ORIGINAL RESEARCH

Impact Strength of Various Types of Acrylic Resin: An *In Vitro* Study

Rajeev Srivastava[1], Sourabh Khandelwal[2], Raveena Makker[3], Rahul Razdan[4], Prashanthi Reddy[5], Chittaranjan Bhogisetty[6], Nassreen H Albar[7], Ahmed Alamoudi[8], Bassam Zidane[9], Shilpa Bhandi[10], Prashanth Panta[11]

Abstract

Aim: The aim of this study is to evaluate and compare the impact strength of conventional acrylic resin, high-impact acrylic resin, high-impact acrylic resin reinforced with silver nanoparticles, and high-impact acrylic resin reinforced with a zirconium oxide powder.

Materials and methods: A total of 60 samples were prepared of dimensions 60 mm length × 7 mm width × 4 mm thickness to test impact strength. Machined stainless steel dies of the same dimension were used to form molds for the fabrication of these samples. Of 60 samples, 15 samples were prepared each from conventional acrylic resin (Group A1), high-impact acrylic resin (Group A2), acrylic resin reinforced with silver nanoparticles (Group A3), and acrylic resin reinforced with zirconium oxide powder (Group A4). Izod-Charpy pendulum impact testing machine was used.

Results: The impact strength of group A1 was in the range of 2.83–3.30 kJ/m^2 (M = 3.12 kJ/m^2, SD = 0.16), group A2 was in range of 5.10–5.78 kJ/m^2 (M = 5.51 kJ/m^2, SD = 0.18), group A3 was in range 3.18–3.56 kJ/m^2 (M = 3.37 kJ/m^2, SD = 0.11), and group A4 was in range 7.18–7.78 kJ/m^2 (M = 7.5 kJ/m^2, SD = 0.18). Statistical analysis using one-way ANOVA and t-test revealed significant differences ($p < 0.001$).

Conclusion: High-impact acrylic resin reinforced with zirconium oxide powder has the highest impact strength.

Clinical significance: This research sheds light on the usefulness of novel filler materials in clinical prosthodontics.

Keywords: Acrylic resin, Impact strength, Nanoparticle, Polymethyl methacrylate, Zirconium oxide.

The Journal of Contemporary Dental Practice (2023): 10.5005/jp-journals-10024-3382

Introduction

Acrylic resin is commonly used to make prosthesis in dentistry. Polymeric materials are used for various applications such as denture bases and teeth, soft liners, custom trays, impression materials, core buildup materials, temporary restoratives, cementing/luting materials, and maxillofacial prostheses.[1] An ideal denture base material is the one that possesses biocompatibility with the oral tissues, excellent esthetics, superior mechanical properties like impact strength, flexural strength, modulus of elasticity, hardness, and sufficient bonding strength with artificial teeth and lining materials, ability to repair or alter the contours, and dimensional accuracy.[2]

Since the mid-1940s, most denture bases have been fabricated using polymethyl methacrylate (PMMA) resins because of the relative ease with which they can be processed. It is commonly supplied as a powder-liquid system. The liquid contains nonpolymerized methyl methacrylate, and the powder contains predominantly pre-polymerized PMMA in the form of microsized beads (or spheres).[1] There has been a constant effort to alter the composition of heat cure acrylic resin to improve its properties.

The fabrication of dentures made up of acrylic resin often fractures that becomes problematic both for the prosthodontist and the patient. A common fracture site is along an anteroposterior line that coincides with the labial notch of the maxillary or mandibular complete denture. The most common causes of these fractures include occlusal disharmony, excessive occlusal forces, flexure, and fatigue of the denture base due to alveolar resorption, spot in the denture base, and impact as a result of dropping of the denture.[3,4] Fracture of dentures results from two different forces: impact forces

[1–4]Department of Prosthodontics, Crown & Bridge, Index Institute of Dental Sciences, Indore, Madhya Pradesh, India

[5]Department of Oral Medicine and Radiology, Government Autonomous College of Dentistry, Sarder Patel Marg, Indore, Madhya Pradesh, India

