Tikrit Journal for Dental Sciences 11(2) (2023) 178-187
https://doi.org/10.25130/tjds.11.2.4

Tikrit Journal
for
Dental Sciences
https://tjds.tu.edu.iq
ISSN:2073-1213

Effect of Beverage Solutions on Surface Roughness of PEEK CAD –CAM, 3D Printing Denture Base and Heat Cure Acrylic Resin Denture Base Materials

Noor Muwafaq Fadhil [1] *
Nada Zuhair Mohammed [2]

[1, 2] Department of Prosthetics Dentistry Mousl University, Collage of Dentistry, Iraq.

Keywords:
Denture base, Beverages, Surface roughness.

Article Info.:

Article History:
Received: 25/3/2023
Received in revised form: 17/4/2023.
Accepted: 7/5/2023
Final Proofreading: 7/5/2023
Available Online: 1/12/2023

Citation: **Fadhil NM, Mohammed NZ. Effect of Beverage Solutions on Surface Roughness of PEEK CAD –CAM, 3D Printing Denture Base and Heat Cure Acrylic Resin Denture Base Materials. Tikrit Journal for Dental Sciences 2023; 11(2): 178-187. https://doi.org/10.25130/tjds.11.2.4**

***Corresponding Author:**
Email:

Master student, Department of Prosthetics Dentistry Mousl University, Collage of Dentistry, Iraq.

Abstract

The Aim: The aim of this research was to investigate how distilled water, tea, coffee, and cola affected the surface roughness of poly ether ether ketone CAD-CAM, 3D printing, and heat cure acrylic resin denture bases at specific intervals (6 ,12days). Materials and Methods: Disk shape 10 mm (diameter) ×2 mm (thickness), manufactured from materials used which were PEEK, 3D printing and heat cure acrylic resin. Total number of samples are n= (75) samples, control samples not immersed in beverage media n= 15, experimental samples immersed in beverage solutions (distilled water, tea, coffee and cola) n=60 for evaluating the surface roughness at (6, 12 and 24 days).Then all collecting data were statically analyzed by spss version 25, by means of descriptive statistics, analysis of variance (ANOVA) and duncan multiple range tests at $p \leq 0.05$. The Results: The results revealed a significant increase in surface roughness in all beverage solutions at $p \leq 0.05$. Conclusions: All beverage solutions had a negative effect on surface roughness of all experimental materials, the surface roughness increased. cola had the most aggressive effect followed by coffee then tea and distilled water have the least effect.

Introduction:

The appearance of aging and material degradation are common causes of the need to replace dentures [1]. The extreme intraoral environment has an impact on the performance and longevity of denture prosthesis. Denture wearers frequently consume beverages, and their saliva's pH changes from acidic to alkaline [2]. Because of its low cost, ease of handling and manipulation, good physical and mechanical properties, and suitable esthetic appearance, polymathylmethacrylate (PMMA) resin material has been the "gold standard" for making traditional complete dentures [3]. With the advancement of digital technology, new CAD-CAM-based material processing processes for dentistry, such as subtractive milling (SM) and additive manufacturing (AM), have emerged [4]. The advantage of constructing denture bases digitally is the ability to create dentures in less time and with fewer processing stages [5]. Additive 3D printing has been found to offer several advantages over subtractive milling, including the ability to build intricate forms, being less expensive due to less material waste, and not exhibiting rotary burr wear [6]. When used as the primary material for dentures, PMMA is known to have several limitations, most notably in terms of mechanical properties. PEEK has been introduced to circumvent the limitations of PMM [7]. PEEK exhibits excellent mechanical properties as well as excellent biocompatibility [8]. The surface properties of any denture base material are of special relevance, as investigations of denture base materials have demonstrated a clear correlation between surface roughness, plaque accumulation and Candida albicans adherence [9, 10]. Candida species have been observed to be more common in denture-related stomatitis [11, 12].

Materials and Methods:

Experimental Design of this Research

Control samples not immersed, experimental samples immersed in beverage solutions (distilled water, tea, coffee, cola), at different intervals (6, 12 and 24 days).

