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A comparative study of the fracture resistance of different overdenture base materials. An invitro study

Khaled Aziz Abdelwahab [1]

Abstract

Objectives: The objective of this study was to compare the fracture resistance of conventional acrylic resin versus reinforced and unreinforced thermoplastic resin as a denture base material of an implant supported mandibular overdenture.

Materials and Methods: A completely edentulous epoxy mandibular model was used in this study with two root form implants installed bilaterally at the canine areas. The model was duplicated 15 times into dental stone according to the sample size calculation. The 15 dentures were divided into three groups, five model in each. In the first group an implant retained overdenture was constructed with conventional heat cured acrylic resin denture base. In group two the overdenture was constructed from thermoplastic resin material, while the denture base of the third group was thermoplastic resin reinforced with 5% nano-zirconium oxide powder. The universal testing machine was used to evaluate the fracture resistance of the three types of overdenture. The recorded data was collected, tabulated and statistically analyzed.

Results: The results of the present study revealed that the mean values of maximum fracture resistance were much higher in the reinforced thermopress with 5% nano-zirconium oxide powder group followed by the unreinforced thermopress and finally the lowest mean values were the conventional acrylic resin.

Conclusion: the thermoplastic resin material either reinforced or not showed higher fracture resistance and could be used as an alternative to conventional acrylic resin material as a denture base in implant supported overdentures.

Key words: Conventional acrylic resins, denture base, mandibular overdenture; denture fracture, fracture resistance.

1. Associate Professor prosthodontic department, faculty of dentistry, Cairo university, New Giza university.

Introduction:

Nowadays, the use of overdentures supported by two implants is considered the first treatment option for rehabilitation of a completely edentulous mandible. This is proved to be a reliable and safe procedure with a long-term clinical success [1]

One of the most common failures that might happen in such cases is the possibility of fracture of the unreinforced denture base especially when using attachments over implants. This could be generally attributed to the absence of enough inter-arch space need for the proper film thickness of the denture base material, additionally the weaking of the denture base following the conventional pick-up procedure of the attachments [2-4].

Its worthy mention that Polymethyl methacrylate (PMMA) is the most popular denture base material due to its good esthetics, accurate fit, biocompatibility with the oral tissues, easily repaired if fractured and finally its coast is affordable. Although it has all these advantages but it has also a major drawback which is low fracture resistance that render it weak and easily fractured either when falling down or due to fatigue from long time use [5,6]

Polymethyl methacrylate acrylic resin (PMMA) has become the most widely used material for the construction of denture base. PMMA continues to be used because of its favorable working characteristics, processing ease, accurate fit, stability in the oral environment, superior esthetics, simplicity in repair and the use with inexpensive equipment. Despite these excellent properties there is a need for improvement in the fracture resistance of PMMA. ([6,7]

Despite its popularity which satisfies excellent aesthetic properties, adequate strength, low water sorption, low solubility, and freedom of toxicity, they can reproduce surface details accurately and can be easily repaired. [8]

Various methods have been investigated to improve the properties of acrylic denture base materials where enhancement of fracture resistance to prevent fracture was a prime concern. This includes chemical modification of acrylic resin and reinforcement of acrylic with other materials, such as metal wires and glass fibers. Also, the development of new materials was attempted. Zirconium oxide powder is one of the components that are used to strengthen different materials. It is a white and hard amorphous powder that is obtained from zirconium which is naturally found and produced by a thermal process. Zirconium oxide is found to be highly resistant to crack propagation and has premium mechanical properties with high fracture toughness and strength. Many authors showed in their studies an improvement in all mechanical properties with the addition of zirconium oxide nanoparticles to PMMA [9-12]

Materials and methods

<u>Model fabrication and implant installation:</u>

An educational model of a completely edentulous mandible was used to obtain a duplicate that were used in this study. constructed from epoxy resin material in order to with stand the load application. A complete trial wax up with full set of teeth is done to enable the accurate allocation of the canine areas. Both canine areas will receive bilateral implants of diameter 3.8 mm and 12 mm in length. At the canine areas implant osteotomies is prepared using sequential drilling protocol followed by implant placement and fixation using a flowy mix of self-cure acrylic resin. Implants were planned to parallel placed parallel to each other and perpendicular to the occlusal plane by the aid of a milling device.

In order to standardize the dimensions of the constructed overdentures, three indices were created in the base of the epoxy model to facilitate the attachment of the putty index later then it is duplicated 15 times in dental stone. These duplicate models were used to fabricate 5 identical dentures.A double layer of pink base plate wax was adapted on one of the casts then artificial teeth were set and waxed up. To ensure that the dimensions of all the dentures are identical, a rubber base index was made for the polished surface and the teeth, this ensured that the duplication of the remaining four dentures with the same denture base thickness and teeth setup.

