EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 68, 1511:1516, April, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 2021-12-06 • Accept Date : 2022-03-30 • Available online: 2022-03-30 • DOI : 10.21608/edj.2022.109740.1894

COMPARISON BETWEEN THE FRACTURE RESISTANCE OF THREE DIFFERENT DENTURE BASE MATERIALS FOR IMPLANT OVERDENTURES. AN INVITRO STUDY

Nagla M.H. Nassouhy*

ABSTRACT

Objectives: this study was conducted to compare the fracture resistance of three different denture base materials for implant overdentures. The three materials tested in this study were heat cured polymethyl methacrylate (PMMA), heat cured PMMA reinforced with 5% zirconium oxide powder, and thermoplastic resin.

Materials and Methods: Two implants were installed in the canine areas bilaterally in an epoxy resin model of a completely edentulous mandible. Duplication of the model was done according to sample size calculation to produce 15 stone models on which overdentures were constructed. The 15 models were divided equally into three groups. Overdentures were made from conventional heat cured PMMA in group I, and conventional heat cured PMMA reinforced with 5% zirconium oxide powder in group II and thermoplastic resin in group III. Fracture resistance of the overdentures was measured using a universal testing machine, and measurements were collected and statistically analyzed.

Results: The highest mean value for fracture resistance was recorded in group III, while the lowest mean value was recorded in group I. A statistically significant difference was found between group I and group III. Group II showed higher fracture resistance than group I, but the difference was not statistically significant.

Conclusions: reinforcement of heat cured PMMA with 5% zirconium oxide powder increases the fracture resistance of implant overdenture denture bases. Thermoplastic resins can also be used as a denture base material for implant overdentures, with a fracture resistance comparable to that of conventional PMMA.

KEYWORDS: Fracture resistance, denture base materials, implant overdentures, zirconium oxide powder, thermoplastic resins.

* Associate Professor, Department of Prosthodontics, Cairo University, New Giza University.

INTRODUCTION

The use of implant overdentures with completely edentulous patients has become a common practice to overcome the several shortcomings of conventional complete dentures [1]. Conventional heat cured acrylic resin (polymethyl methacrylate -PMMA) has been the most commonly used material for fabrication of implant overdentures and complete dentures in general for more than 60 years [2–5]. However, a frequently occurring complication with this material is denture base fracture due to the formation of microscopic cracks at stress concentration areas after repetitive loading [6–10]. The decreased thickness of the denture base at the areas of the attachment copings over the abutments in implant overdentures is another reason for denture base fracture [11,12]. This is why reinforcement of PMMA denture base material is often needed and recommended by several authors [10,11,13,14].

Many materials have been used for reinforcement of heat cured PMMA to prevent denture fracture. Ceramic fillers are a commonly used for reinforcement of PMMA in an attempt to improve its mechanical properties [9,12]. Authors have shown that a structural component of a different size that is added to the acrylic matrix can form a composite structure with higher strength properties. Zirconium oxide particles are known for their biocompatibility, favorable physical and mechanical properties such as high hardness, toughness, mechanical strength, abrasion and corrosion resistance [15–17]. Their crystalline structure makes them among the hardest in the group of metal oxides with a high resistance to crack propagation [17,18].

Thermoplastic resins are another alternative to PMMA as a denture base material [19,20]. Advantages of these resins include high flexural and impact strength, high hardness, low water sorption, high wear resistance, and absence of residual monomer which makes them biologically compatible and hypoallergenic [19–22].

Insufficient data is available regarding the fracture resistance of these materials with single implant overdentures. Hence, this study was carried out to compare the fracture resistance of implant overdenture bases constructed from conventional PMMA, PMMA reinforced with zirconium oxide particles, and thermoplastic resin.

MATERIALS AND METHODS

Model fabrication and Implant placement

A mandibular cast of a completely edentulous patient was used and duplicated into an epoxy model* to be able to withstand the load applied during fracture resistance testing with the universal loading machine. The cast chosen was of sufficient width and height to accommodate two interforaminal implants** (3.7 mm diameter and 12 mm length). A wax up of a denture was fabricated over the epoxy model to ensure proper placement of the implants at the canine areas bilaterally.