Samples Processing Techniques

In this investigation, surface roughness tests were carried out using discs with dimensions of 10 mm (diameter) and 2 mm (thickness) [13], as shown in Fig (1).

PEEK Samples Processing

Samples of PEEK had been digitally designed using CAD software (halot sky, korea), then kept in (STL) file, and then transferred to exocad dental CAD/CAM (MAXX milling machine, dry-milling, 5 axes, korea), as shown in Fig. (2). For milling PEEK blank (Dental Direk, Germany) according to the manufacturer's instructions.

3D Printing Samples Processing.

The same STL file format of PEEK CAD-CAM utilized for 3D printing sample. The (STL) file was sent to 3D printing machine (3D printing Asiga Max Machine, Australia). A50-micrometer layer thickness was chosen for printing the samples, at 0 angle orientation with supporting structures [3]. The 3D printing (Mack 4D Denture, Germany) had been utilized for fabricated samples printed in 385 nm wavelength, with direct light processing (DLP) Then the printed samples were cleaned 2x 3 min in with isopropyl alcohol (99.9%) (essentq, spain) in ultrasonic Bath (acuretta, Taiwan), to remove the excess resin. After complete drying, the specimens were polymerized in post polymerized unite (UV pre pro post curing machine, Taiwan) for 18 min at 405 wave length, according to manufacturer's instructions.

Heat Cure Acrylic Resin Samples Processing

The compression mold technique was used to create specimens that simulated laboratory techniques for the manufacturing of denture bases. The wax specimens were made to a specific size. These wax patterns were inserted in dental stone of type IV (Elite®, Italy) in metallic flasks(Ash, England). After that de-waxing processing prepared [3]. The heat polymerized acrylic (Veracril®/Opti-

Cryl®, New Stetic S.A.) had been utilized, mixed in a 3:1 volumetric proportion with methyl methacrylate (MMA) monomer. The compounds were allowed to stand for 10 minutes, which is the time required to pass the plastic stage according to the product's specifications. It was then put in mechanical pressing molds to make test samples. The molds were pressed to 2000 psi by a laboratory hydraulic press for 5 minutes before being transferred to a thermal reservoir and subjected to a heating curve of 73°C for 90 minutes, followed by a curve of 95°C for 30 minutes before being removed from the reservoir and placed outside for cooling [14]. All specimens had one surface finished and polished to behave like a polishing surface and another surface that appeared like tissue surfaces. All finishing and polishing techniques were carried out by a single trained operator [15]. By utilizing silicon carbide polishing (paper water proof, Greece), and universal polishing machine (universal polisher, Spectrographic Ltd. Metaserv, England), under running water, then the specimens were fined. Polishing was achieved with a muslin cloth brush, polishing paste (Universal polishing paste, Ivoclar vivadent, Germany) and polishing machine [16, 17], after that all of samples kept in distilled water at 37C for 24 hours According to ISO 20795-1:2013.

Beverage Solutions Preparations

Cola premade (Coke®, Iraq), Distilled water premade (Iraq)

Coffee (Mahmood® Coffee Classic Brazilian, Turkey) and tea (Cihan Tea, Sirilanka) prepared by dissolving 2 g of coffee and tea in 200 ml of distilled boiling water for 2 min [15]. The coffee and tea solutions were then stirred for 10min until the temperature of the solution reached 37˚C and the mixture was then run through filter paper to remove any particle remains [18].

Immersion Periods Protocol

According to (Guler *et al*,. 2005) [19] who stated that the average time to spent drinking one cup of a drink is 15 minutes, whereas the average coffee intake among coffee drinkers is 3.2 cups per day. As a result, keeping the drink for 24 hours was equivalent to consuming it over a month. Six days imitate the utilization of the beverage over a six-month period [15]. 12 days of beverage consume in over of a year [20]. Beverage intake for 24 days promotes over 2-years [21].

Each experimental specimen was suspended and immersed in the solutions by threads, ensuring that it did not come into contact with the container or other specimens, and at the end, a label indicating that the specimen's codes were present. All containers were labeled with the type of solution and kept in (37°C) incubator (INB EN, JRAD, Syria), to simulate the oral environment, which was refreshed daily [15].