Fig 1 Epoxy resin model

Grouping of the sample size was performed as follows; groups I: conventional heat cured acrylic resin denture base[1]. Group II: thermopress resin[2] denture base while group III: thrmopress resin denture base reinforced with 5% nano zirconium oxide powder[3]

For the heat cured resin dentures conventional steps of denture processing (flasking, wax elimination, packing, curing, deflasking, finishing and polishing) were followed to obtain the 5 dentures.

Thermopress resin dentures were constructed by conventional injection molding technique following the manufacturer guidelines. Regarding the reinforced thermopress, nano-zirconium powder was pre-weighed in order to ensure a powder concentration of 5% by weight. The nano zirconium particles were treated with 1% of silane coupling agent before mixing with the thermopress resin powder. Mixing and proper blending were done using an electric mixer to obtain a consistent and homogeneous mix before manipulation of the materials.

Ball attachment was fixed to each implant and their female parts were picked up in all denture following the conventional pick-up procedures.

Load application was conducted in the form of two arms connected by a T-Shaped bar was cast in cobalt chrome alloy. The terminal end of each arm was made to fit the occlusal surface of the second premolar on each side to achieve homogenous stress distribution. The load applicator was mounted to the upper part of a universal testing machine. The modified acrylic cast with the denture was fixed to the lower metallic plate of the testing machine[4]. A vertical load was applied at a

[1] Heat cured acrylic resin, Stellon QC-20, Dentsply, USA.
[2] thermopress 400 - bredent UK
[3] Zirconium oxide (ZrO_2) nano powder. Advanced materials, USA
[4] Model LRX-plus; Lloyd instruments Ltd.,Farnham, UK

crosshead speed of 1.00 mm/min until denture fracture as manifested by an audible crack sound and confirmed by a sharp drop at load-deflection curve recorded using the computer software. The load- deformation curve for tested denture was plotted by means of data analysis software installed in a PC connected to the testing machine. Maximum load reached at denture fracture (LF) in Newton (N) was recorded.

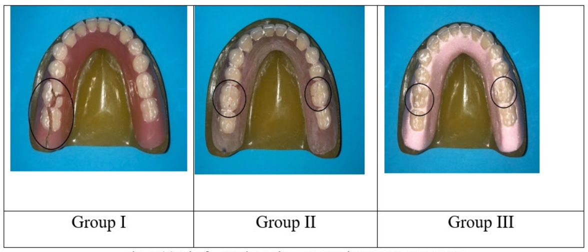

Figure (2): The fractured sample. a: group I. b: group II. c: group III

Results

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.

I) Fracture load results:

There was a statistically significant difference between (Group I), (Group II) and (Group III) where (*p*=0.002). A statistically significant difference was found between (Group II) and each of (Group II) and (Group III) where (p=0.034) and (p=0.001) respectively. No statistically significant difference was found between (Group2) and (Group3) where (*p*=0.173). The highest mean value was found in (Group3) followed by (Group2), while the least mean value was found in (Group1).

	Fracture load	
Group I (Conventional acrylic resin)	1662.4[a]	245.47
Group II (Thermopress))	2231.4[b]	404.92
Group III (Thermopress+ 5%zirconium powder)	2612.4[b]	260.92
p-value	0.002	

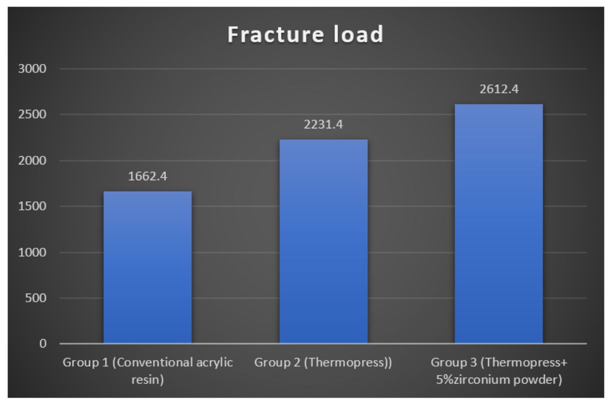

Figure (3): Bar chart representing fracture load for different groups

Discussion

Improving the mechanical properties of the denture base material is always considered a prime concern for all the manufactures especially the fracture resistance property, that might help the denture to withstand more load and resist fracture that might happen due to abrupt falls or masticatory overload.

Several authors had suggested the incorporation of several elements to achieve better fracture resistance property as carbon fibers, glass fibers, polyethylene fibers and metal strengtheners as copper, silver, titanium and zirconium. The use of these elements had also improved many other properties as reduction of polymerization resistance, better thermal conductivity, but always the main problem of these metal particles is bad esthetics of the resulted base material. This might be attributed to the failure of these foreign particles to merge with the original material [10, 13, 14,15].