[6]Department of Prosthodontics, Malla Reddy Institute of Dental Sciences, Jeedimetla, Quthbullapur, Hyderabad, Telangana, India

[7]Department of Restorative Dentistry, College of Dentistry, Jazan University, Jazan, Kingdom of Saudi Arabia

[8]Department of Oral Biology, Faculty of Dentistry, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia

[9]Department of Restorative Dentistry, Faculty of Dentistry, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia

[10]College of Dental Medicine, Roseman University of Health Sciences, South Jordan, Utah, United States of America

[11]Department of Oral Medicine and Radiology, Malla Reddy Institute of Dental Sciences, Jeedimetla, Quthbullapur, Hyderabad, Telangana, India

Corresponding Author: Prashanth Panta, Department of Oral Medicine and Radiology, Malla Reddy Institute of Dental Sciences, Hyderabad, Telangana, India, Phone: +91 9701806830, email: maithreya.prashanth@gmail.com

How to cite this article: Srivastava R, Khandelwal S, Makker R, *et al.* Impact Strength of Various Types of Acrylic Resin: An *In Vitro* Study. J Contemp Dent Pract 2023;24(1):56–60.

Source of support: Nil

Conflict of interest: None

and flexure fatigue. Impact failures often occur due to sudden denture fall while coughing, sneezing, and cleaning.[5,6]

The impact strength of a denture base material plays an essential role in anticipating the clinical performance of dentures on sudden loading.[7] There are three ways to improve the mechanical properties of PMMA: Replacing PMMA with an alternative material, chemical modification, and reinforcement of the PMMA with other materials. Currently, a rubber-modified acrylic polymer is the most popular material as an alternative to conventional PMMA.[8] Silver nanoparticles improve the mechanical properties of acrylic resin, and at low concentrations, nanoparticles increase denture strength.[9] To investigate the effectiveness of modifiers or fillers in denture base resins or to compare the performance of different products, various mechanical tests could be performed. The commonly used methods to predict fracture resistance is transverse strength, impact strength, and water sorption.[10] Studies have shown that zirconia is very biocompatible and has improved the mechanical properties of denture base resins. Furthermore, the exceptional aesthetics make 'zirconia' a superior filler material over other metal fillers.[11–13]

The major disadvantage of adding metal fillers is their dark color pigmentation. It would compromise the esthetics and their use was therefore restricted to areas like posterior occlusion, where esthetics are of less concern.[14–16] Therefore, keeping in mind the importance of the integrating silver nanoparticles and zirconium oxide in PMMA, this *in vitro* study was carried out. This study aimed to evaluate and compare the impact strength of different variations in acrylic resin.

Materials and Methodology

Materials

Conventional heat cure acrylic resin (Trevalon denture base material, Dentsply), high-impact acrylic resin (Lucitone, Dentsply), Dental stone Type III (Kalabhai, Kalrock), sodium alginate separating media (Prodent), silver nanoparticles, zirconia oxide powder, silane coupling agent (Rely X 3M, ESPE), stainless steel dies of dimension (60 mm length × 7 mm width × 4 mm thickness) were utilized for the study. The metal die was fabricated using a precision CNC machine.

Sample Preparation

A total of 60 samples were prepared of dimensions 60 mm length × 7 mm width × 4 mm thickness. Out of 60 samples, 15 samples were prepared each from conventional acrylic resin (Group A1), high-impact acrylic resin (Group A2), acrylic resin reinforced with silver nanoparticles (Group A3), and acrylic resin reinforced with zirconium oxide powder (Group A4).

