Research Article

Evaluating the influence of Ti_6Al_4V alloy particles on mechanical properties of heat-cured PMMA

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Abstract: Background: Titanium alloy (Ti_6Al_4V) is considered a promising material for prosthetic dental applications due to its superior density, high strength, improved corrosion resistance and superior biocompatibility. Due to the low strength and brittleness of the practicable denture foundation material in heat-cured acrylic resin, improving the strength properties is a crucial issue. The present study aimed to evaluate the influence of Ti_6Al_4V alloy particles on the tensile strength transverse strength, and the surface hardness of heat-cured PMMA as a base material. Materials and methods: A total of 75 specimens were prepared by combining heat-cured acrylic resin with Ti_6Al_4V additive particles (0.5, 1, 1.5, and 2 wt. % respectively). Each group was subdivided into three subgroups according to the samples subjected to the test (n = 25), tensile strength; transverse strength; and surface hardness. Results**:** The result showed a significant difference (P= 0.007) in all tested groups. The results showed that the addition of Ti_6Al_4V particles to heat-cured material considerably increased the tensile strength, transverse strength, and surface hardness-a compared to the untreated control specimens. Conclusion**:** It was found that increasing the weight concentration (wt.) of Ti_6Al_4V particles improved the tensile strength, transverse strength, and surface hardness of heat-cured PMMA specimens.

Keywords: Heat-cured acrylic resin, Ti_6Al_4V alloy, Tensile strength, Transverse strength; Hardness

Introduction

Polymethylmethacrylate (PMMA) has been extensively utilised and developed in the construction of acrylic denture bases for many years [(1)]. The acrylic denture base resin offers adequate mechanical, physical and aesthetically pleasing qualities [(2)]. Furthermore, acrylic resin has a cheap price, easy manufacture, satisfactory characteristics, its lightweight, excellent optical quality, colour matching capabilities and biocompatibility as well as ease of polishing and finishing [(3)].

Acrylic denture base resin, on the other hand, has some disadvantages, including low strength, hardness, and fatigue resistance [(4,5,6)]. The possibility of breaking the base resin during function is owing to fatigue failure in the mouth or impact failure outside the mouth [(7)]. The flaws that must be addressed to enhance the performance of acrylic resin material as complete and partial detachable dentures [(8, 9)]. Fracture mechanics analysis using stress concentrations and stress intensity factors suggests that failure only requires one flaw or crack of a critical size and shape [(10)].

The denture base material must be sufficiently abrasive and wear-resistant to prevent severe wear induced by abrasive denture cleansers, food, or general functional stresses. Wear resistance can be improved by improving mechanical qualities, such as hardness [(11)].

Many studies and efforts have been emphasised to integrate the PMMA with different metallic particles to improve its physiomechanical quality [(12)] to suit the patient's needs and comfort of the patient [(13, 14,15, 16)]. Reinforcement particles with PMMA have recently gained popularity due to their anticorrosion properties, biocompatibility, and resistance to fatigue and rupture. The mechanical impacts of PMMA combined with reinforcement particles, for example, copper oxide (CuO), iron oxide (Fe_2O_3), zinc oxide

(ZnO), titanium dioxide (TiO_2), aluminium oxide (Al_2O_3) and silicon oxide (SiO_2) have been investigated in the literature [17,18].

The PMMA reinforcement particles improved the mechanical characteristics of composites by demonstrating acceptable dispersion and good adherence to polymers [19]. The hardness at an intermediate load increases abruptly as the filler content increases [20]. In addition, titanium is frequently utilised in aircraft applications, as well as medical and dental procedures, either as a pure metal or in an alloyed form. It is frequently alloyed with other metals, including vanadium (V) and aluminium (Al). It then generates lightweight but powerful alloys for the fabrication of oral implants or frameworks for fixed dental prostheses (FDPs) [21].