These attempts not only include the reinforcement of the old materials, but also includes the introduction of new material as the thermoplastic resin with is utilized using a different technique (injection moulding technique) with different characteristics as more flexibility when compared to conventional acrylic resin

This study is aiming to compare the fracture resistance of three different materials which are the conventional acrylic versus the non-reinforced and nano zirconium reinforced thermopress material in cases of implant supported overdenture.

Nano-zirconium has been selected for this study as it was proved to be a biocompatible material able to improve fracture resistance of dental materials. It is characterized by its low density and accordingly light weight. Furthermore, the zirconia powder has the advantage of being white and therefore, is less likely to alter the appearance of the denture base material.

Based on a pilot study, 5% by weight nano $ZrO2$ powder produced a significant increase in fracture resistance of acrylic resin. This was attributed to the fact that zirconia powder has flexural and impact strength values that exceed that of acrylic resin. But it was found that exceeding 15 % by weight of the filler gives a reverse effect. That is why the 5% $ZrO2$ powder was used.

Many authors concluded that when incorporating zirconium powder with different dental materials, this improved its mechanical properties [16,17,18]. Also, the white color of zirconia powder does not compromise the esthetics unlike its metal filler counterparts like titanium [14]. Addition of 3-5 wt. % zirconium powder nanoparticles into PMMA resin significantly improved flexural strength, flexural modulus, fracture toughness and surface hardness [19],

One of the main points that should be taken into consideration is the adhesion of the zirconium powder with the resin matrix which effectively improve the properties of the polymer/nanoparticles composite. Therefore, modification of nanoparticles surface with a saline coupling agent might enhance its compatibility with the polymer, which may result in the improvement of material properties [20].

The results of the present study revealed that the mean values of maximum fracture resistance were much higher in the reinforced thermopress with 5% nano-zirconium oxide powder group (2612) followed by the unreinforced thermopress (2231) and finally the lowest mean values were the conventional acrylic resin (1662). This could be attributed to the addition of the nano-zirconium powder which improved the mechanical properties of the thermopress resin, enabling it to better absorb forces, additionally the flexible nature of the unreinforced thermopress enhanced its fracture resistance property when compared to the conventional acrylic resin material. This comes in agreement with many studies [6, 21, 22].

Although there is no significant difference between the unreinforced thermopress group and the reinforced thermopress one, but in the reinforced group the fracture resistance is higher which might be attributed to the incorporation of the nano-zirconium particles which might interfere with any crack propagation initiated in the thermopress [23].

Conclusion:

Within the limitations of this in vitro study, regarding the facture resistance both the thermopress resin material and its reinforcement with 5% nano-zirconium showed to be a good alternatives to conventional acrylic resin as a denture base materials especially in implant supported overdenture cases.

References

1. Wang, F., Monje, A., Huang, W., Zhang, Z., Wang, G., & Wu, Y. (2016). Maxillary Four Implant-retained Overdentures via Locator® Attachment: Intermediate-term Results from a Retrospective Study. *Clinical Implant Dentistry and Related Research*, *18*(3), 571–579. https://doi.org/10.1111/cid.12335
2. Gonda, T., Maeda, Y., Walton, J. N., & MacEntee, M. I. (2010). Fracture incidence in mandibular overdentures retained by one or two implants. Journal of Prosthetic Dentistry, 103(3), 178–181. https://doi.org/10.1016/S0022-3913(10)60026-1
3. Chand, P., Patel, C. B. S., Singh, B. P., Singh, R. D., & Singh, K. (2011). Mechanical properties of denture base resins: An evaluation. Indian Journal of Dental Research, 22(1), 200–204. https://doi.org/10.4103/0970-9290.79997
4. Elsyad, M. A., El-Waseef, F. A., Al-Mahdy, Y. F., & Fouad, M. M. (2013). A comparison of mandibular denture base deformation with different impression techniques for implant overdentures. Clinical Oral Implants Research, 24(A100), 127–133. https://doi.org/10.1111/j.1600-0501.2011.02395.x
5. Meng, T. R., & Latta, M. A. (2005). Physical properties of four acrylic denture base resisns. Journal of Contemporary Dental Practice, 6(4), 93–100. https://doi.org/10.5005/jcdp-6-4-93
6. Nejatian, T., Johnson, A., & Van Noort, R. (2006). Reinforcement of Denture Base Resin. Advances in Science and Technology, 49, 124–129. https://doi.org/10.4028/www.scientific.net/AST.49.124
7. **Tandon R, Gupta S & Samarth KA:** Denture base materials: From past to future. Ind J Dent Sc. 2010; 2: 33-9.
8. **Phillips RW:** Science of Dental Materials. 9th ed. Philadelphia WB Saunders Co., 1991. PP 40:29-60, 157-214.
9. Asar, N. V., Albayrak, H., Korkmaz, T., & Turkyilmaz, I. (2013). Influence of various metal oxides on mechanical and physical properties of heat-cured polymethyl methacrylate denture base resins. The Journal of Advanced Prosthodontics, 5(3), 241. https://doi.org/10.4047/jap.2013.5.3.241
10. Al-Karam, L. Q., & Majeed, S. M. (2019). Evaluation the mechanical properties of PMMA / ZrO2 nanoparticles for dental application. International Journal of Research in Pharmaceutical Sciences, 10(3), 2002–2007. https://doi.org/10.26452/ijrps.v10i3.1409
11. Bangera, M. K., Kotian, R., & N, R. (2020). Effect of titanium dioxide nanoparticle reinforcement on flexural strength of denture base resin: A systematic review and meta-analysis. In Japanese Dental Science Review (Vol. 56, Issue 1, pp. 68–76). Elsevier Ltd. https://doi.org/10.1016/j.jdsr.2020.01.001

