FS	Flexural Strength	L	Distance Between the Two Supported Points
GPa	Grade Point Average	MPa	Mega Pascal
τ_{max}	Maximum Shear Stress	CMP	Chemical-Mechanical Action
σ	Beam Deflection	W	Specimen Width
H	Specimen Thickness		

suspensions in metal polishing due to its CMP action. Unfortunately, there has been limited investigation into the utilization of diamond and colloidal silica solutions as abrasive polishing materials for PMMA denture base resins [7]. The null hypothesis stated that including Al_2O_3 in various weight percentages (wt.%) and polishing with various abrasive polishing agents would enhance the flexural strength (FS) of reinforcement groups compared to the control (unreinforced acrylic resin specimens). This study assessed the flexure strength of heat cure acrylic resin reinforcement with Nano Al_2O_3 at various weight percentages after polishing with various abrasive polishing materials for new contribution research in dental polishing investigations.

2. Materials and Procedures

2.1. Preparation of custom-made plastic mold

In this study, a total of 70 samples rectangular in shape were prepared. The dimension of the samples (65 mm length x 10 mm diameter x 3 mm thickness) (ISO 1567 Standard). They were constructed of plastic; a plastic pattern (solid plastic block) can see in Fig. 1 was designed in AutoCAD 2015 (Autodesk) and processed for 10 minutes on a computer numerical control machine [8].

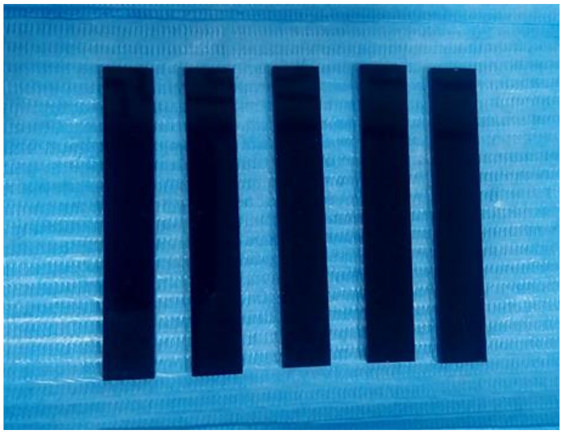

Fig. 1. Plastic patterns used for the preparation of the molds for acrylic samples

2.2. Specimen preparation

A conventional flask technique was used, mixing amount of hard die stone (type 4) according to manufacture (100gm/25mL) (p/w) and filling the flask's lower portion by it then the plastic pattern was inserted into its place after the die stone set applied of separating medium by using a wide brush. After separating medium dried place, the upper half of the flask over the lower half and then added the second layer of the die stone over the first layer until the upper half is filled with die stone as seen in Fig. 2, and covered then place the flask in the clamp, after setting the second layer of die stone open the flask and remove the plastic pattern After this, the mold will obtained, and apply separating medium and it's ready for packing [9].

Fig. 2. Plastic patterns positioned in the lower half of the flask

2.3. Addition of Nano-filler

The incorporation of Nano reinforcement particles (Al_2O_3 (Alpha) grain size 50 nm, purity 99.9%, USA), is a white powder formed of nanoparticles of alpha-phase aluminum oxide 99.9%, a compound made up of two aluminum atoms and three oxygen's formed a bond together in a hexagonal crystal structure), was made by weight in two groups, the adding would include 1%, and 1.5% to acrylic powder (Pink hot-cure acrylic denture base resin (Vertex, Implacryl, Netherlands) [7], sensitive balance high accuracy (±0.0000g, Mettle Type AE260-S SNR H50193) was used as seen in Fig. 3, the filler well dispersed in the powder by amalgamator device (SinaliDent) using (300vibration/minute) for two minutes as seen in Fig. 4 to had homogeneous mixing[10]. To decrease the risk of particle agglomeration and processing conditions, the powder mixture containing Nano filler was simultaneously combined with acrylic powder [10].

Fig. 3. Sensitive balance high accuracy

Fig. 4. Amalgamator device

2.4. Mixing ratio of alumina nanofillers with acrylic

The weight percentages (wt. %) and amounts of hot-cure acrylic polymer, monomer, and Alumina Nano fillers used were included in the research displayed in Table 1.