The Ti_6Al_4V alloy, often known as Ti64, is α-β titanium alloy that has good biocompatibility, high strength [16,22], low density, high fracture toughness, and excellent corrosion resistance [23,24,25]. In addition to its outstanding density, strength, corrosion resistance and biocompatibility, the Ti_6Al_4V alloy is an attractive material for dental applications, such as dental bridges and dental implants [23,26,27] . However, there is insufficient information on the effect of the reinforcement of titanium alloy particles on the physical-mechanical characteristics of the acrylic denture base. Therefore, the evaluation of the incorporation of titanium alloy particles into the heat-cured acrylic denture base resin matrix as a novel contribution research is what distinguishes this study.

The aim of this research was to evaluate varying weight percentages (wt. %) of reinforcement titanium alloy particles Ti_6Al_4V impacted the mechanical characteristics of heat-cured acrylic in terms of tensile strength, transverse strength, and surface hardness. The Ti_6Al_4V were added to the heat-cured acrylic denture base material in this investigation with the objective of developing an acrylic denture base resin material with additive metallic particles.

Materials and Methods

In this investigation, pink heat-cured acrylic resin (powder and liquid) materials were purchased from (Veined, Colombia) as powder particle sizes ranging from (24 μm to 50 μm), and titanium alloy particles (Ti_6Al_4V) were obtained from (Alfa Aesar, UK) with particle sizes ranging from (15 μm to 55 μm) examined under a Scanning Electron Microscope (SEM). The 75 specimens constructed in this study included 25 dumbbell-shaped specimens for the tensile strength test, as well as fifty rectangular-shaped specimens for the transverse strength test according to (ISO I. 20795-1) and surface hardness test. Each mechanical test (tensile strength transverse strength, and surface hardness) included five samples (n = 5) in each group. The following composite groups have been established on the weight percentage (wt. %) of Ti_6Al_4V reinforcements with heat-cured acrylic resin materials:

Study Design

Consist of the following groups; Group A (Control): Heat-cured PMMA without reinforcement of Ti_6Al_4V (0.0 wt. %). Group B: Heat-cured PMMA reinforced with 0.5 wt. % of Ti_6Al_4V. Group C: Heat-cured PMMA reinforced with 1 wt. % of Ti_6Al_4V., Group D: Heat-cured PMMA reinforced with 1.5 wt. % of Ti_6Al_4V and Group E: Heat-cured PMMA reinforced with 2wt. % of Ti_6Al_4V.

Fabrication of the specimens

The wax pattern of the specimens was prepared by using a sheet of base plate wax and cutting this sheet according to the required dimension and shape. The samples were constructed with dimensions (65 mm×12.5 mm×2.5 mm length, width, and thickness), respectively, in a dumbbell shape for the tensile strength test. Furthermore, 50 samples with dimensions (65 mm ×10 mm ×2 mm length, width, and thickness), in a rectangular shape for the transverse strength as well as surface hardness test [28].

Flasking technique

For all specimens, a typical flasking procedure for the manufacture of acrylic dentures was used during mold preparation. The inferior half of the metal flask was filled with dental stone (Type 4, Elite Rock, Zhermack, Italy) mixed according to the manufacturer's instructions (100 mg: 31ml) (P/W), and wax designs were carefully placed in one half of their depth. Following the setting of the stone, it was coated with a separating medium and allowed to dryness before the superior portion of the metal flask was positioned on top of the inferior portion and filled with stone, with vibration to remove trapped air. The metal flask was unlocked after the stone was fully set and the wax designs were removed from the mould using a wax elimination procedure. When the flask was placed in boiling water, the two portions of the metal flask were opened and covered with a separating medium to be ready to pack with acrylic dough (28).

Packing technique

Heat-cured acrylic resin was mixed in the proportion of (2 g: 1 ml) (P / L) as recommended by the manufacturer. The mixture was then covered and left to stand until it reached the dough stage. A packing technique was performed where the resin material was still in the dough phase and then packed into the previously treated mold with a separating medium. Furthermore, both halves of the flask were compactly locked and put under the hydraulic press with a moderate application of pressure to allow a homogeneous distribution of the dough in the mold space (28).

Curing technique

The cure was carried out by immersing the compressed flask in a water bath and heating it at 74 ° C for 1.5 hours before increasing the temperature to boiling 100 ° C for half an hour. After curing, the flask was gradually to ambient temperature for half an hour before being submerged in water for fifteen minutes. Subsequently, the specimens were carefully removed from the stone molds (28).