Preparing group A1 and group A2 sample is relatively easier. For preparing group A1 sample, polymer and monomer of conventional acrylic resin were mixed in a ratio of 2.7:1. For preparing group A2 sample, polymer and monomer of high-impact acrylic resin were mixed in a ratio of 2.7:1. For preparing group A3 sample, high-impact acrylic resin was proportioned with recommended powder-to-liquid ratio (i.e., 35 gm powder and 14 mL liquid). Powdered silver 99.9% pure was mixed with PMMA in the concentration of 5%, i.e., 2.4 gm by weight. Weighing of silver nanopowder was done using an electronic balance. Silver nanoparticles were added to the monomer and sonicated using an ultrasonic scaler to make colloidal dispersion. For preparing group A4, high-impact acrylic resin was proportioned with recommended powder-to-liquid ratio (100 gm powder and 38 mL liquid). Zirconia powder of 99.56% purity was selected as filler, and an electronic balance was used to weigh zirconium oxide (ZrO_2) powder. Zirconium oxide powder was added in a concentration of 10%, i.e., 10 gm of the acrylic polymer powder by weight. Zirconium oxide particles were treated with 1 wt%, i.e., 1 gm of silane coupling agent. Thorough mixing of the zirconium oxide powder with the high-impact heat cure acrylic polymer powder was carried out using porcelain mortar and pestle, and then the monomer was added to the mixture. Initial mixing and blending were done till a uniform mix was obtained. The powder hence obtained was mixed with monomer (2.7:1).

The stainless steel dies were invested in a flask using type III dental stone (Fig. 1). Once the dental stone was set, the two halves were separated, and the blocks were retrieved from molds without distorting the mold space. Sodium alginate separating media was applied to the mold and allowed to dry. Then, all four types of samples (acrylic resin powder) were mixed with monomer respectively in a silicon mixing jar, and the mixture was packed into mold space in the dough stage, and flasks were clamped under hydraulic press. Trial closure was done, and excess was trimmed using B.P. knife. Flasks were kept for bench curing for 20 minutes. Then, resin samples were acrylized by keeping the flasks in water bath at 73°C for 90 minutes and then in 100°C boiling water for 30 minutes (Fig. 2).

