ORIGINAL ARTICLE

Wear Resistance Evaluation of the Thermoplastic Acetal Resin Denture Base Material – An *In Vitro* Study

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ABSTRACT

Purpose: The aim of this study was to evaluate wear resistance of acetal resin material versus heat-cured acrylic resin denture base material. **Materials and Methods:** Fourteen specimens were fabricated with dimensions (15 mm in diameter × 2 mm thickness) according to ISO standard number 14569/2, then divided into two groups (seven specimens for each). Group I contained seven specimens of heat-cured acrylic resin denture base material, while Group II contained seven specimens of acetal resin denture base material. The cycling test for each group was carried out using the chewing simulator. **Results:** For Group I, the weight mean value before wear was (0.155833 ± 0.008 g) while after wear simulation, the mean value was (0.154983 ± 0.008 g) with weight change mean value (0.00085 ± 0.0002 g). For Group II, the weight mean value before wear was (0.145658 ± 0.005 g) while after wear simulation, the weight mean value was (0.14495 ± 0.0058 g) with weight change mean value (0.000708 ± 0.0002 g). The difference between weight changes recorded for groups was statistically non-significant ($P = 0.0861 > 0.05$). **Conclusions:** As there was no statistically significant difference between the two groups regarding wear resistance, the acetal resin can be used as alternative material to conventional heat-cured acrylic resin denture base material.

Key words: Denture base material, acetal resin, POM, wear, removable partial denture

INTRODUCTION

For many years, polymethyl methacrylate (PMMA) was commonly used as denture base material. Properties that contributed to the success of these materials as a denture base are excellent appearance, ease of processing, and ease of repair. However, an inherent disadvantage is the liability of heat-cured acrylic resin denture to break during service, color instability, water sorption, and surface roughness.[1]

PMMA resin surfaces are prone to indentation by different hard objects, which increase the abrasiveness and wear of acrylic base material. These phenomena provide a favorable environment for fungal and bacterial colonization which is associated with several oral and general diseases.[2] Several studies of denture base materials have demonstrated a direct link between acrylic surface abrasion, plaque buildup, and *Candida albicans* adherence.[3]

At present, a new line of thermoplastic acetal, acrylic, nylon, and polycarbonate materials has been introduced.[4] Thermoplastic dentures are excellent alternatives to conventionally used methyl methacrylate dentures; they provide excellent aesthetics and comfort and also adapt to the constant movement and flexibility in partially edentulous patients.[1]

The therapeutic use of thermoplastic materials has increased drastically in the late decade. A new procedure, during which

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a fully polymerized basic material is softened by heat (without chemical changes) and injected afterward, has opened up a new chapter in making dentures.[5]

Thermoplastic acetal also known as polyoxymethylene (POM) derived from formaldehyde. These materials are presented as low molecular weighed (about 150,000) grains having low plasticizing temperature and higher rigidity.[6] The homopolymer, POM is a chain of alternating methyl groups linked by an oxygen molecule. Acetal resins are hard, tough, and rigid materials, which show a low coefficient of friction and have high resistance to fatigue. In industry, they are used at sites where wear of components is a problem.[7,8]

Acetal resins (POM-based materials) used in dentistry exhibits high flexibility, physical strength, heat and chemical resistance, and the exceedingly rare allergy response. Acetal resins show limited water sorption, exhibit lower creep, and superior abrasion resistance with higher surface luster than nylons. The higher stiffness of acetal resin supports conventional clasp designs, connectors, and other components with some compensation required.[9]

Acetal resin or POM is being used for esthetic purpose for denture base and clasps material and especially in individuals who are allergic to Co-Cr alloys as it has a property of biocompatibility.[9,10]

The material has been shown to have good biocompatibility, and this has fostered its use in total hip replacement and as an artificial heart valve prosthesis.[7]

The choice of thermoplastic acetal resin in the case is backed by its several advantageous mechanical properties, namely strength, resistance against warpage and fractures, and inherent flexibility.[11-13]