Trimming, polishing, and conditioning of specimens

To achieve a smooth surface, all acrylic flashes were trimmed with an acrylic bur. After that, a stone bur must be manipulated, followed by (120) grain size sandpaper to remove any residual minor scratches. All samples were polished using a dental lath polishing machine (MESTRA, Spain). For the polishing process, pumice rouge, as well as a small amount of water, were utilized. For 28 days, all samples were kept in distilled water at 37 ° C (29). The samples were examined for any irregularity. Faulty specimens were discarded and final specimens were chosen for each group (30).

Addition of Ti_6Al_4V alloy particles to acrylic resin materials

The quantities of heat-cured acrylic resin particles and Ti_6Al_4V particles used in each group were illustrated in Table 1. The percentages of Ti_6Al_4V employed in this study (0.5, 1, 1.5, and 2 wt. %, respectively) were applied to heat-cured acrylic materials. These weight percentages were used for each test within the scope of this research. The required weight percentages (wt. %) of acrylic and Ti_6Al_4V particles were determined using an electronic scale (accuracy 0.0001g). The mixing technique of Ti_6Al_4V with heat-cured materials was performed by hand, with a tiny amount of Ti_6Al_4V gradually carried by a spatula with continuous mixing until the materials appeared uniform, with no Ti_6Al_4V clustering visible to the human eye (31).

Table 1: The amount of acrylic particles (g) and Ti_6Al_4V particles (g).

Groups	Amount of Acrylic (g)	Amount of Ti_6Al_4V (g)	Wt.% of Ti_6Al_4V
1	100 g	0 g	0 wt.%
2	99.5 g	0.5 g	0.5 wt.%
3	99 g	1 g	1 wt.%
4	98.5 g	1.5 g	1.5 wt.%
5	98 g	2 g	2 wt.%

Specimens tests

Tensile strength test

The tensile strength of the specimen was measured by an Instron universal testing machine with a grip jig suitable for the test specimens and a crosshead speed of 5 mm/min. With a tensile load, the cell was measured on a scale of 50 kg. The recorded force at failure was measured [28].

Transverse strength test

The 3-point flexural bend test was carried out on a universal testing machine, with each specimen positioned on the bending fixture jig, which consisted of two parallel supports (50 mm apart), the load was applied with a rod placed centrally between the supports, making deflection until fracture occurred[28]. The following equation was used to calculate the transverse strength values:

$T= 3PL/2bd^2$

While T = Transverse strength N/mm^2, P = Maximum force exerted on specimens N, L = Space between the supports mm, b = Diameter of the specimens, mm and d = Depth of the specimen

Surface hardness test

Surface hardness was measured using a Shore D durometer hardness device (TIME group Inc.)[28]. The testing device is made up of a spring-loaded indenter (0.8 mm in diameter) that is connected to a digital scale of 0 to 100 units. The standard method is to press on the indenter and record the reading. For each specimen, three measurements were taken (one in the centre and one at each end), as well as the means of the three measurements were determined.

Statistical analysis

Statistical approaches such as descriptive statistics (mean value, standard error, maximum and lowest values for all tests) were used to analyse and assess the results, ANOVA test and least significant difference (LSD) test for statistical analysis, and Microsoft Excel 2013 for graphical representation, and (IBM SPSS Statistical services for Windows V21) were used.

Results:

Data from this study, which resulted in the specific investigations described below, demonstrated comparisons of the mean values of tensile strength, transverse strength, and surface hardness of all investigated samples after the addition of varying weight percentage (wt%) concentrations of Ti_6Al_4V alloy particles to the heat-cured substance.

Tensile strength test

As shown in Table 2, the outcomes of the tensile strength of all composite groups revealed the highest mean value of 73.97 MPa was for the reinforcement specimens of group E reinforcement with 2% Ti_6Al_4V alloy particles and the lowest mean value 52.47 MPa was for group A (control group) without the addition of Ti_6Al_4V alloy particles. Additionally, data were analysed using an ANOVA test with variable concentration and the result showed a highly significant difference with $P=0.007$ ($P<0.01$). Furthermore, the least significant difference (LSD) test revealed highly significant variations in tensile strength in all specimens tested, as presented in Table 2.