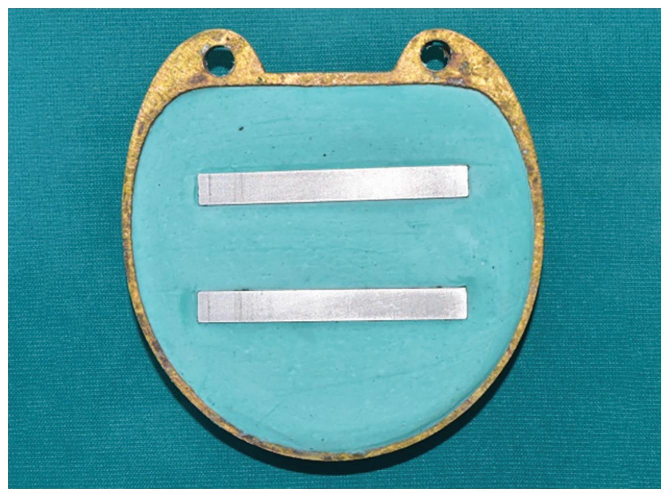


Fig. 1: Stainless steel dies invested in a flask

Fig. 2: Acrylized sample of dimension 60 mm length × 7 mm width × 4 mm thickness

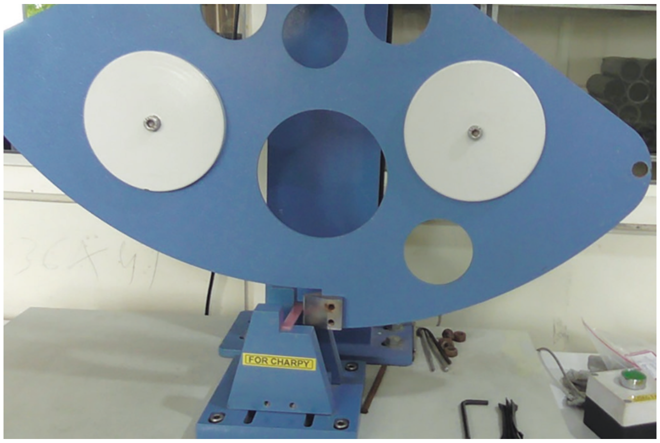


Fig. 3: Izod-Charpy pendulum for impact testing machine

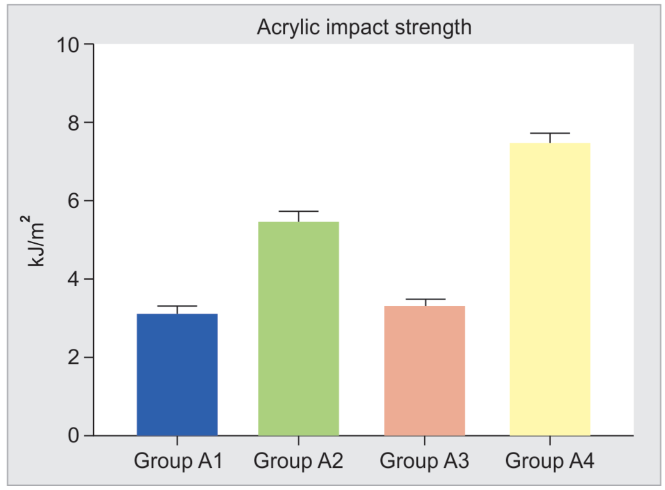


Fig. 4: Mean impact strength of the different groups [conventional acrylic resin (Group A1), high-impact acrylic resin (Group A2), high-impact acrylic resin reinforced with silver nanoparticles (Group A3), and high-impact acrylic resin reinforced with zirconium oxide powder (Group A4)]

Strength Testing

The impact strength of samples was tested by Izod-Charpy pendulum impact testing machine (Fig. 3). The impact strength of a specimen was recorded as a number of joules of energy absorbed in breaking the specimen. The machine gives a digital reading with the least count of 0.01 J.

Statistical Analysis

Graphpad Prism 9.3.0 was used for Statistical analysis. One-way ANOVA test was applied to measure intragroup differences in impact strength and unpaired *t*-test was applied for intergroup comparison. The significance level was fixed at 5%, and $p \leq 0.05$ was considered statistically significant.

Results

The impact strength of group A1 ($n = 15$) was in the range of 2.83–3.30 kJ/m^2 (*M*: 3.12 kJ/m^2, SD = 0.16). The impact strength of group A2 ($n = 15$) was in the range of 5.10–5.78 kJ/m^2 ($M = 5.51$ kJ/m^2, SD = 0.18). The impact strength of group A3 ($n = 15$) was in the range of 3.18–3.56 kJ/m^2 ($M = 3.37$ kJ/m^2, SD = 0.11), and the impact strength of Group A4 ($n = 15$) was in range 7.18–7.78 kJ/m^2 ($M = 7.51$ kJ/m^2, SD = 0.18). The impact strength was in the order group A4, group A2, group A3, and group A1. There were significant intragroup differences in impact strength (ANOVA test; *F*: 2369; $p < 0.001$) (Fig. 4). There was a statistically significant difference in impact strength between the groups: A1 and A2 (unpaired *t*-test; $T = 37.35$; $p < 0.001$), A1 and A3 (unpaired *t*-test; $T = 4.82$; $p < 0.001$), A1 and A4 (unpaired *t*-test; $T = 68.52$; $p < 0.001$), A2 and A3 (unpaired *t*-test; $T = 38.85$; $p < 0.001$), A2 and A4 (unpaired *t*-test; $T = 30.13$; $p < 0.001$), A3 and A4 (unpaired *t*-test; $T = 75.10$; $p < 0.001$) (Fig. 5).

