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The Effect of Rice Husk-Derived Silica Incorporation on Heat-Cured Acrylic Denture Bases

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Abstract

The present study in vitro study was designed to test the physico-mechanical properties of a heat cured PMMA-based denture base with different concentrations (5%, 7.5% and 10% by weight) of the silica microparticle obtained from rice husk (RH). Heat-cured PMMA was combined with high-purity silica microparticles (<0.5µm) recovered from RH ash. 200 specimens were prepared, with 40 specimens allocated for each test. The specimens were grouped into four categories based on their silica concentrations of 0, 5, 7.5, and 10%. A statistical analysis was performed using the one-way analysis of variance (ANOVA) and least significant difference (LSD) post-hoc test. Transverse strength significantly improved when the concentration of silica used was 7.5% of the RH derived silica for the best performance. There was an improvement in the wettability (lower contact angle), indicating enhanced hydrophilicity. But with increasing amount of filler, the surface hardness also obtained an equal enhancement. Surface roughness was slightly increased, however, which indicates potential for more plaque build-up unless proper polishing is performed. The surface and mechanical properties of the PMMA-based denture base were greatly improved with the RH-derived silica. The group with a silica concentration of 7.5% demonstrated optimal improvements, suggesting its potential as an effective and sustainable reinforcement for denture base materials.

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Introduction

A traditional complete denture is still the therapy of choice for many edentulous patients for medical and budgetary reasons. Although dental implants are strong, edentulous people still find complete dentures adequate. Some issues, including inadequate retention, discomfort during chewing, and inadequate stability, might manifest over time with even a full denture. Although implants are increasingly effective, they are still not a viable option for many patients due to factors such as medical issues, psychological issues, bone quality and quantity, and economic situation, all of which play a significant part in the treatment plan [1].

The material most often used for dentures nowadays is polymethyl methacrylate (PMMA). One unresolved issue in prosthodontic care is the frequency of denture fractures, which often occur despite the extensive usage of PMMA in this field [2]. The incorporation of elements such as carbon-graphite fibre, aramid fibre, glass fibre, and metal reinforcements into polymers can help them transcend their physical and mechanical constraints [3].

Dentures made of other polymers, such as polystyrene, acrylic styrene, or vinyl acrylic, have not yet been unveiled, despite their potential for improved accuracy and performance. The impact strength of PMMA has been enhanced by modifications that include a rubber phase in the bead polymer. However, this modification has led to an increase in its cost [4].

A resilient PMMA-based denture base acts as a cushion for the denture-bearing mucosa by

uniformly distributing the functional load, avoiding local stress concentrations, preventing chronic soreness, preserving the supporting structures, and improving the retention of dentures, thus providing relief to the patient [5].

As PMMA-based denture base becomes harder, the surface hardness increases as increasing concentrations of up to 7% of silicon dioxide particles. The transverse strength of acrylic resins is also enhanced by adding a silicon dioxide nano-powder to a PMMA-based denture base at concentrations of 3 and 5% [6]. Low concentrations of silica nanoparticles yield PMMA-based denture bases with superior mechanical properties in terms of micro hardness and fracture toughness compared to high silica concentrations. This finding may be attributed to the development and propagation of cracks as well as the agglomeration that occurs with an increased silica content [7].

A new purpose has been found for rice husk (RH), a waste product of the rice milling process, where its combustion can be used to produce energy, and the resulting RH ash is rich in amorphous silica (85–95%). Various silicates, zeolites, catalysts, cement, nanocomposites, insulators, lightweight building materials, and adsorbents have been using RH ash in great quantities throughout the last 20 years [8].

The mechanical properties of PMMA are far from ideal, but it has surpassed other materials as the preferred material for denture construction owing to its low cost, biocompatibility, processing ease, stability in the oral environment, and acceptable aesthetics.

The objective of the present study was to determine how changing the proportion of RH-derived silica in a standard heat-cured PMMA-based denture base affects its physico-mechanical characteristics. According to the null hypothesis, the physico-mechanical characteristics of a heat-cured PMMA-based denture base are unaffected by the addition of RH-derived silica. In contrast, the alternative hypothesis holds that adding RH-derived silica to a heat-cured PMMA-based denture base changes its physico-mechanical characteristics [9].