Table 2: The outcomes for tensile strength test of all tested groups.

Groups	N	Mean	Std. Deviation	Std. Error	Range Mini.	Range Maxi.	ANOVA test & LSD test
Control	5	52.47	0.51	0.23	51.90	52.97	P=0.007
0.5%	5	56.13	0.99	0.44	54.51	57.23	
1%	5	61.49	0.96	0.43	59.84	62.32	
1.5%	5	67.21	0.98	0.44	65.49	67.89	
2%	5	73.97	1.00	0.44	72.98	75.66	

*High significant $P< 0.01$

Transverse strength test

The results of the transverse strength of the biocomposite groups revealed that the maximum mean value of 94.37 N/mm^2 was for group E reinforcement in conjunction with 2% Ti_6Al_4V alloy particles. The lowest mean value 73.47 N/mm^2 was for the PMMA group without reinforcement of the Ti_6Al_4V alloy particles as shown in Table 3. Furthermore, the data was analysed using an ANOVA test and LSD test with variable concentration, and the outcomes showed highly significant differences with $P=0.00$ ($P<0.01$) as illustrated in Table 3.

Table 3: The outcomes for transverse strength test of all tested groups.

Groups	N	Mean	Std. Deviation	Std. Error	Range Mini.	Range Maxi.	ANOVA test &LSD test
Control	5	73.47	0.93	0.41	72.73	74.93	P=<0.01
0.5%	5	76.13	0.99	0.44	74.51	77.23	
1%	5	82.39	0.97	0.43	81.55	83.58	
1.5%	5	87.41	1.10	0.49	85.49	88.29	
2%	5	94.37	0.89	0.40	93.68	95.66	

*High significant $P< 0.01$

Surface Hardness test

The of the surface of the hardness strength mean values were compared after the various weight concentrations of Ti_6Al_4V alloy particles were added. As shown in Table 4, the results of the surface hardness of composite groups showed the maximum mean value for the samples of group E with reinforcement of 2% Ti_6Al_4V alloy particles, and the lowest mean value for group A (control) without the addition of Ti_6Al_4V alloy particles. Furthermore, the data were analysed using an ANOVA test and LSD test with variable weight concentration. The results revealed highly significant differences with P = 0.001 (P < 0.01), as illustrated in Table 4.

Table 4: The outcomes of surface hardness (Shore D) test for all tested groups.

Groups	N	Mean	Std. Deviation	Std. Error	Range		ANOVA test & LSD test
					Mini.	Maxi.	
Control	5	88.84	2.14	0.95	85.66	91.66	P=0.001
0.5%	5	94.85	1.99	0.89	91.67	96.66	
1%	5	99.25	1.28	0.57	96.95	99.88	
1.5%	5	103.72	1.94	0.86	101.32	106.33	
2%	5	108.39	1.42	0.63	106.33	109.66	

*High significant P< 0.01

Discussion

The influence of the titanium alloy particle reinforcement on the physical and mechanical properties of heat-cured acrylic denture base resin has received little attention. The concentration of reinforced addition particles and their chemical interactions with the polymer acrylic resin substance influence reinforcement. The optimal particle concentration is being studied all the time [15, 16]. A variety of tests have been developed to measure the tensile strength of materials. However, most of these are designed to place tension. The tension means the state of being stretched, strained, or extended [32]. In this investigation, it was found that the addition of alloy Ti_6Al_4V particles to heat-cured PMMA substantially improved tensile strength. The results of the recent study were in agreement with Azeez et al. [19] who concluded that the addition of TiO_2 to PMMA showed an increased in the tensile strength of PMMA.