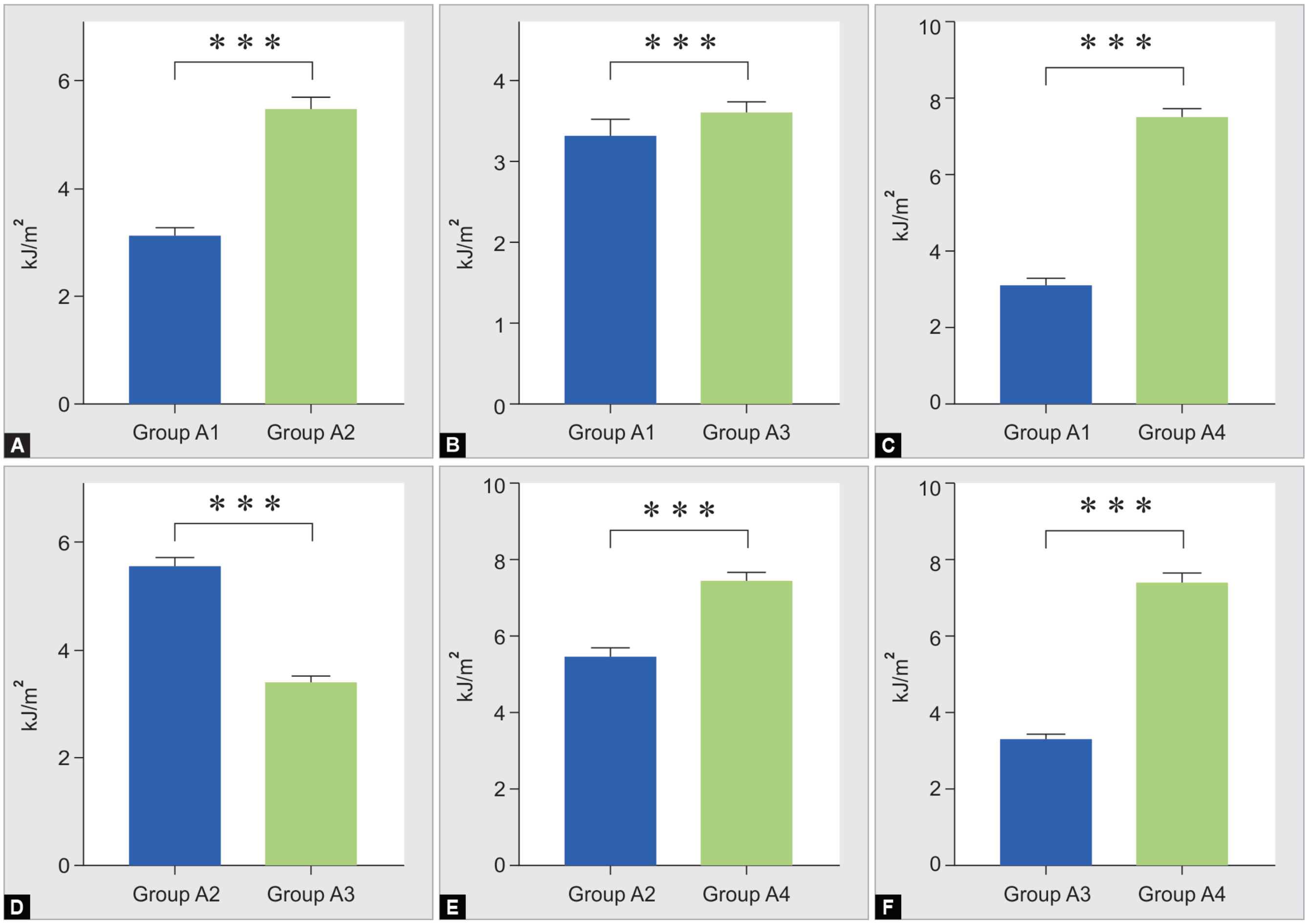
Discussion

The fracture of acrylic resin dentures is an unresolved problem in removable prosthodontics. Denture fracture is a multifactorial issue, and even strengthening measures could not efficiently prevent it.[17,18] Various approaches to strengthening acrylic resin prostheses have been suggested, which include modifying or reinforcing the resin. Approaches to strengthening acrylic resin polymer include incorporating metal powder fillers such as silver, copper, and aluminum particles, metal wire, glass fibers, carbon fibers, aramid fibers, and zirconia, and modifications of the chemical structure of acrylic resin by copolymerization with rubber.[12,19–22]

Silver is a metal with high conductivity; its antimicrobial properties have been reported in several studies when added to the denture base in the form of nanoparticles. Silver nanoparticles significantly inhibit *Candida albicans*, and their addition to the denture base possibly decreases the prevalence of oral diseases in edentulous patients. Moreover, silver nanoparticles improve the mechanical properties of acrylic resin, and at low concentrations, they increase denture strength. The incorporation of silver powder into acrylic resin causes an increase in thermal conductivity, but the tensile strength of the material is decreased making the denture susceptible to fracture.[9,23–25]

The incorporation of zirconia in various dental materials has been studied, and it was found to be biocompatible with improved mechanical properties. Also, the white color of zirconia powder improves aesthetic appearance.[11,12,15,16] Therefore, the study was planned to evaluate and compare the impact strength and transverse strength of conventional acrylic resin, high-impact resin, high-impact resin reinforced with silver nanoparticle, and high-impact resin reinforced with zirconia.