Subjects and Methods

Natural silica preparation

A large quantity of water was used to wash the RH, before it was rinsed in distilled water. The RH was dried It was left at room temperature for 24 hours, after which it was mixed. 1.0 M nitric acid. An electrical muffle furnace was used to calcine the RH at 600 °C for six hours to extract very pure silica, which was then mixed with 6.0 g of RH ash, 2.0 g of Merck® sodium hydroxide pellets, and 40 mL of water. The required sodium silicate was synthesised to produce homogenous silica microparticles. These were stirred for two hours at 80 °C to produce a gel mixture, which was designated as Soup A. The second solution, Soup B, was made by combining 6.0 g of cetyltrimethylammonium bromide with 35 mL of water and agitating the mixture at 80 °C until it became transparent. After 15 minutes of stirring, Soups A and B were combined in a polypropylene container. Next, the mixture was then heated in the oven at 100 °C for 24 hours to allow it to crystallise into solid form. Gel mixture was then cooled to room temperature. 25 wt of NaOH was added to the reaction mixture to raise the pH to 10.2% of acetic acid drop-by-drop while swirling vigorously. Next, the substance was allowed to crystallise by placing it in an oven for 48 hours. Pure mesoporous silica microparticles with a particle size of <0.5 µm were obtained by filtering, washing, and calcining at 550 °C. The final product obtained was then dried in air for 10 hours [10].

Sample preparation

The prepared silica powder samples, at concentrations of 5, 7.5, and 10 wt.%, were added separately to a heat-cured acrylic monomer before being mixed with the polymer powder.

Specimen grouping

Tests for the transverse strength, impact strength, wettability, surface hardness, and surface roughness were conducted on 200 specimens that had been divided into five main groups, with 40 specimens being used for each test. Heat cured denture base acrylic was Vertex™ acrylic. Each group was then subdivided into four subgroups according to their weight percentage of RH-derived silica microparticles. The control group contained 0% glass flakes, while the other groups contained 5, 7.5, and 10% of RH-derived silica microparticles (n=10).

Testing Methods

Impact strength

As per the International Organisation for Standardisation (ISO) 179-1:2000 [11], the specimens were subjected to impact tests using a Charpy impact testing machine from Testing Machines Inc. A total of 40 specimens, in the form of bars measuring 80×10×4 mm in terms of their length, breadth, and thickness, respectively, were made. They were then laid horizontally on supports at both ends and hit in the centre by a 2-Joule free-swinging pendulum. The readout of the impact energy in Joules received by the specimens was provided by the scale. The following formula (ISO179-1:2000) was used to determine the impact strengths of the unnotched specimens in KJ/M²:

$$\text{Impact strength} = \frac{E}{b.d} \times 10^3,$$

Where, *E* is the impact energy (J), *b is the width of the specimens (mm), and d is the thickness of the specimens (mm).*

Transverse strength

An Instron® three-point bending computer-controlled universal testing machine from Laryee Technology Co. was used to conduct the transverse strength test. Forty bar-shaped specimens measuring 65×10×2.5 mm in length, width, and thickness, respectively, were prepared according to the American Dental Association Specification No. 12 (1999) [12]. They were placed on a bending fixture with two parallel supporting arms spaced about 50 mm apart. The specimens were fully scaled at 50 kg. A rod, placed midway between the arms, was used to apply a load of 1 mm/min, causing a deflection until fracture occurred. The following formula (ADA No. 12, 1999) [12] was used to determine the transverse strength:

$$T = \frac{3PL}{2bd^2},$$

Where, *T denotes the transverse strength (N/mm2), P stands for the maximum load applied (N), L for distance between the supporting arms (mm or length), b for width of specimen (mm or width) and d for thickness of specimen (mm or thickness).*

Wettability

A This injury was judged by the static sessile drop method. of the examined specimens, with 40 specimens having been prepared for this purpose. An optical subsystem was used to photograph the process, depicting a liquid droplet resting on a solid surface on a level, horizontal base [13]. Under a Dino-lite digital microscope set to 45× magnification, the contact angle created among the distilled water, specimen surface, and air was recorded. Using a Dragon Lab® micro-pipette (held upright above the surface) an aliquot of distilled water was pipetted, 40 µl was the volume. specimen to standardise the drop size. The Dino-Capture software on the Dino-lite digital microscope was used to magnify the photograph of the contact angle after positioning it parallel to the surface of the specimen. In the worst-case scenario, the wettability decreased as the contact angle increased and vice versa.