It can be recognised from the obtained results through Table 2 that the heat-cured PMMA study group with 2% of Ti_6Al_4V alloy particles had the highest tensile strength mean value (73.97 MPa) among the studied groups. The regular control group of heat-cured PMMA-Ti_6Al_4V alloy had the lowest mean tensile strength mean value (52.47 MPa). These results may be due to the Ti_6Al_4V particles as reinforcement ingredients causing acceptable integration with heat-cured PMMA resin ingredients. As a result, because the load applied to the composite elements is the local stress and cracking form in the matrix of the composite materials [12], resulting in excellent strength characteristics due to the reinforcement ingredients that have not agglomerated[12, 15]. Additionally, the tensile strength of the specimen increased with increasing concentration of Ti_6Al_4V alloy particles, which may disagree with Shirkav and Moslehifard [5] who concluded that when the concentration of TiO_2 increases in the PMMA, this probably did not increase the tensile strength of the denture base and this might due to a difference between the two materials. The TiO_2 nanoparticles and Ti_6Al_4V fillers, in addition to the difference between the nature and size of the particles for each of these two materials.

In addition, Table 2 indicated that there were substantial differences between all specimens. Consequently, it may be due to the fact that the titanium alloy has a very high tensile strength. Since the titanium alloy makes up most of the titanium component; therefore, it means that Ti_6Al_4V particles have high tensile strength [22]. Consequently, when the addition of Ti_6Al_4V particles to the acrylic resin matrix, this helped to increase the tensile strength in generally synthesised composite specimens [14,16].

On the other hand, transverse strength can be defined as the resistance of the material to fracture, it is also described as the modulus of rupture or flexural strength [6, 7]. In this study, it was found that the addition of Ti_6Al_4V particles to acrylic resin increased the transverse strength of the manufactured biocomposite specimens. The results of this investigation could agree with the outcomes of Ahmed et al., 2016, who concluded that adding TiO_2 to PMMA showed an improvement in the flexural strength of the denture base [30].

Furthermore, it can be recognised from the obtained results through Table 3 that the experimental group of heat-cured acrylic mixed with 2% Ti_6Al_4V particles had the highest transverse strength value (94.37 N/mm^2) among the studied groups. However, still the heat-cured acrylic Ti_6Al_4V alloy particles had the lowest mean transverse strength value (73.47 N/mm^2). Furthermore, the transverse strength of the sample increased with the increase of alloy Ti_6Al_4V alloy particles concentration. The current findings contradicted the findings of Edwin et al., who concluded that increasing the concentration of TiO_2 added to PMMA did not result in an improved transverse strength. This could be due to the divergence of properties between Ti_6Al_4V alloy particles and TiO_2 components[31, 18].

Besides, Table 3 shows that there were highly significant differences between all studied groups. This may be because titanium and its alloys had excellent mechanical properties [16] when compared to more conventional polymer materials, stainless steel alloys and cobalt-based alloys [15]. Consequently, when the additions of Ti_6Al_4V alloy particles were of acrylic resin material, this helped to increase transverse strength in general. Furthermore, Ti_6Al_4V particles may have reduced the porosity of PMMA and increased its transverse strength [9, 21].

Furthermore, surface hardness refers to the capability of a substantial to withstand significant wear [32, 17]. The durometer hardness is used to characterise the bulk hardness of viscoelastic and elastomeric polymers [10]. It can be anticipated from the results obtained through Table 4 that the group with the heat-cured PMMA mixed with 2% of Ti_6Al_4V particles had the highest surface hardness mean value (108.39) among the studied groups. The lowest mean value of surface hardness (88.84) was detected with heat-cured acrylic Ti_6Al_4V alloy particles. Therefore, the surface hardness of the specimens increased with increasing concentration of Ti_6Al_4V particles. This result may be in agreement with Patra et al. [20] who concluded that the surface hardness of the PMMA/TiO_2 compounds increased with increasing concentration of TiO_2 nanoparticles added to the PMMA. Due to the high adhesion between TiO_2 NPs and PMMA, the motions of the polymer chain are hampered by TiO_2 NP dispersion within the matrix. This was entirely supported by the increase in stiffness of the material as a result of the presence of hard particles throughout the matrix, as well as a reduction in matrix mobility [11].

