Research Article

Evaluation of abrasive wear resistance of polymethyl methacrylate material reinforced with zirconium and dental stone

Monadle R. Hadi[1]*, Azal H. Al-masoody[1], Al-Mohammad Baqer Osamah[2], Mohammed Saab Abdulsattar[3]

ABSTRACT

Background: The numerous advantages of polymethyl methacrylate)PMMA) make it the most dominant polymer material used in dentistry. Recently, specific attention was given to the effect of fibers, fillers, and nanofillers addition on PMMA properties. The aim of this study was to investigate the effect of zirconium and dental stone addition on the abrasive wear resistance of the PMMA material. **Materials and Methods:** Zirconium and dental stone powders were added to the powder of PMMA material by weight in different amounts. Seventy specimens were constructed and divided into seven groups according to the test (each group consists of 10 specimens). Abrasion wear test was performed at a constant rotation speed of 50 rounds per minute and with a load of 10 N. The duration of each test was 60 min. **Results:** Reduced values of abrasive wear rate were recorded for Group 2 specimens made from PMMA with 15 mg (half ratio) of dental stone which were nearer to the values of readymade teeth in Group 7 than those of pure PMMA in Group 1. **Conclusions:** Reinforcing PMMA with dental stone increases abrasive wear resistance of the PMMA material, while adding of untreated zirconium particles does not increase the abrasive wear resistance of PMMA.

KEY WORDS: Polymethyl methacrylate, Stone, Wear rate, Zirconium

INTRODUCTION

Abrasive wear can be defined as the wearing away or removal of material by the act of rubbing, cutting, or scraping and occurs when a rough surface or loose hard particles plough out softer material. Abrasion depends on many factors including hardness, size and shape of the abrasive, speed of movement of the abrasive and the substrate against each other, pressure applied on the substrate, and the amount and type of lubrication between them.[1] Conventional acrylic resin material polymethyl methacrylate (PMMA) is low in strength, soft and fairly flexible, brittle on impact, and fairly resistant to fatigue failure.[2] PMMA is frequently used due to its various advantages including low cost, biocompatibility, and ease of processing. However, it is not considered as an ideal material due to its inferior physical and mechanical properties.[3] Many additives have been suggested to enhance the properties of the resin such as fibers, fillers, or nanofillers. Several studies found that incorporating zirconia (ZrO_2) fillers in PMMA significantly increased its flexural strength in addition to the impact of strength and fracture toughness. Hardness of PMMA was also increased significantly by incorporating of ZrO_2.[4-7] Addition of ZrO_2 significantly increases thermal conductivity of PMMA.[8] Different results were obtained regarding the effect of ZrO_2 on the water sorption and solubility of PMMA. It was found that adding of ZrO_2 significantly decreased the water sorption and solubility of PMMA.[3] Wear of a material is usually undesirable, but under controlled conditions may be useful for finishing and polishing procedures, wear is highly beneficial. Wear is a function of a number of material and environmental factors including the nature of wearing surfaces (i.e., inhomogeneity, crystal orientation, phases, and inclusions present); the microscopic contact; and interaction between sliding surfaces (i.e., elevated stress, temperature, and flow at contact points), leading to localized yielding. In general, wear is a function of opposing materials and the interface between them. The presence of a lubricating

Access this article online	
Website: jprsolutions.info	ISSN: 0975-7619

[1]Department of Conservation, College of Dentistry, University of Alkafeel, Najaf, Iraq, [2]Department of Basic Science, College of Medicine, Ibn Sina University of Medical and Pharmaceutical Sciences, Baghdad, Iraq, [3]Diyala Cocational School, Diyala Education Directorate, Ministry of Education, Iraq

***Corresponding author:** Monadle R. Hadi, Department of Conservation, College of Dentistry, University of Alkafeel, Najaf, Iraq. E-mail: monadle.almansoor@alkafeel.edu.iq

Received on: 06-07-2019; Revised on: 01-08-2019; Accepted on: 03-09-2019

film, such as saliva, separates surfaces during relative motion and reduces frictional forces and wear.[1] When testing the laboratory wear of materials, it is important that the results correlate with the clinical situation. Wear tests of various combinations of acrylic resin and porcelain and natural tooth structure were made using conditions similar to those of masticatory function by simulating the loads, sliding distances, and contact times encountered in the human masticatory cycle.[9] For the purpose of simulating the clinical situation of preparing natural tooth to receive crown or bridge restorations in the preclinical courses of graduating students, our work was concentrated on introducing an artificial material which has an abrasive properties which make the artificial teeth more easy and helpful for the training students than the conventional acrylic.