Table 1. Showed the weight percentages (wt. %), as well as the polymers, monomers, and Al2O3 Particles Nano-filler, amounts employed in this study [11]

Proportion of polymer	Proportion of monomer (ml)	Al_2O_3 Weight percentage (wt. %)	Proportion of Al_2O_3 Weight percentage (wt. %)
21.000g	10ml	0%	0%
20.790g	10ml	1%	0.210%
20.685g	10ml	1.5%	0.3150%

2.5. Acrylic resin packing

The acrylic resin-packed process was initiated once the acrylic approached the dough form. Prior to actually placing the molds, the resin was withdrawn from the Jar and started rolling. After making metal-on-metal friction, the flask's two sides were rejoined beneath pressure (hydraulic press) for 5 minutes. Then clamping and transport to the boiling water follow [12, 13].

2.6. Curing

This was performed by putting the clamped flask in a water bath (Digital Stainless Steel Water Bath, WB-2R4H-15, China) and heating it for 90 minutes at 20 ˚C-70 ˚C and 30 minutes at 100 ˚C. Before deflasking and extracting the acrylic samples from the die stone molds, the metal flask was allowed to cool in the water bath to room temperature [14, 15].

2.7. Finishing and polishing

Always use (120) grit sandpaper for touch-ups to achieve a smooth finish (soaking the rubber tube in cold water). A gear lathe was used to make a sample test. The sample and brush distance were kept to a minimum of 1-2 mm. By polishing with a bristle brush (Vertex) containing pumice, diamond slurry, and colloidal silica, the dental lathe speed was set to a comfortable relatively low speed (1425 rpm). The amount of pumice stone (50g x 100ml), diamond, and colloidal silica used to polish the sample is 50ml for one sample, and the polishing time is (2 minutes) [16].

2.8. Flexure strength test

The capacity of composites or materials to withstand bending deflection when energy is imparted to the structure is specified as the flexure strength test. The flexural test was performed at room temperature in accordance with ISO 178, 2003, using a universal bending test machine produced by (Laryee Corporation in China); model (WDW-50) shown in Fig. 5. The crosshead speed was 0.7mm/min, and the stress (5KN) was gradually raised until the specimen shattered. The following equations can be used to compute flexural strength, flexural modulus, and maximum shear stress:

$$Б = = \frac{3fL}{2wh^2}$$

$$Ef = \frac{FL^3}{4dwh^3} = \frac{mL^3}{4wh^2}$$

$$\tau_{max} = \frac{4F}{4wh}$$

Where: Б: Flexural strength (MPa). E_f: Flexural modulus (GPa). (Б) Whenever a weight F is delivered to a beam, it deflects. (τ_{max}): Shear stress at maximum (MPa). (F): (N). (L): The distance between each of the places recommended. (W): specimen width (mm). (H): specimen thickness (mm) [17].

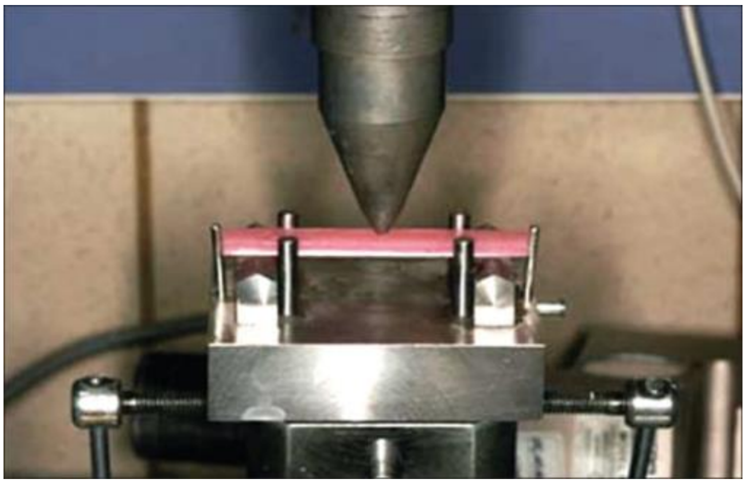

Fig. 5. Showed an acrylic sample being tested on a Universal bending test machine

3. Results

3.1. Descriptive statistics of flexure strength test

Descriptive statistics of flexure strength of all groups with mean values of flexure strength test, slandered deviation, as well as the standard error of the mean for each group were all listed in Table 2. For seven groups of 70 specimens showed high mean values of flexure strength in group (B) (87.3), and least group (F) (56.9). showed the mean distribution and standard deviations of flexure strength values as demonstrated in Fig. 6.