It is reported to have a sufficiently high resilience and modulus of elasticity, high impact strength, and resistance to organic solvents, oils, and hot and cold water,[14] which allows its use in the manufacture of retentive clasps, connectors, and support elements for removable partial dentures.[15]

Exploratory studies in the past have also highlighted the advantages of acetal resins over metal alloys which compared the modulus of elasticity of acetal resin (2.9–3.5 kN/mm^2) with that of Cr-Co alloy (22.43 kN/mm^2). His study suggested that acetal resin has superior flexibility, which allows its use in larger retentive undercuts such as in interproximal area.[15-19]

However, few disadvantages of acetal resin are needed to be accounted as well. One such disadvantage is to include a greater thickness of material required compared to metal clasps due to its lowered flexural modulus, which can cause plaque accumulation and affect gingival and periodontal health; hence, patient should be encouraged for hygiene maintenance.[20,21]

Many researches[2,3,22-25] had been carried out to study the properties of resins, however, until now there are little data available regarding the wearing resistance of the heat-cured acrylic resin denture base material and acetal resin materials; therefore, this study is aimed to compare the wear resistance of heat-cured acrylic resin denture base material and acetal resin material.

MATERIALS AND METHODS

Two different resin materials were used for this study, namely heat-cured acrylic denture base and acetal flexible resin material. Using G power 3.1 statistical program, the number of samples required for this study was seven specimens for each test depending on acceptable level of statistical significance $P < 0.05$. The power of the study will be equal 0.8 and effect size equal 0.5.

Samples grouping

- Group I: Seven specimens of acrylic resin material (Vertex TM, Netherlands) were fabricated with dimensions (15 mm in diameter × 2 mm thickness) according to ISO standard number 14569/2 [Figure 1a].
- Group II: Seven specimens of acetal flexible resin material (Biocetal, Roko, Poland) were fabricated with dimensions (15 mm in diameter × 2 mm thickness) according to ISO standard number 14569/2 [Figure 1b].

Wear test

The two-body wear testing will be performed using a programmable logic-controlled equipment using the newly developed four stations multimodal Dual-axis ROBOTA chewing simulator. The device allows simulation of the vertical and horizontal movements simultaneously in the thermodynamic condition. The chewing simulator has four chambers, each chamber consists of an upper Jacob's chuck as antagonist holder and a lower Teflon sample holder. All the samples will be tested under standard conditions. A weight of 700 g which is comparable to 7N of chewing force will be exerted. Samples will be subjected to a revolution of 10,000 cycles, which run approximately 54 min. After

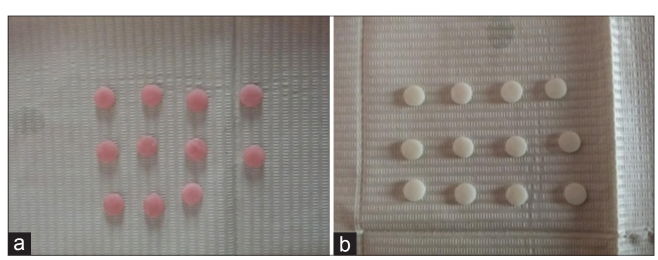

Figure 1: (a) Acrylic resin specimens. (b) Acetal resin specimens

10,000 cycles, the samples will be removed from the holder, cleaned with running water, and followed by cleaning in ultrasonic cleaner for 2 min to remove any abraded particles from the surface of the samples before measuring. The weight will be checked to calculate the loss. Table 1 demonstrates the wear test parameters of the ROBOTA chewing simulator device.