Implants were inserted after drilling the model at the canine areas following the drilling sequence recommended by the manufacturer. The drilling sites were then slightly widened to allow easy placement of the implants without interference. The remaining space was then filled with auto-polymerizing resin to maximize contact between the denture base material and the implants in an attempt to resemble osseointegration with bone. Implant parallelism during insertion was ensured by means of a dental surveyor (Figure 1). Indices were created at the base of the model to facilitate the placement of a putty index that will be later used in overdenture fabrication. The epoxy model was then duplicated into 15 stone casts.

---

* Clear heat cured acrylic resin, Acrostone, Egypt.

** Osteoseal dental implants, California, USA

Fig. (1)

Overdenture fabrication

The 15 models were divided into three groups and five identical overdentures were constructed for each group in the following manner. First, a layer of base plate wax was adapted on one of the casts in an even thickness, and then teeth were set and denture base was waxed up following the conventional guidelines for setting and polished surface shape. Then, a rubber base index was created for the teeth and the polished surface to be used for duplication of the remaining overdentures in the study to ensure that they were of the same denture base thickness and teeth setting for standardization purposes.

Sample size and grouping

The three groups in this study were group I: implant overdentures fabricated from conventional heat cured PMMA* denture base, group II: implant overdentures fabricated from conventional heat cured PMMA denture base reinforced with 5% zirconium oxide, Group III: implant overdentures fabricated from thermoplastic resin

Zirconia powder was treated with 1% silane coupling agent before being mixed with the PMMA powder in group II. Pre-weighing of the powder particles was done with the PMMA as well as the zirconium oxide before mixing to obtain an accurate 5% concentration of zirconia. An electric mixer was used to mix and blend the materials together to ensure a homogenous mix.

As for group III, sealed cartridges of polyamide thermoplastic material ** were injected in a programmable injection molding machine. Injection was carried out under accurately controlled temperature and pressure with a uniform transmission of force.

The overdentures were all then manufactured in the conventional manner in each group according to the manufacturer's instructions. Ball attachments were connected to the implants on the model followed by pick up of the housings and female parts for the overdentures in the conventional pick-up procedure.

Fracture Resistance Testing

A computer controlled universal testing machine*** was used for fracture resistance testing. The epoxy model was secured and locked to the base of the universal testing machine. Each overdenture was placed and secured in position over the epoxy model by the overdenture attachments. The inverted T-shaped metallic load applicator was used to apply compressive forces. The applicator was positioned over the central fossae of the first molars bilaterally to distribute the load equally. The upper movable compartment of the machine was adjusted to move at a crosshead speed of 5 mm/minute. Fracture was manifested by an audible crack sound as well as a sharp drop at the load deflection curve as recorded by the computer software (Figure 2 a,b,c). The load value at which the sample fractured was recorded in Newton. The test was repeated for all

* Acrostone heat cured PMMA (Cross linked heat cured pink denture base material, Acrostone manufacture, Egypt, Licensed by WHW, England

** Bre.flex 2nd edition (Bredent, 5400F605, GmbH & Co.KG. Weissenhorner Str. 2, 89250 Senden, Germany)

*** Model 3345; Instron Industrial Products, Norwood, MA, USA

Fig. (2) (a) Group I (b) Group II (c) Group III

the overdenture samples. Data was collected and statistically analyzed.

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests and showed parametric (normal) distribution. One-way ANOVA followed by Tukey post hoc test was used to compare between more than two groups in non-related samples. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

TABLE (1) Means and standard deviation values (SD) with different letters in the same column indicating statistically significance difference.

	Fracture load	
	Mean	SD
Group I (Conventional acrylic resin)	1662.40 [b]	245.47
Group II (Conventional acrylic resin + 5% zirconium powder)	4941.20 [a]	560.29
Group III (Thermoplastic resin)	2231.40 [b]	404.92
p-value	<0.001*	

; significant (p<0.05)

RESULTS

The results of the study show that the highest mean value for fracture resistance was found in Group II (4941.2 N) followed by Group III (2231.4 N), while the lowest mean value was found in Group I (1662.4 N). A statistically significant difference was found between Group II and each of Group I and Group III where (p<0.001). No statistically significant difference was found between Group I and Group III where (p=0.126) (table 1, figure 3).