3.2. Inferential statistical of flexure strength test

The Least Significant Difference (LSD) analysis in Table 3 confirmed statistically important distinction exists among the groupings (A, B, C, D, E, F, and G). According to the flexure strength data, the addition of Alumina Nano filler and polishing with various abrasive materials has a substantial influence on the mean values. There were no significant differences in all groups except between the control group and B1, F1, C1.5 and other groups significant differences with each other's, there were significant differences between them (P-value $P<0.001$).

Table 2. Flexure strength descriptive statistics conducted on the tested samples

Flexure strength test								
Polishing	Studied Groups	N	Mean	Std. Deviation	Std. Error	Range Mini.	Range Maxi.	ANOVA test (P-value)
A- Control		10	65.2	6.893	2.180	54	75	P = 0.00 Highly sign. ($P<0.01$)
Pumice	B- Al_2O_3 (1 %)	10	87.3	9.019	2.852	75	100	
	C- Al_2O_3 (1.5 %)	10	64.1	5.486	1.735	59	75	
Colloidal	D- Al_2O_3 (1 %)	10	61.4	5.038	1.593	53	69	
	E- Al_2O_3 (1.5 %)	10	62.8	6.477	2.048	53	69	
Diamond	F- Al_2O_3 (1 %)	10	56.9	7.325	2.316	50	70	
	G- Al_2O_3 (1.5 %)	10	59.8	4.290	1.356	53	64	
	Total	70						

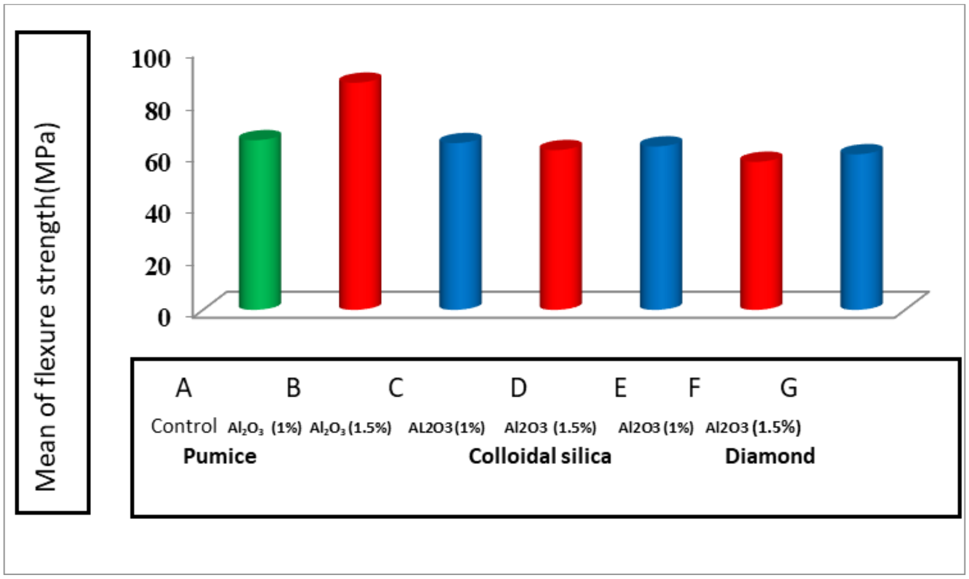

Fig. 6. Bar chart showed a mean distribution of flexure strength test (MPa) for all investigated groups

Table 3. A least significant difference (LSD) analysis for the flexure strength test of the studied groups