The study results were found to be correlated with previous studies. Asar et al.[26] observed that 2% ZrO_2 reinforced PMMA had highest impact strength of 6.5 ± 0.07 kJ/m^2 and fracture toughness of 1.66 ± 0.003 MPa compared to 1% TiO_2 + 1% ZrO_2, 2% Al_2O_3, 2% TiO_2, and unreinforced PH. Unreinforced PMMA had the lowest impact strength of 4.6 ± 0.07 kJ/m^2 and fracture toughness of 1.27 ± 0.002 MPa. Narendra et al.[27] found that Acrylan-H had the highest impact strength of 62.19 J compared to Stellon, Trevalon, Lucitone 199, Acralyn-H, Trevalon HI while Stellon had the lowest, i.e., 9.11 J impact strength. Hameed et al.[28] concluded that the addition of 5% modified nano zirconia filler particles increased the impact strength, i.e., 8.95 ± 0.13 kJ/m^2 and transverse strength, i.e., 103.14 ± 3.01 MPa of denture base material, and this strength decreases with further increase of nano zirconia filler content. Ihab et al.[29] observed a significant increase in impact strength in acrylic resin reinforced with 5 wt% silanated zirconia oxide nanofillers, i.e., 9.95 kJ/m^2 compared to standard acrylic resin, i.e., 8.7 95 kJ/m^2.



Figs 5A to F: Intergroup comparisons and *t*-test results (*p*-value reported as per APA style: 0.033*, 0.002**, <0.001***)

Ayad et al.[30] concluded that reinforcing high-impact acrylic resin with 15% zirconia oxide nanoparticle increases its transverse strength to 139.3 ± 13.9 MPa, followed by 5% zirconia oxide nanoparticles, i.e., 101.8 ± 1.55 MPa and unreinforced high-impact acrylic resin, i.e., 79.1 ± 1.14 MPa. Soygun et al.[2] observed the highest transverse strength, i.e., 117.22 ± 37.80 MPa and impact strength 0.76 ± 37.80 in Valplast group compared to PMMA, E-glass, nylon 6 and nylon 66. Ravindranath et al.[31] concluded that incorporation of zirconium oxide into PMMA increased in flexural strength, impact strength, and hardness of polymethyl methacrylate. Ihab and Moudhaffar[32] resulted that there was a highly significant increase in impact strength and transverse strength in acrylic resin on the addition of 5 wt% zirconia oxide, but no significant increase was observed at 7 wt% as compared to unreinforced acrylic resin.

The results of the present study showed that the high-impact acrylic resin reinforced with zirconium oxide powder has the highest impact strength, followed by high-impact acrylic resin reinforced with silver nanoparticles and conventional acrylic resin. Furthermore, data suggest that adding silver nanoparticles may reduce the impact strength of high-impact acrylic resin.

There were a few limitations to the present study. This study was conducted *in vitro* to evaluate the impact strength only, and the sample size was relatively less. Also, only a single concentration of silver nanoparticles and zirconium oxide powder was implemented in this study. Further modifications can be done using different concentrations of the material. Moreover, evaluation of flexural strength of acrylic resin and the growth of *C. albicans* can also be assessed in future work.

Increasing the impact strength of acrylic resin by incorporating silver nanoparticles and zirconium oxide powder may prolong the life of dentures in patients with poor neuromuscular skills. Furthermore, the incorporation of silver nanoparticles inhibits the growth of *C. albicans* on the surface of the denture, thereby preventing conditions like denture stomatitis.