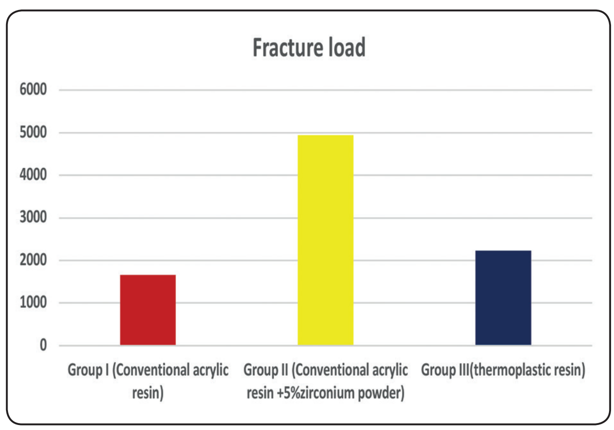

Fig. (3) Bar chart showing the difference between the three groups.

DISCUSSION

Conventional acrylic resin (PMMA) is still the most widely used denture base material due to its several advantages such as low cost, ease of manipulation and repair, patient acceptance, and esthetics. However, its relatively low fracture resistance remains one of its drawbacks especially with implant overdentures, where denture base thickness is not sufficient to resist loads at the areas of the abutments resulting in high risk of denture fracture. Several alternatives are now available for denture base fabrication, including reinforcement of PMMA as well as thermoplastic resins.

The results of this study show that the addition of 5% zirconium oxide particles has a statistically significant increase on the fracture resistance of PMMA, raising it from 1662.4 N (group I) to 4941.2 N (group II). This comes in accordance with other studies that reported an improvement in mechanical properties of PMMA when smaller particles of other materials were added to it [17,18,23]. Zirconium oxide particles were found to enhance several physical and mechanical properties such as flexural strength and surface hardness [24]. Gad et al. [18] reported that the zirconium oxide particles occupied the spaces between the linear chains of the polymer thereby restricting the segmental motion and increasing strength and rigidity of the resin. Studies have reported that the greatest increase was observed when the zirconium oxide particles were 5% by weight, and that higher concentrations resulted in particle agglomeration and cluster formation, causing weakening of the material instead of strengthening it [10,24,25].

Zirconium oxide particles have additional advantages over other fillers, such as good adhesion to the resin matrix after modification with silane coupling agent. Additionally, the white color of the particles does not compromise esthetics when compared to other metallic alternatives like aluminum or silver [18].

Thermoplastic resin denture base had also shown greater fracture resistance than PMMA in this study, but comparably less than that of PMMA reinforced with zirconium oxide powder. The type used in this study is a polyamide based thermoplastic material which is characterized by favorable biological, physical, and mechanical properties. It has high impact and flexural strengths which makes it a good choice as a denture base material for implant overdentures. Studies have reported that thermoplastic resins have a relatively low flexural modulus, which means they exhibit various degrees of flexibility [19,26]. This might be the reason for their lower fracture resistance than PMMA reinforced with zirconium oxide powder.

CONCLUSIONS

Within the limitations of this study, it can be concluded that reinforcing PMMA with zirconium oxide powder significantly increases the fracture resistance of the denture base of implant overdentures. Additionally, thermoplastic materials can be used an alternative to PMMA as denture base materials in implant overdentures as it exhibits comparable fracture resistance levels.

REFERENCES

1. Melescanu Imre M, Marin M, Preoteasa E, et al. Two implant overdenture--the first alternative treatment for patients with complete edentulous mandible. J Med Life 2011; 4: 207–209.
2. Carlsson GE, Omar R. The future of complete dentures in oral rehabilitation. A critical review. Journal of Oral Rehabilitation 2010; 37: 143–156.
3. HARGREAVES AS. Polymethylmethacrylate as a denture base material in service. J Oral Rehabil 1975; 2: 97–104.
4. Krishna Alla Scholar R, Swamy Professor RK, Vyas R, et al. Conventional and Contemporary polymers for the fabrication of denture prosthesis: part I-Overview, composition and properties. ~ 82 ~ Int J Appl Dent Sci 2015; 1: 82–89.
5. Rickman LJ, Padipatvuthikul P, Satterthwaite JD. Contemporary denture base resins: Part 1. Dent Update 2012; 39: 25–30.

6. Khuder T, Yunus N, Sulaiman E, et al. Finite element analysis and clinical complications in mandibular implant-overdentures opposing maxillary dentures. J Mech Behav Biomed Mater 2017; 75: 97–104.