Studied groups (Flexure)		LSD test (P-value)
A Control	B 1 % Al_2O_3 (Pumice)	P = 0.00 Highly sign. (P<0.01)
	C 1.5 % Al_2O_3 (Pumice)	P = 0.738 Non sign. (P>0.05)
	D 1 % Al_2O_3 (Colloidal)	P = 0.198 Non sign. (P>0.05)
	E 1.5 % Al_2O_3 (Colloidal)	P = 0.414 Non sign. (P>0.05)
	F 1 % Al_2O_3 (Diamond)	P = 0.006 Highly sign. (P<0.01)
	G 1,5 % Al_2O_3 (Diamond)	P = 0.069 Non sign. (P>0.05)
B 1 % Al_2O_3 (Pumice)	C 1.5 % Al_2O_3 (Pumice)	P = 0.00 Highly sign. (P<0.01)
	D 1 % Al_2O_3 (Colloidal)	P = 0.00 Highly sign. (P<0.01)
	F 1 % Al_2O_3 (Diamond)	P = 0.00 Highly sign. (P<0.01)
C 1.5 % Al_2O_3 (Pumice)	E 1.5 % Al_2O_3 (Colloidal)	P = 0.658 Non sign. (P>0.05)
	G 1.5 % Al_2O_3 (Diamond)	P = 0.146 Non sign. (P>0.05)
D 1 % Al_2O_3 (Colloidal)	E 1.5 % Al_2O_3 (Colloidal)	P = 0.633 Non sign. (P>0.05)
	F 1 % Al_2O_3 (Diamond)	P = 0.128 Non sign. (P>0.05)
E 1.5 % Al_2O_3 (Colloidal)	G 1.5 % Al_2O_3(Diamond)	P = 0.308 Non sign. (P>0.05)
F 1 % Al_2O_3 (Diamond)	G 1.5 % Al_2O_3 (Diamond)	P = 0.324 Non sign. (P>0.05)

4. Discussion

Aluminum oxide is a chemical made up of two aluminum atoms and three oxygen atoms that are linked together in a hexagonal crystal structure. Because of its availability and abrasiveness, alumina has found various applications in the industry. Including metal nanoparticles in polymer matrices can improve their mechanical characteristics. Nanoparticles (NPs) play an important role in various fields and were extensively studied due to their excellent physical and chemical properties [22]. The purpose of this study was to see how Nano aluminum oxide affected heat cure denture base resin flexural strength after polished with (Pumice, colloidal/diamond) materials. Six groups of heat cure denture base resin with 1wt.% and 1.5wt.% Nano aluminum oxide were studied, as well as a control group polished with various materials.

Previous study found that adding aluminum oxide to the Polymethylmeth acrylate (PMMA) denture base resin enhances flexural strength [18]. There were substantial variations in flexural strength between hot-cure acrylic resin testing groups, according to the null hypothesis. Moreover, PMMA is the ideal material for denture bases due to its crucial attribute of being a suitable denture-based material. Acrylic resin has a number of drawbacks. Low heat conductivity, monomer leftovers, potential porosity, porous and easily fractured; low flexural strength against metal frames [19]. Also Because of its great qualities such as simplicity of production, lightweight, cheap cost, aesthetic properties, and oral durability, PMMA is a desirable material for tooth replacement applications. PMMA outperformed in terms of biomaterials, reliability, as well as a lack of flavor, odor, and tissue irritation. A sense of security is enhanced by color, practicality, and attractiveness. PMMA-based polymers used in a variety of biological applications, including intraocular lenses and orthopedic bone cements. PMMA is also employed in the design of interiors, transparent dielectric films, glass replacements, acrylic paints, and Nano-sized foams [20]. PMMA, on the other hand, has poor strength, is fragile on impact, and has limited fatigue resistance. To address these problems and enhance mechanical qualities of PMMA denture bases, the incorporation of filler particles and rubber particles in the PMMA matrix material has been proposed [20]. The inclusion of a weight percentage (1wt%) of aluminum oxide powder boosted the flexural strength of PMMA composites in this investigation, especially in Groups B and F. This discovery might be linked to the right distribution of alumina spheres inside acrylic denture base materials, which could be ascribed to microscopic particle size and proper distribution of Al_2O_3 nanoparticles in the acrylic matrix. Incorporating 1.5wt.% aluminum oxide powder into heat cure denture base resin (Groups C, E, and G) did not lead to a substantial rise in flexural strength compared to traditional denture resin (Group-A), and there was a significant relation between this decrease in mechanical characteristics and an increase in flexural strength.