By comparison, in this study, Table 4 showed high surface hardness among all specimens. This result is probably attributed to the titanium alloy particles bonding with acrylic resin material, resulting in durable attachment because of powered interconnecting via the coarseness of the metallic surface, chemical reaction by a bonding agent monomer, and also the combination of surface alteration and adhesive monomer. In terms of resin attachment, titanium and its alloys are also equivalent [15, 22]. In addition, it may be that the alloys in the Ti_6Al_4V particles consequently improved the hardness of PMMA, for example, vanadium is harder than PMMA [15, 16, 25]. These findings could be explained by the chemical and physical interactions between Ti_6Al_4V alloy particles and heat-cured acrylic resin material.

When reinforcement particles are dispersed in an acrylic resin matrix incorrectly, the monomer reaction slows, and the amount of nonreactive monomers increases. It is also possible that the stress concentrations of the reinforcement particles affect the strength module and crack during the resin development mode. However, if the particles are evenly distributed in the resin, the stress concentration can be avoided, and the mechanical properties of the resin can be improved [17]. As a result, additional analyses, such as fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), and energy dispersive spectroscopy (EDS), could be performed in this research to determine these chemical and physical interactions.

Conclusions

The mechanical properties of the Ti_6Al_4V alloy particles in heat-cured acrylic resin material were improved based on the findings of the investigation, such as tensile strength, transverse strength, and surface hardness. Consequently, increasing (wt. %) of Ti_6Al_4V alloy particles addition considerably improved the mechanical properties of all synthesised composite specimens. In addition to the tensile strength, the 2 wt. % Ti_6Al_4V alloy particles group performed best in the tests of transverse strength and surface hardness testing. Despite having the lowest tensile strength, transverse strength, and surface hardness, the 0.5% value was still higher than the PMMA without of Ti_6Al_4V of alloy particles reinforcement 0.0 wt. % control group.

Conflict of interest

The authors have no conflicts of interest to declare.

Authors' contributions

All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by NHA. The first draft of the manuscript was written by NHA, ShFA, and SSBQ commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Informed consent

Consent to participate for this type of study, formal consent is not required.

References

1. Patil SS, Patil AG, Kanathila H. An in vitro study to evaluate and compare the effects of various polymerisation cycles on the physical and mechanical properties of Heat cure Polymethylmethacrylate resin. Eur Chem Bull 2023; 12(3), 983-998

2. Pires-de-Souza FdCP, Panzeri H, Vieira MA, Garcia LdFR, Consani S. Impact and fracture resistance of an experimental acrylic polymer with elastomer in different proportions. Mat Res 2009; 12(4):415-8. https://doi.org/10.1590/S1516-14392009000400007

3. Rakhshan V. Marginal integrity of provisional resin restoration materials: A review of the literature. Saudi J Dent Rese 2015; 6(1):33-40. https://doi.org/10.1016/j.sjdr.2014.03.002

4. Han Z, Zhu B, Chen R, Huang Z, Zhu C, Zhang X. Effect of silver-supported materials on the mechanical and antibacterial properties of reinforced acrylic resin composites. Materials & Design (1980-2015) 2015; 65:1245-52. https://doi.org/10.1016/j.matdes.2014.10.023

5. Shirkavand S, Moslehifard E. Effect of TiO2 nanoparticles on tensile strength of dental acrylic resins. J Dent Res Dent Clin Dent Prospects 2014; 8(4):197.

6. Jagger D, Jagger R, Allen S, Harrison A. An investigation into the transverse and impact strength ofhigh strength'denture base acrylic resins. J Oral Rehabil 2002; 29(3):263-7. https://doi.org/10.1046/j.1365-2842.2002.00830.x

7. Narendra R, Reddy NS, Reddy SD, Purna CS, Shekar MC, Balasubramanyam S. 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 Cont Dent Prac 2013; 14(6):1115. https://doi.org/10.5005/jp-journals-10024-1461

8. Dhir G, Berzins DW, Dhuru VB, Periathamby AR, Dentino A. Physical properties of denture base resins potentially resistant to Candida adhesion. J Prosthodont 2007; 16(6):465-72. https://doi.org/10.1111/j.1532-849X.2007.00219.x

9. Nam KY, Lee CH, Lee CJ. Antifungal and physical characteristics of modified denture base acrylic incorporated with silver nanoparticles. Gerodontology 2012; 29(2):e413-e9. https://doi.org/10.1111/j.1741-2358.2011.00489.x