PH of Beverage Solutions

The pH level of the solutions was measured by pH meter (eco test PH2,China) for indicated the PH value of beverage media (Distilled Water 7, Tea 4.8, Coffee 4.2, Cola 2.3).

Surface Roughness Test.

The surface roughness was measured using the talysurf 10 roughness tester (Taylor Hobson Ltd, UK), as shown in Fig.(3). Which could detected minutest surface alterations by altering a diamond stylus in contact with the surface while altering laterally across the sample. The surface roughness rate was calculated as the mathematical average of the absolute rates of the searched profile height of surface imperfections, measured from a mean line within a predetermined sample length. The vertical movement of the stylus was measured as the surface variations. The radius of stylus tip was 2.5µm with a scan length range of 0.8mm [22].

Results:

Surface Roughness of PEEK Denture Base

The outcomes for the effect of beverage media on the surface roughness of PEEK denture base mean and stander deviation Table (1) the surface roughness of PEEK denture base increased in all beverage

solutions types, with cola having the greatest surface roughness value as compared to the control group.
One-way analysis of variance (ANOVA) Table (2) showed that all beverage solution types had a statistically significant impact on the surface roughness of the PEEK denture base (at $p \leq 0.05$).
Duncan s Multiple comparison Test table (1) showed that of all beverage solutions significantly increased the surface roughness of PEEK denture base (at $p \leq 0.05$).

Surface Roughness of 3D Printing Denture Base
The outcomes for the effect of beverage media on the surface roughness of 3D printing denture base, mean and standard deviation Table (3) noticed that all beverage solutions types elevated the surface roughness of 3Dprinting, with cola having a higher value than the control group.
One-way analysis of variance (ANOVA) Table (4) revealed that whole beverage solutions has a statistically significant influence on the surface roughness of 3D printed denture base (at $p \leq 0.05$).
Duncan s Multiple comparison Test Table (3) shown that all types of beverage solutions significantly increased the surface roughness of 3D printing denture base (at $p \leq 0.05$).

Surface Roughness of Heat Cure Acrylic Resin Denture Base
The outcomes for the effect of beverage media on the surface roughness of heat cure acrylic denture base, mean and standard deviation Table (5) demonstrated that all beverage solutions raised the surface roughness of heat cure acrylic, with cola achieving the highest levels in comparison to the control group.
One-way analysis of variance (ANOVA) Table (6) revealed that whole beverage solutions showed a statistically significant impact on the surface roughness of heat cure acrylic denture base (at $p \leq 0.05$).
Duncan s Multiple comparison Test Table (5) demonstrated that the effect of all forms of beverage solutions significantly roughened the surface roughness of heat cure acrylic denture base (at $p \leq 0.05$).

Discussion:
The denture base is in close contact with oral cavity tissues, and the denture base's poor surface structure encourages the growth of microorganisms [(23)].

PEEK Denture Base
The outcomes owing to the fact that PEEK has a high degree of nanoscale surface characteristics, including a higher nano-rough surface topography, which significantly increases surface area and shows the new chemical composition. As a result, the PEEK group had the highest surface roughness before and after solution treatment [(16)]. This results was in agreement with study of Chaijareenont et al . (2018) [(24)] who illustrated that PEEK surface roughness and irregularity had been increased when concentrations of sulfuric acid increased. Due to PEEK possesses chemical connections that degrade when the pH is changed, and under acidic conditions, hydrolyze quickly to the corresponding carbonyl molecule (aldehyde and ketone) and alcohol [(25)] .

3D Printing Denture Base
The outcomes attributed to water sorption causes water to penetrate into the matrix of a 3D printing polymer structure [(26)]. This results was agreed with Radwan (2021) [(27)] ; Gad et al. (2022) [(28)]. Acidic pH and beverage pigments such as coffee, tea, lemon juice, orange juice, red wine, and coke-based drinks have been shown to have a negative impact on acrylic resin dentures, resulting in increased surface roughness [(29)]. Which could be attributed to alterations in the properties of the polymeric materials, softening caused by leaching of the some components that contributing to the formation of a rough surface [(30)].