This study's findings agreed with the findings of a previous study by (Marei et al.) that increasing the weight percentage of (Nano- Al_2O_3) particles decreased the flexural strength values of PMMA composite specimens, because any increase in particle number leads to agglomeration because of its elevated surface energy, which will function as localised stress distribution zones where the collapse will commence, and this decreasing may also be due to the fact that [20].

This research appears to contradict the outcomes of (Pentapati et al.), Large amounts of aluminum oxide nanoparticles appear to boost flexural strength, possibly due to the formation of scaffolds inside the composite resin, thus raises the specimens' breakdown resistance when a force is put on them [3]. Different polishing techniques can have used with acrylic denture base Acrylic resin is traditionally finished in a dental laboratory and polished by mechanical technique utilizing felt-cones and slurry of fine pumice and water, then feel cones using. Water with chalk powder. Mechanical polishing produces sur-facial abrasion and gradually lowering notches till. The final output is a smooth, polished surface. The polishing sequence was eliminated by a new acrylic resin polishing method known as chemical polishing (CP). The acrylic resin finishing stages are only necessary. The technique consists of immersing the prosthesis after finishing procedures into a heated methyl-methacrylate monomer bath (75 °C) for 10 s [21].

5. Conclusion

Inside the topic of this investigation: -

- It was concluded that the flexural strength was decreased in the groups polished with diamond suspension due to the diverse composite structures obtained after mixing Al2O3 with acrylic materials with different topography, while it was increased in the groups polished with pumice.
- It was concluded that the polishing abrasive materials (Diamond and Pumice) was significantly increased flexure strength than colloidal abrasive material.

Acknowledgement

I would want to thank Mrs. Sahera Sabar for her invaluable assistance in completing this work.

References

[1] Totu, E.E., et al., On physical and chemical characteristics of Poly (methylmethacrylate) nanocomposites for dental applications. Mater. Plast, 2017. 54: p. 666-672, https://www.revmaterialeplastice.ro/pdf/15%20TOTU%204%2017.pdf.
[2] Jehan, A., S. Ahila, and B. Muthukumar, Evaluation of flexural strength and surface hardness of heat activated provisional PMMA resin reinforced with nanoparticles–An in vitro study. J Med Pharm Allied Sci, 2022, 11: p. 4340-8 https://jmpas.com/admin/assets/article_issue/1645974436JMPAS_JANUARY_-_FEBRUARY_2022.pdf.
[3] Barzegar, A., T. Ghaffari, and A. Parizad, Effect of incorporating aluminum oxide nanoparticles on thermal conduction and flexural strength of acrylic resins. Dental Research Journal, 2022. 19, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9164662/.
[4] Hamad, Q., Study the Effect of Nano Ceramic Particles on Some Physical Properties of Acrylic Resins. Engineering and Technology Journal, 2017. 35(2 Part A).
[5] Vojdani, M., R. Bagheri, and A.A.R. Khaledi, Effects of aluminum oxide addition on the flexural strength, surface hardness, and roughness of heat-polymerized acrylic resin. Journal of dental sciences, 2012. 7(3): p. 238-244 https://doi.org/10.1016/j.jds.2012.05.008.
[6] Gopi Chander, N., V. Jayaraman, and V. Sriram, Comparison of ISO and ASTM standards in determining the flexural strength of denture base resin. European Oral Research, 2019. 53(3): p. 137-140, https://dergipark.org.tr/en/pub/eor/issue/58126/807534.
[7] Janardanan Kavitha, V., Effect of zirconium oxide and cellulose nanoparticles addition on the flexural strength, impact strength and translucency of heat polymerized acrylic resin: an in vitro study. 2021, https://www.researchgate.net/profile/Vivek-Nair-18/publication/356669087_Effect_of_zirconium_oxide_and_cellulose_nanoparticles_addition_on_the_flexural_strength_impact_strength_and_translucency_of_heat_polymerized_acrylic_resin_an_in_vitro_study/links/632acdef70cc936cd3236f96/Effect-of-zirconium-oxide-and-cellulose-nanoparticles-addition-on-the-flexural-strength-impact-strength-and-translucency-of-heat-polymerized-acrylic-resin-an-in-vitro-study.pdf.
[8] Chi, Y., Effect of silica filler on the mechanical properties of silicone maxillofacial prosthesis. MSc Thesis, Indiana University School of Dentistry, Indianapolis (MI), 2014, https://scholarworks.iupui.edu/handle/1805/4470.
[9] Abdulkareem, M.M. and N.A. Hatim, the effect of adding metallic nano fillers on flexural strength of heat cure acrylic resin treated by microwave. International Journal of Enhanced Research in Science, Technology & Engineering, 2016. 5(8): p. 17-25 https://www.erpublications.com/sitepanel/download.php?filename=download/download_11_08_2016_15_21_04.pdf.
[10] Gad, M.M., et al., Double-layered acrylic resin denture base with nanoparticle additions: An in vitro study. The Journal of Prosthetic Dentistry, 2022. 127(1): p. 174-183, https://doi.org/10.1016/j.prosdent.2020.08.021.
[11] Ali Sabri, B., et al., A review on enhancements of PMMA denture base material with different nano-fillers. Cogent Engineering, 2021. 8(1): p. 1875968, https://doi.org/10.1080/23311916.2021.1875968.
[12] Ghosh, P., K. Kumar, and A. Kumar, UDM processed superior acrylic resin based ZrO2 nanoparticle reinforced composite for dental application. Materials Research Express, 2019. 6(10): p. 105404, https://iopscience.iop.org/article/10.1088/2053-1591/ab3917/meta#:~:text=DOI%2010.1088/2053%2D1591/ab3917.
[13] Gad, M.M., et al., PMMA denture base material enhancement: a review of fiber, filler, and nanofiller addition. International journal of nanomedicine, 2017. 12: p. 3801, https://doi.org/10.2147%2FIJN.S130722.

