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EVALUATION OF THE EFFECT OF ADDING ZIRCONIUM OR TITANIUM OXIDE POWDER TO HEAT CURED ACRYLIC RESIN ON THE FRACTURE RESISTANCE OF DENTURE BASE OF THE MANDIBULAR IMPLANT SUPPORTED OVERDENTURE. AN INVITRO STUDY

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ABSTRACT

Objectives: The objective of this study was to compare the fracture resistance of denture base of an implant supported mandibular overdenture when incorporating either 5% zirconium or titanium oxide powder to conventional heat cured acrylic resin.

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 models 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 after adding 5 % zirconium powder to the conventional denture base material, while the denture base of the third group contained 5% titanium oxide powder added to the conventional denture base material. 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 this study revealed that there was a statistically significant difference between the 3 types of denture bases regarding the fracture resistance where the highest mean value was recorded for the conventional acrylic denture base reinforced with 5% zirconium powder followed by that containing the titanium oxide powder while the conventional denture base showed the least values of fracture resistance

Conclusion: Reinforcement of the conventional heat cured acrylic resin denture base material increased the fracture resistance of the denture base when used in mandibular overdenture cases retained with two implants.

KEY WORDS: Conventional acrylic resins, denture base, mandibular overdenture; denture fracture, fracture resistance.

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INTRODUCTION

The rehabilitation of a completely edentulous mandible with a two-implant assisted overdenture is a common procedure that is now expanding rapidly in the daily practice. This is proved to be a reliable and safe procedure with a long term clinical success[1].

Failure or fracture of the denture base is one of the common complications that occurs with overdenture when not reinforced with metal framework. This fracture might occur either extraorally due to sudden fall of the prothesis on a hard surface (impact failure) or might occur intraorally due to fatigue (flexure fatigue failure) [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]

Many authors suggested that strengthening of polymethyl methacrylate is possible through the addition of a structural component of different size distributed in the acrylic matrix, thus forming a strong composite structure [7,8].

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].

METHODOLOGY

Model fabrication and implant installation

Epoxy resin models* where used in this study. These models were duplicated from a mandibular cast of a completely edentulous patient having a ridge that is suitable to accommodate two implants 3.7 mm in diameter and 12 mm in length** at the canine areas bilaterally (figure 1). The accurate area of the canines was ensured by constructing a trial waxed up denture that was used as a guide to mark the canine areas bilaterally. The drilling sequence of the implant system was followed to create the osteotomy site and then slightly widened to ensure the placement of the two implants without any interference and at the same time leaving a space for the self-cured acrylic resin that will be used to fix the implants in their prepared site simulating osseointegration. The two implants were placed parallel to each other by the aid of a dental surveyor.

Fig. (1): The epoxy model.

The epoxy model was duplicated 15 times in dental stone after creating indices in the base to facilitate the construction of putty index later. These duplicate models were used to fabricate 5 identical

* Clear heat cured acrylic resin, Acrostone, Egypt.

** Osteoseal dental implants, California, USA overdentures in each group. An even thickness of pink base plate wax was adapted on one of the duplicate casts then teeth were set according to the standard guidelines followed by waxing up. To ensure that the dimensions of all the overdentures are identical, a rubber base index was made for the polished surface and the teeth, this facilitated the duplication of the remaining four overdentures of each group with the same denture base thickness and teeth setting.

The sample size grouping was as follows; groups I: conventional heat cured acrylic resin denture base. Group II: conventional heat cured acrylic resin denture base added to it 5% zirconium oxide powder while group III: conventional heat cured acrylic resin denture base added to it 5% titanium oxide powder

The PMMA, zirconium powder and titanium oxide powder, were pre-weighed in order to ensure a powder concentration of 5% by weight. Zirconium powder particles were treated with 1% of silane coupling agent before mixing with the conventional acrylic resin powder. Mixing and proper blending were done using an electric mixer to obtain a consistent and homogeneous mix before manipulation of the materials.

The conventional steps of denture processing (flasking, wax elimination, packing, curing, deflasking, finishing and polishing) were followed to obtain the 15 overdentures. A ball attachment was fixed to each implant and their female parts were picked up in the denture following the conventional pick up procedures.

Fracture resistance testing (figure 2)

The epoxy model was secured to the base of computer controlled universal testing machine[3] by the aid of a lock. The overdenture was fixed on the cast by the aid of the attachment. Compressive force was applied on the occlusal surface of the teeth using inverted t-shaped metallic load applicator fixed to the upper part of machine. The applicator was positioned over the central fossae of the 1st molars bilaterally to achieve homogenous stress distribution. The upper movable compartment of testing machine was adjusted to move at crosshead speed of 5mm/min. The load value where the sample fractured was recorded as it was manifested by an audible crack sound and confirmed by a sharp drop at load-deflection curve recorded using the computer software. This test was repeated for the 15 samples. The load was recorded in Newton. The data was collected and tabulated for statistical analysis.