10. Omidi M, Fatehinya A, Farahani M, Akbari Z, Shahmoradi S, Yazdian F, et al. Characterization of biomaterials. 2017: 97-115. https://doi.org/10.1016/B978-0-08-100961-1.00007-4

11. Altaie SF. Tribological, microhardness and color stability properties of a heat-cured acrylic resin denture base after reinforcement with different types of nanofiller particles. Dent Med Probl 2023; 60:295-302. https://doi.org/10.17219/dmp/137611

12. Atallah W, AlFuraiji N, Hussein OH. Nanocomposites for Prosthetic Dental Technology: A Systemic Review. Journal of Techniques 2023; 5(1):129-36. https://doi.org/10.51173/jt.v5i1.1178

13. Li Y-H, Shang X-Y, Li Y-J. Fabrication and characterization of TiMoCu/PMMA composite for biomedical application. Materials Letters 2020; 270:127744. https://doi.org/10.1016/j.matlet.2020.127744

14. 14. Kavitha Janardanan DV. Effect of titanium dioxide nanoparticles incorporation on tensile and impact strength in two different acrylic denture base resins. Int Dent J Students Res 2020; 8(2):65-74. https://doi.org/10.18231/j.idjsr.2020.014

15. Kodaira A, Koizumi H, Hiraba H, Takeuchi Y, Koike M, Shimoe S. Bonding of resin luting materials to titanium and titanium alloy. J of Oral Sci 2022; 64(3):181-4. https://doi.org/10.2334/josnusd.22-0036

16. Wei G, Tan M, Attarilar S, Li J, Uglov VV, Wang B, et al. An Overview of Surface Modification, A Way Toward Fabrication of Nascent Biomedical Ti-6Al-4V Alloys. J Mater Res Tech 2023; 24: 5896-5921. https://doi.org/10.1016/j.jmrt.2023.04.046

17. Ata SO, Canan A, Mumcu E. The effects of metal nanoparticles incorporation on the mechanical properties of denture base acrylic resin. Eur Oral Res 2023;57(1):36-40.

18. Alrahlah A, Fouad H, Hashem M, Niazy AA, AlBadah A. Titanium oxide (TiO2)/polymethylmethacrylate (PMMA) denture base nanocomposites: mechanical, viscoelastic and antibacterial behavior. Materials 2018; 11(7):1096. https://doi.org/10.3390/ma11071096

19. 19. Azeez ZA, Kareem RA, Abdulwahhab SS. The effect of nano titanium oxide particle incorporation on characteristic of denture base material. Materials Today: Proceedings 2021; 42:2102-5. https://doi.org/10.1016/j.matpr.2020.12.292

20. Patra N, Barone AC, Salerno M, Caputo G, Cozzoli D, Athanassiou A, editors. Thermal and mechanical characterization of PMMA TiO2 nanocomposites. Adv Mater Res 2009: 67:209-214. https://doi.org/10.4028/www.scientific.net/AMR.67.209

21. Özcan M, Hämmerle C. Titanium as a reconstruction and implant material in dentistry: advantages and pitfalls. Materials 2012; 5(9):1528-45. https://doi.org/10.3390/ma5091528

22. Guo S, Li Y, Gu J, Liu J, Peng Y, Wang P, et al. Microstructure and mechanical properties of Ti6Al4V/B4C titanium matrix composite fabricated by selective laser melting (SLM). J Mat Res and Techn 2023; 23:1934-46. https://doi.org/10.1016/j.jmrt.2023.01.126

23. Cui C, Hu B, Zhao L, Liu S. Titanium alloy production technology, market prospects and industry development. Materials & Design 2011; 32(3):1684-91. https://doi.org/10.1016/j.matdes.2010.09.011

24. Donachie MJ. Titanium: a technical guide: ASM international; 2nd edition, 2000. https://doi.org/10.31399/asm.tb.ttg2.9781627082693

25. Veiga C, Davim J, Loureiro A. Properties and applications of titanium alloys: a brief review. Rev Adv Mater Sci 2012; 32(2):133-48.