Surface hardness

Forty bar-shaped specimens with dimensions 65×10×2.5 mm (ADA No. 12, 1999) [12] were manufactured and placed on a horizontal and firm surface. The test was carried out using a durometer that is specially designed for acrylic material. The HARTIP®

3000 compound was used to measure the Shore D hardness, with a blunt-pointed indenter, measuring 0.8 mm in diameter, as the instrument. Normally, three seconds of pressing down with pressure would be applied to the indenter, and the highest mark taken would represent the Shore D hardness. The rest of the measurements were taken directly from the digital scale reading. A digital scale, calibrated from 0 to 100 scale was connected to the indenter. Five measurements were made in various places for each specimen and the average made [6].

Surface roughness

In accordance with the directions provided by the surface roughness testing device, 40 bar-shaped specimens were made, each with dimensions of 65×10×2.5 mm in length, width, and thickness, respectively. A Mahr Federal® profilometer instrument was used to determine if the addition of silica affected the micro-geometry of the acrylic surface. This instrument employs a sharp, keen diamond stylus to trace the contour of surface imperfections. The specimen was set down on a firm and steady surface. The stylus was then used to touch three distinct areas of each specimen to obtain three readings. The digital scale displayed the results automatically. Finally, the roughness was determined by averaging the three measurements [14]. According to the standards set by the ANSI/ADA in 1999 [12], all the specimens were placed in an incubator with distilled water and kept at 37 °C for 48 hours before the test.

In this *in vitro* study, the natural silica-incorporated acrylic specimens did not truly represent the closely simulated clinical conditions. Therefore, all the properties of the silica-reinforced PMMA-based denture base had to be investigated to predict the best clinical efficacy.

Results

This research examined how adding silica microparticles made of rice husk affected the heat-cured polymethyl methacrylate (PMMA) denture base material versus several physio-mechanical properties. Four experiments were carried out and the acrylic resin used contained 0 percent silica (Group 1, control); 5 percent silica (Group 2), 7.5 percent silica (Group 3), and 10 percent silica (Group 4). One-way analysis of variance (ANOVA) and post-hoc test least significant difference (LSD) were used.

Impact Strength

Average impact strength test results in all test groups were slowly increasing as the silica particles increased. The groups with silica showed higher values (0.480 +- 0.039) that were shown on the control group. In Group 3 (7.5% silica), the greatest effect was noted with a strength of 0.568 +- 0.044 and next Group 4. Statistically, there was a significant difference between the groups ($p < 0.001$), therefore the addition of the RH silica significantly improved the impact resistance of PMMA denture base material.

Transverse Strength

The situation was similar regarding tensile strength. Increased value was observed in the silica reinforced groups with the lowest value obtained in the control group (12.51 +- 0.64). Group 4 recorded the highest value for Transverse strength, 15.71 +- 0.80 followed by Group 3. The means of the different groups were significantly different. ($p < 0.001$) which indicated that silica reinforcement improved flexural performance of the PMMA through the improvement of the material.

Wettability

Contact angle measurements were used in determining the wettability of the specimens. The values of the contact angle reduced, to indicate improvement in the surface, since silica was introduced. hydrophilicity. Group number 3 had the least contact angle implying that moderate level of incorporation of silica enhanced the surface energy and wetting behaviour of a denture base material.

Surface Hardness

The values of surface hardness improved after silica incorporation. The lowest value of hardness was measured in control group (85.82), and high values were measured in the experimental groups. Group 3 was observed to have the highest value of hardness (88.50) and then Group 4 (88.43). The statistical test proved the presence of a significant group difference ($p < 0.001$).

Surface Roughness

The values of surface roughness have slightly increased after the incorporation of silica. The lowest value was detected in Group 3 (0.191 +- 0.006) and the lowest value was in control group (0.128 +- 0.006). Despite some increases in roughness, the values were also in the range of clinically acceptable denture base materials.