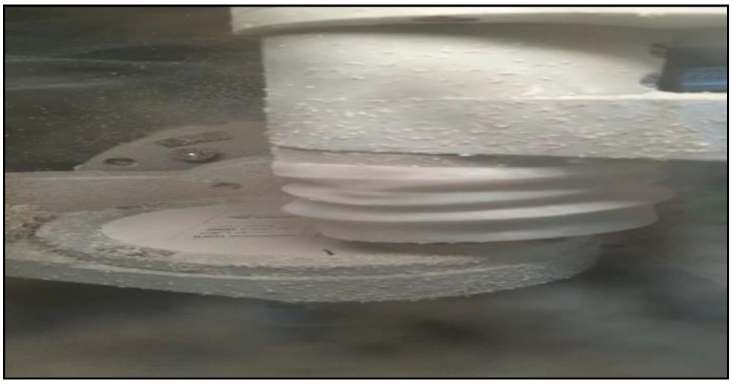
Heat Cure Acrylic Resin Denture Base
The results confirming to the truth that acrylic resin possess a polar ester group (COOH). Polar substances are hydrophilic, that means they absorb fluids quickly [(31)]. In addition, Surface disintegration of

polymers in an acidic environment, resulting in a rougher surface [32]. Because of their acid content, the aging impact of heat-cured acrylic resin in tea and coffee beverages with moderate acidity resulted in increased surface roughness in heat-cured acrylic [33]. Coca-Cola possess a low PH because it includes phosphoric acid which might to be as a causal factor because it acts as a plasticizer and produces alterations in surface roughness [34]. Moreover, the explanation for the small surface change of acrylic resin denture base is the neutral PH level of distilled water [15].

Conclusion:

All tested materials negatively affected by beverage solutions. Cola had the highest roughness affect followed by coffee followed by tea followed by distilled water which had the lest effect on surface roughness of tested materials.

Figure (1): Shape and dimensions disc of surface roughness sample of all tested materials



Figure(2): PEEK blank in milling machine

Figure(3): Talysurf 10 Roughness Tester

Table (1): Mean, standard deviation and duncan test for the effect of beverage media on the surface roughness of PEEK denture base

Beverage Media	**Immersion periods**	**Mean (μm)**	**± Std. Deviation**	**Duncan**
Control	**Non- immersed**	.5100	.07416	**A**
DW	6-months 1-year 2-years	.5940 .6880 .7720	.06189 .04658 .04868	**B** **C** **D**
Tea	6-months 1-year 2-years	6760 .7980 .9300	.05244 .12814 .02828	**B** **C** **D**
Coffee	6-months 1-year 2-years	.6800 .8180 .9540	.06066 .03899 .02702	**B** **C** **D**
Cola	6-months 1-year 2-years	.7580 .9180 1.3440	.03768 .04764 .15726	**B** **C** **D**

Table (2): One-way analysis of variance(ANOVA) for the effect of beverage media on the surface roughness of PEEK denture base

Beverage Media	Immersion periods	Sum of squares		Df	Mean square	F-ratio	*p*-value
D.W	0-time 6months 1-year 2-years	Between Groups Within Groups Total	.194 .055 .249	3 16 19	.065 .003	18.621	.000
Tea	0-time 6months 1-year 2-years	Between Groups Within Groups Total	.480 .106 .585	3 16 19	.160 .007	24.225	.000
Coffee	0-time 6months 1-year 2-years	Between Groups Within Groups Total	.542 .042 .584	3 16 19	.181 .003	68.812	.000
Cola	0-time 6months 1-year 2-years	Between Groups Within Groups Total	1.842 .136 1.978	3 16 19	.614 .008	72.425	.000

Table (3): Mean, standard deviation and duncan test for the effect of beverage media on the surface roughness of 3D printing denture base