MATERIALS AND METHODS

The materials used in this study were auto-polymerizing acrylic resin PMMA from (SpofaDental A Kerr Company, Czech Republic) and dental stone (Durguix, Protechno, Vilamalla, Spain) in addition to zirconium powder collected from computer-aided design and computer-aided manufacturing milling machine of zirconium blocks, as shown in Table 1.

In this *in vitro* study, a total of 70 specimens used for abrasion wear testing were prepared in the form of cylinder with 10 mm in diameter and 20 mm in height. Molds with 10 × 20 mm dimensions were made 10 mm for diameter and 20 mm for length fabricated from the heavy body material of silicone impression material (Protesil Putty Vannini Dental Industry, Grassina, Italy) for easy packing of the mixed material and for easy removal of set material of specimens.

Seven groups of materials were prepared (10 specimens for each group), as shown in Table 2: Group 1 for PMMA material as control, Group 2 PMMA with 15 mg dental stone powder, Group 3 PMMA with 13 mg zirconium powder in addition to 15 mg of stone, Group 4 PMMA with 13 mg zirconium powder, Group 5 PMMA with 30 mg dental stone powder plus, Group 6 PMMA with 26 mg zirconium powder, and Group 7 artificial teeth made by Nissin Company used by training students. The PMMA material was mixed by the ordinary way according to the manufacturing company instruction (for Group 1). The PMMA material was mixed with the powder of zircon oxide (for Groups 4 and 6) and with stone powder (for Groups 2 and 5) and with zirconium and dental stone (for Group 3).

The powders were mixed with 2 ml of monomer liquid until the mixture reaches to the workable stage the material packed inside the mold and pressed from both sides by glass slides until the material sets hard. The specimens removed, finished, and prepared for abrasion testing.

Abrasion wear test was performed at room temperature and the experiment was carried out at constant rotation speed of 50 rounds per minute and with a load of 10 N. The duration of each test was 60 min and measured according to ASTM G99 by employing a pin on a disc method. Hardened tool steel disc of 62 HRC was used. Tachometer was used to determine linear sliding velocity of about 1 mm/s. Difference in weight of each sample was measured by a digital scale with the accuracy of 0.001 g according to the weight lost. Wear rate of each sample was calculated using the following equation:

$$WS = \Delta W/P.L$$

Where, WS: Wear rate
ΔW: Weight difference of sample before and after test (g)
P: Applied load (Newton)
L: Sliding distance (mm).
The correlation between wear rates of different groups was analyzed.

RESULTS

Mean values of the weight loss of the test samples for each group and wear rate are presented in Table 3.

The results show slow values of wear rate of Groups 2, 3, 4, and 5 than Group 1 while there is a high-value wear rate for Group 6 than other groups. In Table 3, the values of weight loss reveal little weight loss of Groups 2, 3, 4, and 5 than Groups 1 and 6. The least value recorded for wear rate was for Group 2 samples made from PMMA with 15 mg (half ratio) of dental stone. The values of weight loss and wear rate of Group 7 were nearer to those of Group 3. The values of Group 2 show reduced values than those of Group 7 while other groups show increased values.

DISCUSSION

From the results of abrasive wear test by mechanical removal of sample material of reinforced acrylic, we

Table 1: Tested materials used in the study

Material	Lot no.	Manufacturer
SpofaDental (cold-cured acrylic resin)	428069	Duracryl Plus Czech Republic
Protesil condensation silicone putty		Vannini Dental Industry – Italy
Dental stone	3ISO6873	Durguix Vilamalla – Spain
Vita zirconium	79842	Vita Zahnfabrik – Germany

Table 2: Percentages and amounts of PMMA polymer, monomer, zirconium, and dental stone powder and different groups used in this study

Group	Amount of polymer (g)	Amount of monomer (ml)	Amount of zirconium powder (g)	Amount of stone powder (g)
1	400	2		
2	400	2		15
3	400	2	13	15
4	400	2	13	
5	400	2		30
6	400	2	26	
7	Readymade teeth material			

PMMA: Polymethyl methacrylate

Table 3: Wear rate values of tested groups

Number of groups	Weight loss (ΔW g)	Wear rate ($\times 10^{-10}$) g/min
1	0.017	12.025
2	0.0043	3.0416
3	0.005	3.5367
4	0.0066	4.6685
5	0.007	4.9514
6	0.0113	79.931
7	0.0053	3.5365

found different results. The control material in this study was the readymade teeth (in addition to pure acrylic material) which are used by the students in the training laboratories. The wear rate of this material showed reduced values than acrylic samples. Acrylic resin showed good wear resistance provided no third-party abrasive or opposing hard, rough surface was present. When a mild abrasive was incorporated in the system, the acrylic resin versus acrylic resin combination wore almost 7 times more than porcelain versus porcelain.[10] The aim of this study was to reinforce the acrylic PMMA material to produce a material with wear rate similar to the traditional material used to fabricate artificial teeth used.