26. Weaver JS, Kalidindi SR, Wegst UG. Structure-processing correlations and mechanical properties in freeze-cast Ti-6Al-4V with highly aligned porosity and a lightweight Ti-6Al-4V-PMMA composite with excellent energy absorption capability. Acta Materialia 2017; 132:182-92. https://doi.org/10.1016/j.actamat.2017.02.031

27. Sirvent P, Garrido MÁ, Sharp J, Rainforth WM, Poza P. Improving the oscillating wear response of cold sprayed Ti-6Al-4V coatings through a heat treatment. Surf Coat Tech 2020; 399:126128. https://doi.org/10.1016/j.surfcoat.2020.126128

28. ISO I. 20795-1 Dentistry-Denture Base Polymers. ISO: Geneva, Switzerland. 2008.

29. Polyzois GL, Tarantili PA, Frangou MJ, Andreopoulos AG. Fracture force, deflection at fracture, and toughness of repaired denture resin subjected to microwave polymerization or reinforced with wire or glass fiber. J Prosthet Dent 2001; 86(6):613-9. https://doi.org/10.1067/mpr.2001.120069

30. 30. Ahmed MA, El-Shennawy M, Althomali YM, Omar AA. Effect of titanium dioxide nano particles incorporation on mechanical and physical properties on two different types of acrylic resin denture base. World J Nano Sci Engineer 2016; 6(3):111-9. https://doi.org/10.4236/wjnse.2016.63011

31. 31. Tandra E, Wahyuningtyas E, Sugiatno E. The effect of nanoparticles TiO2 on the flexural strength of acrylic resin denture plate. Padjadjaran J Dent 2018; 30(1):35-40. https://doi.org/10.24198/pjd.vol30no1.16110

32. O'Brien WJ, editor. Dental materials and their selection. Chicago: Quintessence; 2002.

تقييم تأثير جزيئات سبائك Ti_6Al_4V على الخواص الميكانيكية لـ PMMA المعالج بالحرارة

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المستخلص:

الخلفية: تعتبر سبائك التيتانيوم (Ti_6Al_4V) مادة واعدة لتطبيقات طب الأسنان الاصطناعي بسبب كثافتها العالية، وقوتها العالية، ومقاومتها المحسنة للتآكل، وتوافقها الحيوي الفائق. ومع ذلك، نظرًا لقوته المنخفضة وهشاشته، فإن راتينج الأكريليك المعالج بالحرارة ليس مادة أساس طقم أسنان عمليًا بكل الطرق. ونتيجة لذلك، يعد تحسين خصائص قوة راتينج الأكريليك المعالج بالحرارة أمرًا بالغ الأهمية. تهدف الدراسة الحالية إلى تقييم تأثير جزيئات Ti_6Al_4Vعلى قوة الشد والقوة العرضية والصلابة السطحية لمادة قاعدة طقم أسنان راتينج الأكريليك المعالج بالحرارة. المواد والطرق. تم صنع خمسة وسبعين عينة من خلال دمج راتينج الأكريليك المعالج بالحرارة مع جزيئات Ti_6Al_4V بنسب (0.5، 1، 1.5، و 2٪ بالوزن على التوالي). تم تقسيم كل مجموعة إلى ثلاث مجموعات فرعية حسب الاختبار الذي تم إجراؤه 25 عينة لكل مجموعة فرعية: عينات قوة الشد؛ عينات اختبار القوة العرضية؛ وعينات اختبار صلابة السطح على التوالي. ومن ثم تم تقييم نتائج هذه الاختبارات. النتائج: أظهرت النتائج وجود فرق معنوي كبير عند P=0.007 في جميع المجموعات التي تم اختبارها. أظهرت النتائج أن إضافة Ti_6Al_4V إلى المواد المعالجة بالحرارة أدى إلى زيادة كبيرة في قوة الشد والقوة العرضية وصلابة عينات الأكريليك المعالجة بالحرارة عند مقارنتها بعينات التحكم دون إضافة Ti_6Al_4V. الاستنتاج: لقد وجد أن زيادة تركيز الوزن (wt.%) لجزيئات Ti_6Al_4V أدى إلى تحسين قوة الشد والقوة العرضية وصلابة السطح لعينات PMMA المعالجة بالحرارة.