Beverage Media	Immersion Period	Mean(µm)	± Std. Deviation	Duncan
Control	**Non - immersed**	.4220	.04550	**A**
D.W.	6-Months 1-Year 2-Years	.4980 .6060 .7200	.04207 .07057 .06042	**B** **C** **D**
Coffee	6-Months 1-Year 2-Years	.6280 .7360 .8540	.04604 .05550 .06580	**B** **C** **D**
Tea	6-Months 1-Year 2-Years	.6340 .7320 .8620	.04722 .04438 .06181	**B** **C** **D**
Cola	6-Months 1-Year 2-Years	.7280 .8560 1.0080	.06140 .04827 .06979	**B** **C** **D**

Table(4): One-way analysis of variance(ANOVA) for the effect of Beverage media on the surface roughness of 3D Printing Denture Base

Beverage Media	Immersion periods	Sum of squares		Df	Mean square	F-ratio	*p*-value
D.W	0-time 6months 1-year 2-years	Between Groups Within Groups Total	.253 .050 .303	3 16 19	.084 .003	27.049	.000
Tea	0-time 6months 1-year 2-years	Between Groups Within Groups Total	.516 .040 .557	3 16 19		94.999	.000
Coffee	0-time 6months 1-year 2-years	Between Groups Within Groups Total	.505 .046 .552	3 16 19	.168 .003	58.092	.000
Cola	0-time 6months 1-year 2-years	Between Groups Within Groups Total	.929 .052 .981	3 16 19	.310 .003	94.999	.000

Table(5): Mean, standard deviation and duncan test for the effect of beverage media on the surface roughness of heat cure acrylic resin denture base

Beverage Media	Immersion Period	Mean(µm)	± Std. Deviation	Duncan
Control	**Non - immersed**	.3720	.05215	**A**
D.W.	6-Months 1-Year 2-Years	.4640 .5720 .6680	.07537 .07563 .05263	**B** **C** **D**
Tea	6-Months 1-Year 2-Years	.5720 .6860 .8120	.06535 .09839 .05541	**B** **C** **D**
Coffee	6-Months 1-Year 2-Years	.5860 .6900 .8220	.07127 .06042 .02490	**B** **C** **D**
Cola	6-Months 1-Year 2-Years	.6720 .7960 .9320	.05263 .05595 .02588	**B** **C** **D**

Table(6): One-way analysis of variance(ANOVA) for the effect of Beverage media on the surface roughness of heat cure acrylic resin denture base

Beverage Media	Immersion periods	Sum of squares		Df	Mean square	F-ratio	*p*-value
D.W	0-time 6months 1-year 2-years	Between Groups Within Groups Total	.248 .068 .316	3 16 19	.083 .004	19.595	.000
Tea	0-time 6months 1-year 2-years	Between Groups Within Groups Total	.542 .048 .590	3 16 19	.181 .003	59.839	.000
Coffee	0-time 6months 1-year 2-years	Between Groups Within Groups Total	.547 .045 .592	3 16 19	.182 .003	64.753	.000
Cola	0-time 6months 1-year 2-years	Between Groups Within Groups Total	.856 .037 .893	3 16 19	.285 .002	122.865	.000