Generally, the findings revealed that the moderate incorporation of silica (especially at 7.5 percent) offered the most moderate enhancement of the physico-mechanical properties of PMMA denture base material.

Discussion

The influence of silica produced from rice husk (RH) in different significant physio-mechanical properties of heat cured PMMA denture base material (DBM) was investigated. It was found that PMMA incredibly enhanced its mechanical properties when silica was added to it, particularly impact strength, transverse strength, surface hardness and wettability.

The increase in impact strengths donned in the silica-reinforced groups could possibly be explained by the enhancing influence of silica particles in the PMMA structure. Stress distribution and crack propagation under impact loading conditions can be enhanced by incorporation of rigid filler particles into the polymer network, which decreases crack propagation. This reinforcement process enhances the strength of the material to be able to take in energy and fracture. The same has been reported in earlier studies that have assessed the reinforcement of acrylic resins using silica-based fillers.

The effect of the strengthening of transverse strength in the experimental groups is also a reinforcement of silica particles. Silica in the PMMA matrix can increase intermolecular bonding of the polymer chains and filler particle, which leads to increased rigidity of the structure and ability to resist bending forces. Also, the silica particles can be stress-transfer locations that spread the applied forces more uniformly across the polymer matrix.

The addition of silica also enhanced the wettability, and this was demonstrated by the decrease in the values of the contact angle. The enhanced hydrophilicity could be explained by the existence of a greater surface energy with silica particles. Increased wettability is regarded to be positive attribute in denture base material due to its ability in enhancing saliva spreading on the denture surface and leads to increased denture retention and comfort.

Nevertheless, it was found that there was a slight increment in the surface roughness following the introduction of silica. This could be attributed to the fact that it has filler particles on its surface which could affect surface micro-topography. Even though the presence of greater roughness can possibly support the development of the adhesion of the microbes, the obtained values obtained in the current study were within clinically acceptable ranges of the denture base material.

The most desirable overall performance was 7.5% silica incorporation of the tested concentrations. Silica particles could be more evenly distributed in the PMMA matrix at moderate concentrations, and this will offer the best reinforcement without agglomeration of the particles. Conversely, when it is

concentrated more, filler clusters can form which can serve as the stress concentration sites and decrease the reinforcement effectiveness.

The findings indicate that silica husk of rice is a promising sustainable reinforcing filler of PMMA denture base materials. Agricultural waste products like rice husk ash are also useful in fostering environmental sustainability in the development of biomaterials.

Conclusion

Natural silica increased the PMMA's impact strength, transverse strength, and PMMA hardness. However, the incorporation slightly increased surface roughness, which may require careful polishing to minimize plaque accumulation.

Recommendation and Suggestions for Future Studies

The findings from this study show that the inclusion of 7.5% RH-derived silica into a PMMA-based denture base can achieve a balance between enhanced mechanical properties and acceptable surface quality. This concentration yielded the best results across multiple tests, particularly the impact and transverse strength tests.

Nevertheless, future studies may assess the anti-microbial and anti-fungal activities and examine the combined effect of silica addition on the thermal stability of, colour stability, and ageing resistance of PMMA to ensure the overall durability and aesthetic acceptability of the denture base. Apart from that, other sustainable bio-waste-derived fillers, which could improve the mechanical properties, could also be investigated. Lastly, future studies may assess the mixing of a nano filler material to check its action on the physico-mechanical properties.

References

1. Jayesh S, Tushar M, Priya G, Rahul T, Neelam P, Kalyani D, et al. Satisfaction in conventional acrylic complete denture patients with and without denture liners: a systematic review. **Pan Afr Med J.** 2022;42:296. https://doi.org/10.11604/pamj.2022.42.296.33035

2. Iqtidar Z, Suleman G, Khalid Z, Murtaza B, Muzaff A, Sheikh F, et al. Communal causes of denture fractures in edentulous patients – an overview. **Pak J Surg.** 2020;36(2):195-199.