7. Alla RK, Sajjan S, Alluri VR, et al. Influence of Fiber Reinforcement on the Properties of Denture Base Resins. J Biomater Nanobiotechnol 2013; 4: 91–97.

8. Al-Thobity AM. The Impact of Polymerization Technique and Glass-Fiber Reinforcement on the Flexural Properties of Denture Base Resin Material. Eur J Dent 2020; 14: 92–99.

9. Aldegheishem A, Aldeeb M, Al-Ahdal K, et al. Influence of reinforcing agents on the mechanical properties of denture base resin: A systematic review. Polymers; 13. Epub ahead of print 2021. DOI: 10.3390/polym13183083.

10. Gad MM, Fouda SM, Al-Harbi FA, et al. PMMA denture base material enhancement: A review of fiber, filler, and nanofiller addition. International Journal of Nanomedicine 2017; 12: 3801–3812.

11. Fajardo RS, Pruitt LA, Finzen FC, et al. The effect of E-glass fibers and acrylic resin thickness on fracture load in a simulated implant-supported overdenture prosthesis. J Prosthet Dent 2011; 106: 373–377.

12. Ali Sabri B, Satgunam M, Abreeza NM, et al. A review on enhancements of PMMA Denture Base Material with Different Nano-Fillers. Cogent Eng; 8. Epub ahead of print 2021. DOI: 10.1080/23311916.2021.1875968.

13. Gibreel MF, Khalifa A, Said MM, et al. Biomechanical aspects of reinforced implant overdentures: A systematic review. Journal of the Mechanical Behavior of Biomedical Materials 2019; 91: 202–211.

14. Rostom EM, Moussa AR, Elboraey AN. Effect of Nano-zirconia reinforcement on stresses and fracture resistance of lower implant retained overdenture. Res J Pharm Biol Chem Sci 2016; 7: 897–903.

15. Ayad N, Badawi M, Fatah A. Effect of reinforcement of high-impact acrylic resin with zirconia on some physical and mechanical properties. Rev clín pesq odontol 2008; 145–151.

16. Gad M, Arrejaie AS, Abdel-Halim MS, et al. The Reinforcement Effect of Nano-Zirconia on the Transverse Strength of Repaired Acrylic Denture Base. Int J Dent; 2016. Epub ahead of print 2016. DOI: 10.1155/2016/7094056.

17. Gad MM, Abualsaud R, Rahoma A, et al. Effect of zirconium oxide nanoparticles addition on the optical and tensile properties of polymethyl methacrylate denture base material. Int J Nanomedicine 2018; 13: 283–292.

18. Gad MM, Al-Thobity AM, Rahoma A, et al. Reinforcement of PMMA denture base material with a mixture of ZrO 2 nanoparticles and glass fibers. Int J Dent; 2019. Epub ahead of print 2019. DOI: 10.1155/2019/2489393.

19. Hamanaka I, Takahashi Y, Shimizu H. Mechanical properties of injection-molded thermoplastic denture base resins. Acta Odontol Scand 2011; 69: 75–79.

20. Hamanaka I, Takahashi Y, Shimizu H. Properties of injection-molded thermoplastic polyester denture base resins. Acta Odontol Scand 2014; 72: 139–144.

21. Hemmati MA, Vafaee F, Allahbakhshi H. Water Sorption and Flexural Strength of Thermoplastic and Conventional Heat-Polymerized Acrylic Resins. J Dent (Tehran) 2015; 12: 478–84.

22. Kalivradzhian ES, Soroka D V., Podoprigora A V. The evaluation of the applicability of thermoplastic polymers as a denture base material. Stomatologiya 2019; 98: 92.

23. Alhareb AO, Ahmad ZA. Effect of Al2O3/ZrO2 hybrid on the fracture toughness and flexural properties of PMMA denture base. In: Advanced Materials Research. 2011, pp. 18–23.

24. Alhotan A, Yates J, Zidan S, et al. Flexural strength and hardness of filler-reinforced pmma targeted for denture base application. Materials (Basel); 14. Epub ahead of print 2021. DOI: 10.3390/ma14102659.

25. Moudhaffar NSI and M. Evaluation the effect of modified nano-fillers addition on some properties of heat cured acrylic denture base materia. J Baghdad Coll Dent 2011; 23: 23–29.

26. 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.