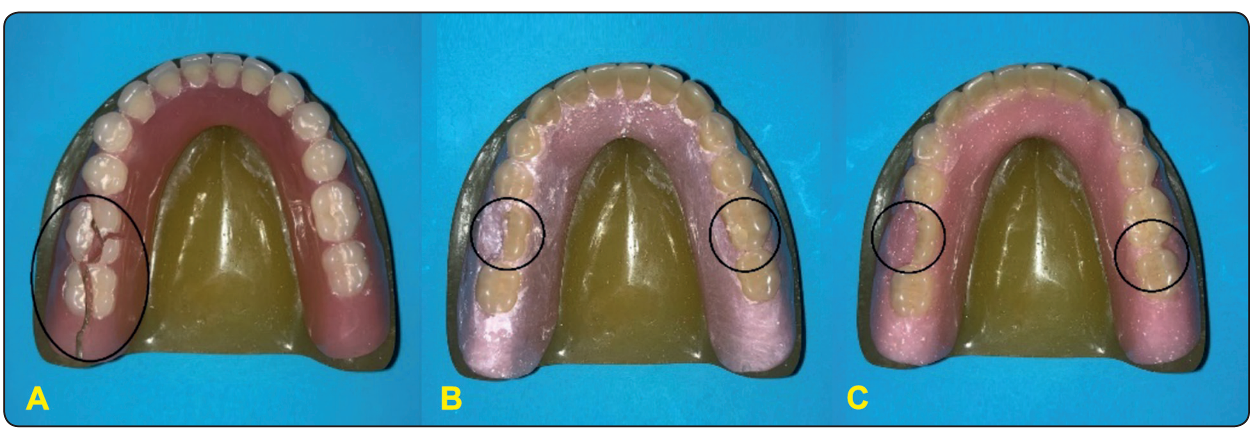

Fig. (2): The fractured sample. (A) group I. (B) group II. (C) group III.

RESULTS

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

The mean, standard deviation (SD) values of Fracture load of different groups.

	Fracture load	SD
Group I (Conventional acrylic resin)	1336[a]	134.15
Group II(conventional acrylic resin+5% Zirconium powder)	2371.6[b]	308.31
Group III (Conventional acrylic resin +5% TiO2 powder)	2231.4[b]	404.92
p-value	**<0.001***	

Means with different letters in the same column indicate statistically significance difference. *; significant (p<0.05)

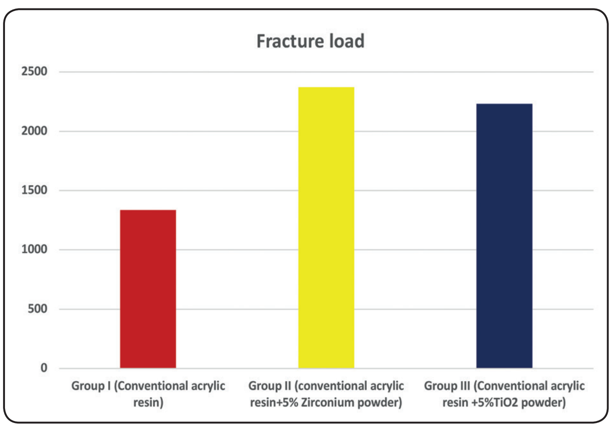

Fig. (3): Bar chart showing the difference between the three groups.

The results of this study showed that there was a statistically significant difference between group I and each of groups II and III in which the highest mean value of 2371.6 N was recorded for group II followed by group III where the value was 2231.4 N and finally the least value was for group I which was 1336 N.

DISCUSSION

Many attempts are made to increase the fracture resistance of conventional denture base material. This included the addition of silver, copper, aluminum. Titanium or zirconium powder. These additives not only give the denture base an advantage of increased strength and improved thermal conductivity, but also minimize the denture base warpage, reduces the polymerization shrinkage, and inhibits the growth of bacteria over the denture surface. The major disadvantage of adding metal fillers however is the poor esthetics due to incorporation of metal filler [10, 13, 14,15].

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 3-5wt% 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 values of maximum fracture resistance were much higher in the conventional acrylic resin reinforced with 5% titanium oxide powder group and also in the group where zirconium powder is added with no statistically significant difference between them. While both were much higher than the conventional acrylic resin group with statistically significant difference between the conventional group and each of the two other groups. This could be attributed to the addition of the metal powder which improved the chemical properties of conventional acrylic resin powder, enabling it to better absorb forces. This comes in agreement with many studies [6, 21, 22].

Although there was no significant difference between the titanium oxide group and the zirconium oxide one, but in the titanium oxide group the fracture resistance was lower this might be attributed to the poor adhesion between the metal particles and the matrix, which might lead to unwanted dispersion of cracks around the metal particles. This is unlike the zirconium oxide powder which is treated first by silane coupling agent which enhance adhesion between the zirconium oxide particles and the matrix [23].

CONCLUSION

Within the limitations of this in vitro study, the incorporation of 5% zirconium or titanium oxide powder into conventional acrylic resin denture base materials improved the fracture resistance. The high fracture resistance of the conventional acrylic resin denture base after reinforcement renders it as a good alternative to conventional acrylic denture base for construction of mandibular implant supported over denture. But, more studies are needed to find a solution for increasing the fracture resistance of the denture base without compromising esthetics which is a drawback of incorporating metal fillers to the conventional acrylic resin.

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