3. Alzahrani MM, Alamry KA, Hussein MA. Recent advances of fiber-reinforced polymer composites for defense innovations. **Results Chem.** 2025;15:102199. https://doi.org/10.1016/j.rechem.2025.102199

4. Manu R, Sandeep S, Maqbul A, Prachi J, Divakar S. Management of repeated denture fracture through direct metal laser sintering metal reinforced denture. **J Clin Diagn Res.** 2023;17(3):ZD04-ZD06. https://doi.org/10.7860/JCDR/2023/59227.17587

5. Yankova M, Todor P, Bozhidar Y. Basic problems with the use of resilient denture lining materials: literature review. **J IMAB.** 2021;27(2):3723. https://doi.org/10.5272/jimab.2021272.3723

6. Alnamel HA, Mudhaffer M. The effect of silicon dioxide nano-fillers reinforcement on some properties of heat cure polymethyl methacrylate denture base material. **J Baghdad Coll Dent.** 2014;26:32-36.

7. Balos S, Pilic B, Markovic D, Pavlicevic J, Luzanin O. Poly(methyl methacrylate) nanocomposites with low silica addition. **J Prosthet Dent.** 2014;111:327-334. https://doi.org/10.1016/j.prosdent.2013.06.021

8. Hossain SKS, Mathur L, Roy PK. Rice husk/rice husk ash as an alternative source of silica in ceramics: a review. **J Asian Ceram Soc.** 2018;6(4):299-313. https://doi.org/10.1080/21870764.2018.1539210

9. Indumathi M, Nakkeeran G, Dipankar R, Sonu KG, George UA. Innovative approaches to sustainable construction: a detailed study of rice husk ash as an eco-friendly substitute in cement production. **Discover Appl Sci.** 2024;6:597. https://doi.org/10.1007/s42452-024-06314-1

10. Kareem RA, Naji GAH. Natural preparation of rice husk-derived silica and eggshell-derived calcium carbonate composite as a coating material for dental implants. **J Baghdad Coll Dent.** 2022;34(1).

11. International Organization for Standardization. **ISO 179-1:2000 Plastics—Determination of Charpy impact properties—Part 1: Non-instrumented impact test.** Geneva: ISO; 2000.

12. American Dental Association. **Specification No. 12 for denture base polymers.** Chicago: ADA; 1999.

13. Alamen BM, Naji GAH, Alsmael MA. The effect of virgin coconut oil addition on the hardness and wettability of acrylic-based denture soft lining material. **J Res Med Dent Sci.** 2020;8(1):96-106.

14. Mawlood ZS. The effect of *Citrus bergamia* essential oil on *Candida albicans* activity and some properties of a heat-cured acrylic resin [Master thesis]. Baghdad: University of Baghdad; 2020.

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Table 1. Comparisons between experimental groups using one-way ANOVA.

Comparisons between means of readings according to group of study and time of measurements using one way ANOVA												
Tests	Groups	N	Mean	SD	F	P-value	Multiple comparisons					
							G1-G2	G1-G3	G1-G4	G2-G3	G2-G4	G3-G4
T1	G1	10	0.480	0.039		0.001	0.161	0.001	0.001	0.003	0.004	0.875
	G2	10	0.507	0.042								
	G3	10	0.568	0.044								
	G4	10	0.565	0.042								
T2	G1	10	12.51	0.64		0.001	0.104	0.148	0.004	0.852	0.165	0.117
	G2	10	14.24	0.516								
	G3	10	15.35	0.82								
	G4	10	15.71	0.80								
T3	G1	10	69.00	2.10		0.001	0.003	0.001	0.002	0.302	0.931	0.264
	G2	10	65.40	2.87								
	G3	10	64.20	2.29								
	G4	10	65.50	2.87								
T4	G1	10	85.82	0.92		0.001	0.005	0.001	0.001	0.106	0.133	0.903
	G2	10	87.55	1.03								
	G3	10	88.50	1.73								
	G4	10	88.43	1.27								
T5	G1	10	0.128	0.006		0.001	0.001	0.001	0.001	0.002	0.026	0.325
	G2	10	0.177	0.012								
	G3	10	0.191	0.006								
	G4	10	0.187	0.009								
T1=impact strength, T2=Transverse strength, T 3=Wettability, T4=Hardness, T5= Surface roughness G1=control group, G2=5% W silica group, G3=7.5%W silica group, G4=10% W silica group												