References

1. Mohamed S, Eltamimi K. Effect of different beverags on colour stability of different denture base materials (a compartive spectromertic study). Egyptian Dental Journal. 2021 Apr 1;67(2):1549-1556.
2. Kamal M. Evaluation of Surface Micro-hardness and Fracture Toughness of Conventionally Constructed versus CAD/CAM Constructed Denture Base Materials-an In-Vitro Study. Egyptian Dental Journal. 2021 Jan 1;67(1-January (Fixed Prosthodontics, Removable Prosthodontics and Dental Materials)):757-765.
3. Alfouzan AF, Alotiabi HM, Labban N, Al-Otaibi HN, Al Taweel SM, AlShehri HA. Color stability of 3D-printed denture resins: Effect of aging, mechanical brushing and immersion in staining medium. The journal of advanced prosthodontics. 2021 Jun;13(3):160.
4. Perea-Lowery L, Gibreel M, Vallittu PK, Lassila LV. 3D-printed vs. heat-polymerizing and autopolymerizing denture base acrylic resins. Materials. 2021 Oct 3;14(19):5781.
5. Abdelrahim R, Abdel Hameed B. Assessment of Hardness, Flexural Modulus, and Bond Strength of Acrylic Denture bases Fabricated by 3D Digital Methods. Egyptian Dental Journal. 2021 Jul 1;67(3):2559-2566.
6. Al-Qarni FD, Gad MM. Printing Accuracy and Flexural Properties of Different 3D-Printed Denture Base Resins. Materials. 2022 Mar 24;15(7):2410.
7. Shrivastava SP, Dable R, Raj AN, Mutneja P, Srivastava SB, Haque M. Comparison of mechanical properties of PEEK and PMMA: an in vitro study. The Journal of Contemporary Dental Practice. 2021 Feb 1;22(2):179-183.
8. Kamal M. Evaluation of Surface Micro-hardness and Fracture Toughness of Conventionally Constructed versus CAD/CAM Constructed Denture Base Materials-an In-Vitro Study. Egyptian Dental Journal. 2021 Jan 1;67(1-January (Fixed Prosthodontics, Removable Prosthodontics and Dental Materials)):757-765.
9. Radford DR, Sweet SP, Challacombe SJ, Walter JD. Adherence of Candida albicans to denture-base materials with different surface finishes. Journal of dentistry. 1998 Sep 1;26(7):577-583.
10. Yamauchi M, Yamamoto K, Wakabayashi M, KAWANO J. In vitro adherence of microorganisms to denture base resin with different surface texture. Dental materials journal. 1990 Jun 25;9(1):19-24.
11. Abuzar MA, Bellur S, Duong N, Kim BB, Lu P, Palfreyman N, Surendran D, Tran VT. Evaluating surface roughness of

a polyamide denture base material in comparison with poly (methyl methacrylate). Journal of oral science. 2010;52(4):577-581.