Conclusion

This *in vitro* study evaluated and compared the impact strength of conventional acrylic resin, high-impact acrylic resin, high-impact acrylic resin reinforced with silver nanoparticles, high-impact acrylic resin reinforced with silver nanoparticles, and high-impact acrylic resin reinforced with zirconium oxide powder. Further, it was deduced from the above study that high-impact acrylic resin reinforced with zirconium oxide powder has the highest impact strength, and adding silver nanoparticles to the high-impact acrylic resin did not improve the impact strength. The use of technology, materials, and nanoscience has substantially evolved the material science of dentistry. Our *in vitro* investigation throws light on the improvement of properties of PMMA. For further evidence and to know patient satisfaction, an *in vivo* study can be carried out to know the impact strength and various other features.

References

1. Anusavice KJ, Shen C, Rawls HR. Phillips' science of dental materials. 12th edition, St. Louis, Mo: Elsevier/Saunders, 2013.
2. Soygun K, Bolayir G, Boztug A. Mechanical and thermal properties of polyamide versus reinforced PMMA denture base materials. J Adv Prosthodont 2013;5:153–160. DOI: 10.4047/jap.2013.5.2.153
3. Rodrigues AHC. Metal reinforcement for implant-supported mandibular overdenture. J Prosthet Dent 2000;83(5):511–513. DOI: 10.1016/s0022-3913(00)70006-0.
4. John J, Gangadhar SA, Shah I. Flexural strength of heat – polymerized polymethyl methacrylate denture resin reinforced with glass, aramid, or nylon fibers. J Prosthet Dent 2001;86(4):424–427. DOI: 10.1067/mpr.2001.118564.
5. EL-Sheikh AM, AL-Zahrani SB. Causes of denture fracture: survey. Saudi Dent J 2006;18(3):149–153. ID: emr-81056.
6. Dogan OM, Bolayir G, Keski NS, et al. The effect of esthetic fibers on impact resistance of a conventional heat-cured denture base resin. Dent Mater J 2007;26(2):232–239. PMID: 17621939.
7. Memom MS, Yunus N, Razak AAA. Some mechanical properties of a highly cross-linked, microwave-polymerized, injection-molded denture base polymer. Int J Prosthodont 2001;14(3):214–218. PMID: 11484567.
8. Vojdani M, Bagheri R, Khaledi AAR. Effect of aluminum oxide addition on the flexural strength, surface hardness and roughness of heat polymerized acrylic resin. J Dent Sci 2012;7:238–244. http://dx.doi.org/10.1016/j.jds.2012.05.008.
9. Ghafari T, Rad FH, Ezzati B. Does addition of silver nanoparticles to denture base resin increase its thermal conductivity. Beheshti Univ Dent J 2014;32(2):76–81. https://doi.org/10.22037/jds.v32i3. 24789.
10. Paladugu LS, Sivakumar M, Ganta R. Evaluation of flexural strength, impact strength and water sorption of various denture base resins: An in vitro study. J Res Adv Dent 2014;3(2):94–99. DOI:10.5005/jp-journals-10019–1271.
11. Vallittu PK. Comparison of two different silane compounds used for improving adhesion between fibres and acrylic denture base material. J Oral Rehab 1993;20:533–539. DOI: 10.1111/j.1365-2842.1993.tb01640.x.
12. Ladizesky NH, Chow TW, et al. Denture base reinforcement using woven polyethylene fiber. Int J Prosthodont 1994;7:307–314. PMID: 7993541.
13. Vallittu PK. A review of methods used to reinforce polymethyl methacrylate resin. J Prosthodont 1995;4(3):183–187. DOI: 10.1111/j.1532-849x.1995.tb00338.x.
14. Jagger DC, Jagger RG, Allen SM, et al. An investigation into the transverse and impact strength of high strength denture base acrylic resins. J Oral Rehabil 2002;29:263–267. DOI: 10.1046/j.1365-2842.2002.00830.x.