Weight loss measurement will be done by weighing samples in the electronic analytical balance (Sartorius, Biopharmaceutical, and Laboratories, Germany) with an accuracy of 0.0001 g to show the difference in weight before and after wear test. As this electronic balance had a fully automated calibration technology and a micro weighing scale, values of all the mounted discs and antagonist samples will be accurately measured. Each mounted sample will be cleaned and dried with tissue paper before weighing. To ensure accuracy, the balance will be kept on a free-standing table at all times away from vibrations and weighed the samples with the glass doors of the balance closed to avoid the effect of air drafts [Figure 2]. The collected data were statistically analyzed using SPSS software V20 for windows.

Table 1: Wear test parameters of ROBOTA chewing simulator machine

Wear test parameters	
Vertical movement: 1 mm	Horizontal movement: 5 mm
Rising speed: 90 mm/s	Forward speed: 90 mm/s
Descending speed: 40 mm/s	Backward speed: 40 mm/s
Cycle frequency 1.6 Hz	Weight per sample: From 700 g
Torque: 2.4 N.m	

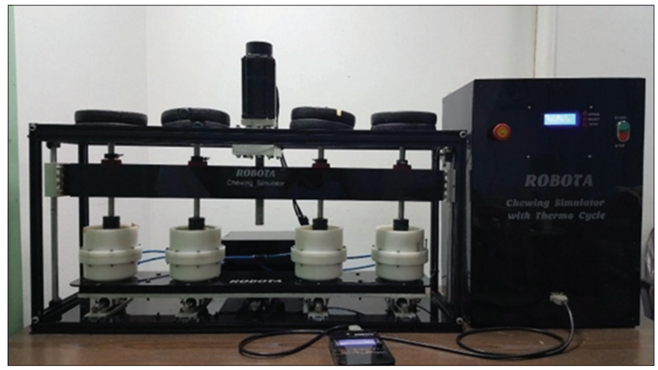

Figure 2: Multimodal dual-axis ROBOTA chewing simulator

RESULTS

The mean values and standard deviations for weight measured in grams recorded on all materials before and after 4 months wear simulation cycles summarized in Table 2 and graphically represented in Figure 3. Weight recorded for the antagonistic enamel cusp is also shown.

For acrylic group, it was found that the weight mean value before wear was (0.155833 ± 0.008 g) while after wear simulation, the mean value was (0.154983 ± 0.008 g) with weight change mean value (0.00085 ± 0.0002 g) as shown in Table 2. The change in weight was statistically significant as validated by paired *t*-test ($P \leq 0.0001 < 0.05$).

For acetal group, it was found that the weight mean value before wear was (0.145658 ± 0.005 g) while after wear simulation, the mean value was (0.14495 ± 0.0058 g) with weight change mean value (0.000708 ± 0.0002 g) as shown in Table 2. The change in weight was statistically significant as validated by paired *t*-test ($P \leq 0.0001 < 0.05$).

The difference between weight changes recorded for groups was statistically non-significant as indicated by *t*-test ($P = 0.0861 > 0.05$).

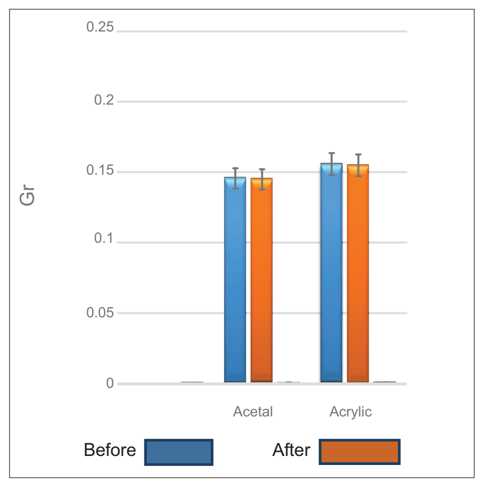

Figure 3: Weight mean values for all materials before and after 4 months wear simulation cycles

DISCUSSION

For long decades, PMMA has dominated the field of denture base materials, but flexible dentures have emerged as a major competitor to PMMA dentures.[18]