12. A Mahmoud, T., E Sanad, M., & I Seif-ElNasr, M. (2018). Effect of nano-gold reinforcement of polymethyl methacrylate and flexible polyamide denture base materials on impact strength#. Al-Azhar Journal of Dental Science, 21(1), 47–50. https://doi.org/10.21608/ajdsm.2020.71474
13. Ellakwa, A. E., Morsy, M. A., & El-Sheikh, A. M. (2008). Effect of aluminum oxide addition on the flexural strength and thermal diffusivity of heat-polymerized acrylic resin. Journal of Prosthodontics, 17(6), 439–444. https://doi.org/10.1111/j.1532-849X.2008.00318.x
14. Shukla, S., & Seal, S. (2003). Phase stabilization in nanocrystalline zirconia. Reviews on Advanced Materials Science, 5(2), 117–120.
15. Asopa, V., Suresh, S., Khandelwal, M., Sharma, V., Asopa, S. S., & Kaira, L. S. (2015). A comparative evaluation of properties of zirconia reinforced high impact acrylic resin with that of high impact acrylic resin. The Saudi Journal for Dental Research, 6(2), 146–151. https://doi.org/10.1016/j.sjdr.2015.02.003
16. Ayad, N., Badawi, M., & Fatah, A. (2008). Effect of reinforcement of high-impact acrylic resin with zirconia on some physical and mechanical properties. Rev. Clín. Pesq. Odontol. (Impr.). https://doi.org/10.7213/aor.v4i3.23218
17. Korkmaz, T., Dŏan, A., & Usanmaz, A. (2005). Dynamic mechanical analysis of provisional resin materials reinforced by metal oxides. Bio-Medical Materials and Engineering, 15(3), 179–188.
18. Ahmed Omran Alhareb, & Zainal Arifin Ahmad. (2011). Effect of Al2O3/ZrO2 reinforcement on the mechanical properties of PMMA denture base. Journal of Reinforced Plastics and Composites, 30(1), 86–93. https://doi.org/10.1177/0731684410379511
19. Zidan, S., Silikas, N., Alhotan, A., Haider, J., & Yates, J. (2019). Investigating the mechanical properties of ZrO2-impregnated PMMA nanocomposite for denture-based applications. Materials, 12(8). https://doi.org/10.3390/ma12081344
20. Sarac, Y. S., Sarac, D., Kulunk, T., & Kulunk, S. (2005). The effect of chemical surface treatments of different denture base resins on the shear bond strength of denture repair. The Journal of Prosthetic Dentistry, 94(3), 259–266. https://doi.org/10.1016/j.prosdent.2005.05.024
21. Gad, M. M., Rahoma, A., Al-Thobity, A. M., & ArRejaie, A. S. (2016). Influence of incorporation of ZrO2 nanoparticles on the repair strength of polymethyl methacrylate denture bases. International Journal of Nanomedicine, 11, 5633–5643. https://doi.org/10.2147/IJN.S120054
22. Soygun, K., Bolayir, G., & Boztug, A. (2013). Mechanical and thermal properties of polyamide versus reinforced PMMA denture base materials. The Journal of Advanced Prosthodontics, 5(2), 153. https://doi.org/10.4047/jap.2013.5.2.153
23. Hamouda, I.M and Beyari. M. M (2014). Addition of glass fibers and titanium dioxide nanoparticles to the acrylic resin denture base material: comparative study with the conventional and high impact type. oral health and dental management 13 (1): 107-12