12. Barbeau J, Séguin J, Goulet JP, de Koninck L, Avon SL, Lalonde B, Rompré P, Deslauriers N. Reassessing the presence of Candida albicans in denture-related stomatitis. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2003 Jan 1;95(1):51-59.
13. Ozyilmaz OY, Akin C. Effect of cleansers on denture base resins' structural properties. Journal of applied biomaterials & functional materials. 2019 Feb;17(1):2280800019827797.
14. Vásquez-Niño AF, Ochoa-Alzate JR, Osorio-Amariles D, Rodríguez-Quirós HA. Denture base polymers for analog and digital manufacturing: comparative study of the flexural strength, elastic modulus, and compressive strength of their mechanical properties. Revista Facultad de Odontología Universidad de Antioquia. 2021 Jun;33(1):6-16.
15. Azmy E, Al-Kholy MR, Gad MM, Al-Thobity AM, Emam AN, Helal MA. Influence of different beverages on the color stability of nanocomposite denture base materials. International Journal of Dentistry. 2021 Nov 11;2021:1-9.
16. Erdağ ÜH, Şahin O, Köroğlu A, Özdemir T, Dede DÖ. Performance of polyether ether ketone (peek) for dental applications: surface roughness and color stability. Polymer Bulletin. 2022 Jul 29:1-6.
17. Jain S, Sayed M, Ahmed WM, Halawi AH, Najmi NM, Aggarwal A, Bhandi S, Patil S. An in-vitro study to evaluate the effect of denture cleansing agents on color stability of denture bases fabricated using CAD/CAM milling, 3D-printing and conventional techniques. Coatings. 2021 Aug 13;11(8):962.
18. Dayan C, Guven MC, Gencel B, Bural C. A comparison of the color stability of conventional and CAD/CAM polymethyl methacrylate denture base materials. Acta Stomatologica Croatica. 2019 Jun;53(2):158.
19. Guler AU, Yilmaz F, Kulunk T, Guler E, Kurt S. Effects of different drinks on stainability of resin composite provisional restorative materials. The Journal of prosthetic dentistry. 2005 Aug 1;94(2):118-124.
20. Mankar S. Evaluation of Flexural Strength, Modulus, Translucency, Stain Resistance, and Gloss of Different 3d Printing Materials (Doctoral dissertation, The University of Alabama at Birmingham).
21. Nagy M Omar , Hussein R Mohammed and Khalid M Hagag. Effect of Various pH Media on Fracture Toughness and Hardness of Bilayered Reinforced Polymer and Monolithic Hybrid Ceramic. Al-Azhar Journal of Dental Science. 2020 Apr 1;23(2):103-109.
22. Mohammed N.Z. The Influence Of Polymeric Additive On Some Properties Of Heat Polymerized Denture Base Resin.(Doctoral dissertation. University of Mosul, College of Dentistry at Iraq).
23. Degirmenci K, Hayati Atala M, Sabak C. Effect of different denture base cleansers on surface roughness of heat polymerised acrylic materials with different curing process. Odovtos International Journal of Dental Sciences. 2020 Dec;22(3):145-153.
24. Chaijareenont P, Prakhamsai S, Silthampitag P, Takahashi H, Arksornnukit M. Effects of different sulfuric acid etching concentrations on PEEK surface bonding to resin composite. Dental materials journal. 2018 May 28;37(3):385-392.
25. Fathy SM, Emera RM, Abdallah RM. Surface Microhardness, Flexural Strength, and Clasp Retention and Deformation of Acetal vs Poly-ether-ether Ketone after Combined Thermal Cycling and pH Aging. The Journal of Contemporary Dental Practice. 2021 Feb 1;22(2):140-145.
26. Al-Dulaijan YA, Alsulaimi L, Alotaibi R, Alboainain A, Alalawi H, Alshehri S, Khan SQ, Alsaloum M, AlRumaih HS, Alhumaidan AA, Gad MM. Comparative Evaluation of Surface Roughness and Hardness of 3D Printed Resins. Materials. 2022 Oct 1;15(19):6822.
27. Radwan H. Surface roughness and color stability of 3D printed temporary crown material in different oral media (In vitro study). Int. J. Appl. Decis. Sci.. 2021;7:327-334.
28. Gad MM, Fouda SM, Abualsaud R, Alshahrani FA, Al-Thobity AM, Khan SQ, Akhtar S, Ateeq IS, Helal MA, Al-Harbi FA. Strength and surface properties of a 3D-printed denture base polymer. Journal of Prosthodontics. 2022 Jun;31(5):412-418.
29. Alfouzan AF, Alotiabi HM, Labban N, Al-Otaibi HN, Al Taweel SM, AlShehri HA. Effect of aging and mechanical brushing on surface roughness of 3D printed denture resins: A profilometer and scanning electron microscopy analysis. Technology and Health Care. 2022 Jan 1;30(1):161-173.
30. Bitencourt SB, Catanoze IA, da Silva EV, Dos Santos PH, Dos Santos DM, Turcio KH, Guiotti AM. Effect of acidic beverages on surface roughness and color stability of artificial teeth and acrylic resin. The journal of advanced prosthodontics. 2020 Apr;12(2):55.
31. Sofya PA, Rahmayani L, Purnama RR. Effect of soft drink towards heat cured

acrylic resin denture base surface roughness. Padjadjaran Journal of Dentistry. 2017 Mar 31;29(1).

32. Al Taweel SM, Al Fouzan A, Al-Otaibi HN, Labban N, AlShehri HA. Thermal-cycling, simulated brushing, and beverages induced color changes and roughness of CAD/CAM poly (methyl methacrylate) denture resins. Materials Research Express. 2021 Dec 15;8(12):125401.
33. Kodir K, Tanti I, Odang RW. Surface roughness of denture bases after immersion in fishcake vinegar solution. InJournal of Physics: Conference Series 2017 Aug 1 (Vol. 884, No. 1, p. 012075). IOP Publishing.
34. Ikram FS. The Effect of Coca Cola Drink on the Impact Strength and Surface Roughness of Acrylic Denture Base. Al-Kitab Journal for Pure Sciences. 2018;2(2):120-131.