Flexible dentures have got various advantages over the traditional rigid denture bases regarding esthetics, translucency, absence of clasp visibility in partial dentures, and flexibility which allow it to act as stress breaker and biocompatibility.[2,19,23]

A systematic review of 143 articles shows that the thermoplastic material is an attractive modern material to use in prosthodontics due to its favorable chemical, mechanical, and physical properties.[2,3,23]

PMMA resin surfaces are prone to indentation by different hard objects, which increase the abrasiveness and wear of

Table 2: Mean values and standard deviations of weight results for the materials before and after 4 months wear simulation cycles

Variables	Samples			*P* value
	Before	After	Change	
Acetal	0.145658±0.005	0.14495±0.0058	0.000708±0.0002	<0.0861 ns
Acrylic	0.155833±0.008	0.154983±0.008	0.000850±0.0002	

*Significant (*P*<0.05) ns: Non-significant (*P*>0.05)

acrylic base material. These phenomena provide a favorable environment for fungal and bacterial colonization which is associated with several oral and general diseases.[24] Several studies of denture base materials have demonstrated a direct link between acrylic surface abrasion, plaque buildup, and *C. albicans* adherence.[3] Furthermore, surface roughness facilitates the adhesion of microorganisms to the restoration and tooth structure.[24]

This *in vitro* study compared the amount of wear which occurred under same laboratory conditions between acrylic resin and acetal resin materials using a two-body wear testing machine.

Although this contact between the maxillary and mandibular dentures does not occur significantly during mastication of food, it normally occurs during swallowing and parafunctional habits that lead to wear of denture teeth. Therefore, the two-body wear test was selected in this study. As the oral cavity displays masticatory cycles ranging 5000–30,000 cycles in a month, to simulate this condition a wear cycle of 10,000 was selected. This was in accordance with study done by Hirano *et al*.[25]

There was a statistically significant loss in the weight for the specimens of Group I (heat-cured acrylic resin group) ($P < 0.05$), Furthermore, there was a statistically significant loss in the weight for the specimens of Group II (acetal resin group) ($P < 0.05$).

However, there was no statistically significant difference in the weight loss between Group I and Group II ($P > 0.05$).

On the other hand, the results of the present study were not in accord with Hamanaka *et al*. who found that wear depth of PMMA conventional heat-polymerized denture-based polymer was significantly higher than that of other injection-molded thermoplastic denture base resins.[22]

Based on the results of the present study, the acetal resin can be used as an alternative material to conventional heat-cured acrylic resin.

Little is known about the wear resistance of injection-molded thermoplastic denture base resins. An evaluation of the hardness and wear resistance of denture base resins is beneficial for clinical purposes because surface roughness has an effect on microbial adhesion to the surface. High surface roughness is caused by adhesive dental plaque and dental calculus among others.[23]

Hence, this study recommended the surface roughness of injection-molded thermoplastic denture base resins for future work.

CONCLUSIONS

Within the limitation of the study, it was concluded that there was no statistically significant difference between the two groups regarding wear resistance so that the acetal resin can be used as alternative material to conventional heat-cured acrylic resin.

REFERENCES

1. Singh J, Dhiman R, Bedi R, Girish S. Flexible denture base material a viable alternative to conventional acrylic denture base material. Contemp Clin Dent 2011;2:313-7.
2. Santos M, Soo S, Petridis H. The effect of parylene coating on the surface roughness of PMMA after brushing. J Dent 2013;41:802-8.
3. Abuzar MA, Bellur S, Duong N, Kim BB, Lu P, Palfreyman N, *et al*. Evaluating surface roughness of a polyamide denture base material in comparison with poly (methyl methacrylate). J Oral Sci 2010;52:577-81.
4. Moftah H, Turkmani I, Darwich K. Fracture strength of acrylic resin reinforced with glass fibers in simulated implant-supported overdenture abutments. Yemeni J Med Sci 2017;11:31-7.
5. Abhay PN, Karishma S. Comparative evaluation of impact and flexural strength of four commercially available flexible denture base materials: An *in vitro* study. J Indian Prosthodont Soc 2013;13:499-508.
6. Negrutiu M, Bratu D, Rominu M. Polymers used in technology of removable dentures. Rom J Stomatol 2001;4:30-41.
7. Fitton JS, Davies EH, Howlett JA, Pearson GJ. The physical properties of a polyacetal denture resin. Clin Mater 1994;17:125-9.
8. Smith D. Recent developments and prospects in dental polymers. J Prosthet Dent 1962;12:1066-78.
9. Lekha K, Savitha N, Roseline M, Nadiger R. Acetal resin as an esthetic clasp material. J Interdiscp Dent 2012;2:11-4.
10. Phoenix RD, Mansueto MA, Ackerman NA, Jones RE. Evaluation of mechanical and thermal properties of commonly used denture base resins. J Prosthodont 2004;13:17-27.