[14] Deste, G., R. Durkan, and P. Oyar, Evaluation of the Transverse Strength and Elastic Modulus of High Impact Denture Base Material. JournalofDentalMaterials&Techniques, 2020. 9 (3).
[15] Kuhar, M. and N. Funduk, Effects of polishing techniques on the surface roughness of acrylic denture base resins. The Journal of prosthetic dentistry, 2005. 93(1): p. 76-85, https://doi.org/10.1016/j.prosdent.2004.10.002.
[16] Salih, S.E., J.K. Oleiwi, and T. Alaa Mohammed, Investigation of hardness and flexural properties of pmma nano composites and pmma hybrids nano composites reinforced by different nano particles materials used in dental applications. Engineering and Technology Journal, 2016. 34(15 Part), https://www.iasj.net/iasj/download/64631667015a9636.
[17] Satyanarayan, A., et al., Assessing The Outcomes of Aluminium Oxide On Surface Roughness and Flexural Strength of Heat Cure Denture Base Resin. Journal of Pharmaceutical Negative Results, 2022: p. 1116-1118, https://doi.org/10.47750/pnr.2022.13.S03.175.
[18] Aboshama, M., A. Sayed, and A.F. Elhagali, Effect of Different Nano-Fillers Addition on The Mechanical Properties of Heat-Polymerized Acrylic Resin. Al-Azhar Assiut Dental Journal, 2022. 5(2): p. 141-148, https://dx.doi.org/10.21608/aadj.2022.267266.
[19] Bhat, A., et al., Review on nanocomposites based on aerospace applications. Nanotechnology Reviews, 2021. 10(1): p. 237-253, https://doi.org/10.1515/ntrev-2021-0018.
[20] Kitao, N., et al., Mechanical properties of artificial porcelain denture teeth. Journal of Osaka Dental University, 2015. 49(2): p. 245-251, https://doi.org/10.18905/jodu.49.2_245.
[21] M. Q. Al-Rifaiy, "The effect of mechanical and chemical polishing techniques on the surface roughness of denture base acrylic resins," The Saudi dental journal, vol. 22, no. 1, pp. 13-17, 2010. https://doi.org/10.1016/j.sdentj.2009.12.006.
[22] W. Atallah, N. AlFuraiji, and O. H. Hussein, "Nanocomposites for Prosthetic Dental Technology: A Systemic Review," Journal of Techniques, vol. 5, no. 1, pp. 129-136, 2023. https://doi.org/10.51173/jt.v5i1.1178.