Our study differs from other clinical studies when high abrasion rate value is not considered as unfavorable value because we want to introduce material which can be abraded easily by the preparing burs of the high-speed turbines without sticking or burned like the pure acrylic material and does not have low abrasive rate such as porcelain or zirconium which are considered difficult to be cut by the burs. Recently, nanotechnology invaded the dental field and initiated investigative research projects to explore the possible applications and expected benefits within dentistry.[11] In addition to the treatment of zirconium particles surface with reactive solutions to enhance reaction between polymeric matrix and added particles.[12] Abrasive wear involves a soft surface in contact with a harder surface. In this type of wear, particles are pulled off of one surface and adhere to the other during sliding.[2] High abrasive rate values of Group 6 with 26 mg zirconium powder may be due to large size and untreated particles used in our study which lead to the dislodgement of zirconium particles during testing leaving acrylic matrix for quick abrasion forces.

Several studies were conducted on using fillers to strengthen denture base resin, and they found significant improvement in its properties. Reinforcement of PMMA with metal oxides improved the physical and mechanical properties of the material.[3] Samples in Group 2 with 15 mg powder of dental stone showed lower values of abrasive wear rate and this due to small size particles and chemical reaction between stone and acrylic polymeric matrix. This explanation is in agreement with Gad *et al*. who said that nanoscale reinforcing agents produce new mechanical and physical properties of polymeric nanocomposites which are made of polymer matrix and filler at the nanoscale.[11]

CONCLUSIONS

According to the results of this study, it has been found that reinforcing of PMMA with dental stone increases abrasive wear resistance of the PMMA material and adding of untreated zirconium particles does not increase the abrasive wear resistance of PMMA.

REFERENCES

1. Ferracane JL. Materials in Dentistry: Principle and Application. Philadelphia, PA: J.B Lippincott; 1995. p. 293-311.
2. Robert GC, John M. Restorative Dental Materials. 11th ed. St. Louis: Powers; 2002.
3. Gad MM, Fouda SM, Harbi AA, Näpänkangas R, Raustia A. PMMA denture base material enhancement: A review of fiber, filler, and nanofiller addition. Int J Nanomedicine 2017;12:3801-12.
4. Asar NV, Albayrak H, Korkmaz T, Turkylmaz I. Influence of various metal oxides on mechanical and physical properties of heat-cured polymethyl methacrylate denture base resins. J Adv Prosthodont 2013;5:241-7.
5. Asopa V, Suresh S, Khandelwal M, Sharma V, Asopa SS, Kairal LS. Comparative evaluation of properties of zirconia reinforced high impact acrylic resin with that of high impact acrylic resin. Saudi J Dent Res 2015;6:146-51.
6. Hameed HK, Rahman HA. The effect of addition nano particle ZrO_2 on some properties of autoclave processed heat cure acrylic denture base material. J Bagh Coll Dent 2015;27:32-9.
7. Franklin P, Wood DJ, Bubb NL. Reinforcement of poly (methyl methacrylate) denture base with glass flake. Dent Mater 2005;21:365-70.
8. Kul E, Aladağ LI, Yeşildal R. Evaluation of thermal

conductivity and flexural strength properties of poly (methyl methacrylate) denture base material reinforced with different fillers. J Prosthet Dent 2016;116:803-10.
9. Harisson A. Wear of combinations of acrylic resin and porcelain, on an abrasion testing machine. J Oral Rehabil 1978;5:111-5.
10. Ghazal M, Yang B, Ludwig K, Kern M. Two-body wear of resin and ceramic denture teeth in comparison to human enamel. Dent Mater 2008;24:502-7.
11. Gad MM, Abualsaud R. Behavior of PMMA denture base materials containing titanium dioxide nanoparticles: Literature review. Int J Biomater 2019;2019:14.
12. Mudhaffar M, Mohammed D. Effect of modified zirconium oxide nano-fillers addition on some properties of heat cure acrylic denture base material. J Bagh Coll Dent 2012;24:1-7.

Source of support: Nil; Conflict of interest: None Declared