15. Sehajpal SB, Sood VK. Effect of metal fillers on some physical properties of acrylic resin. J Prosthet Dent 1989;61(6):746–751. DOI: 10.1016/s0022-3913(89)80055-1.
16. Dixon DL, Breeding LC. The transverse strengths of three denture base resins reinforced with polyethylene fibers. J Prosthet Dent 1992;67(3):417–419. DOI: 10.1016/0022-3913(92)90261-8.
17. Beyli MS, Von Fraunhofer JA. An analysis of causes of fracture of acrylic resin dentures. J Prosthet Dent 1981;46(3):238–241. DOI: 10.1016/0022-3913(81)90206-7.
18. Nejatian T, Sefat F, Johnson T. Impact of packing and processing technique on mechanical properties of acrylic denture base materials. Materials 2015;8:2093–2109. DOI: 10.3390/ma8052093.
19. Stafford GD, Smith DC. Flexural fatigue tests of some denture base polymers. Br Dent J 1970;128(9):442–445. DOI: 10.1038/sj.bdj.4802483.
20. Carroll CE, Von Fraunhofer JA. Wire reinforcement of acrylic resin prostheses. J Prosthet Dent 1984;52(5):639–641. DOI: 10.1016/0022-3913(84)90132-x.
21. Vallittu PK, Lassila VP. Reinforcement of acrylic resin denture base material with metal or fibre strengtheners. J Oral Rehab 1992;19: 225–230. DOI: 10.1111/j.1365-2842.1992.tb01096.x.
22. Arnold AD, Vargas MA, Shaull KL, et al. Flexural and fatigue strength of denture base resin. J Prosthet Dent 2008;100(1):47–51. DOI: 10.1016/S0022-3913(08)60136-5.
23. Monterio DR, Group LF, Takamiya AE, et al. Silver distribution and release from an antimicrobial denture base resin containing silver colloidal nanoparticles. J Prosthodont 2012;21:7–15. DOI: 10.1111/j.1532-849X.2011.00772.x.
24. Yadav P, Mittal R, Sood VK, et al. Effect of incorporation of silane-treated silver and aluminum microparticles on strength and thermal conductivity of PMMA. J Prosthodont 2012;21:546–551. DOI: 10.1111/j.1532-849X.2012.00873.x.
25. Hamedi-Rad F, Ghaffari T, Rezaii F, et al. Effect of nanosilver on thermal and mechanical properties of acrylic base complete dentures. J Dent 2014;1(5):495–505. PMCID: PMC4290768.
26. Asar NV, Albayrak H, Korkmaz T, et al. Influence of various metal oxides on mechanical and physical properties of heat-cured polymethyl methacrylate denture base resins. J Adv Prosthodont 2013;5:241–247. DOI: 10.4047/jap.2013.5.3.241.
27. Narendra R, Reddy NS, Reddy SD, et al. A comparative evaluation of impact strength of conventionally heat cured and high impact heat cured polymethyl methacrylate denture base resins: An in vitro study. J Contemp Dent Pract 2013;14(6):1115–1121. DOI: 10.5005/jp-journals-10024-1461.
28. Hameed HK, Rahman HA. The effect of addition nano particle Zro2 on some properties of autoclave processed heat cure acrylic denture base material. J BaghColl Dent 2015; 27(1):32–39. DOI: 10.12816/0015262.
29. Ihab NS, Hassanen KA, Ali NA. Assessment of zirconium oxide nano-fillers incorporation and silanation on impact, tensile strength and color alteration of heat polymerized acrylic resin. J BaghColl Dentistry 2012;24(2):36–42. DOI: 10.0001/1354.
30. Ayad NM, Badawi MF, Fatah AA. Effect of reinforcement of high impact acrylic resin with zirconia on some physical and mechanical properties. Rev Clin Pesq Odontol 2008;4(3):145–151. DOI: 10.7213/AOR.V4I3.23218.
31. Ravindranath, Sabarigirinathan C, Vinayagavel K, et al. A comparative study to evaluate the mechanical properties of zirconium oxide added polymethyl methacrylate by two different methods at two different concentrations – *In vitro* study. Ann Int Med Dent Res 2015;1(3):161–165. Corpus ID: 212492631.
32. Ihab NS, Moudhaffar M. Evaluation the effect of modified nano fillers addition on some properties of heat cured acrylic denture base material. J Bagh Coll Dent 2011;23(3):23–29. Corpus ID: 37039524.