11. Meenakshi A, Gupta R, Bharti V, Sriramaprabu G, Prabhakar R. An evaluation of retentive ability and deformation of acetal resin and cobalt-chromium clasps. J Clin Diagn Res 2016;10:ZC37-41.
12. Turner JW, Radford DR, Sherriff M. Flexural properties and surface finishing of acetal resin denture clasps. J Prosthodont 1999;8:188-95.
13. Latta G, Wu J. Deformation of acetyl resin and metal alloy removable partialdenture retainers J Prosthdont 2002;11:334.
14. Kirsch A, Ackermann KL. The IMZ osteointegrated implant system. Dent Clin North Am 1989;33:733-91.
15. Ladizesky NH, Pang MK, Chow TW, Ward IM. Acrylic resins reinforced with woven highly drawn linear polyethylene fibres. 3. Mechanical properties and further aspects of denture construction. Aust Dent J 1993;38:28-38.
16. Shah RJ, Lagdive SB, Saini SL, Verma VB, Shah SR. An ingenious modification in conventional swing lock cast partial denture for rehabilitating a hemi mandibulectomy defect. J Clin Diagn Res 2017;11:ZD01-3.
17. Wu JC, Latta GH Jr., Wicks RA, Swords RL, Scarbecz M. *In vitro* deformation of acetyl resin and metal alloy removable partial denture direct retainers. J Prosthet Dent 2003;90:586-90.
18. Abd-Elrahman AA, Helal MA, Saqar HM, Abas M. Evaluation of fatigue resistance of acetal resin and cobalt-chromium removable partial denture clasps. An *in vitro* study: Part 1. J Dent Oral Care Med 2016;2:304.
19. Helal MA, Abd-Elrahman IA, Saqar HM, Salah A, Abas M. Evaluation of acetal resin and cobalt-chromium clasp deformation and fatigue resistance in removable partial denture clasps - An *in vitro* study. J Clin Res Dent 2018;1:1-5.
20. Teoh SH. Effect of saline solution on creep fracture of Delrin. Biomaterials 1993;14:132-6.
21. Gladstone S, Kumar A. An evaluation of the hardness of flexible denture base resins. Health Sci 2012;1:1-10.
22. Hamanaka I, Iwamoto M, Lassila LV, Vallittu PK, Takahashi Y. Wear resistance of injection-molded thermoplastic denture base resins. Acta Biomater Odontol Scand 2016;2:31-7.
23. Kawara M, Iwata Y, Iwasaki M, Komoda Y, Iida T, Asano T, *et al*. Scratch test of thermoplastic denture base resins for non-metal clasp dentures. J Prosthodont Res 2014;58:35-40.
24. Tekçe N, Pala K, Tuncer S, Demirci M. The effect of surface sealant application and accelerated aging on posterior restorative surfaces: An SEM and AFM study. Dent Mater J 2017;36:182-9.
25. Hirano S, May KB, Wagner WC, Hacker CH. *In vitro* wear of resin denture teeth. J Prosthet Dent 1998;79:152-5.

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