EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 69, 2235:2243, July, 2023

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 22-05-2023 • Accept Date : 12-06-2023 • Available online: 01-07-2023 • DOI : 10.21608/EDJ.2023.212083.2560

EFFECT OF AGING ON FLEXURAL STRENGTH AND RETENTION OF DIFFERENT MAXILLARY DENTURE BASE MATERIAL: IN VITRO STUDY

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ABSTRACT

Background: the most commonly used treatment plane for edentulous patients is complete denture, many denture wearers complain from denture retention. Various materials have been used as a denture base to improve denture retention and denture base flexural strength. Nanoparticles was discovered that its inclusion as a reinforcing agent influences the physical properties of acrylic resins.

Aim of the study: this comparative in-vitro study was done to compare retention of maxillary denture bases and their flexural strength using three different denture bas material**.**

Material and methods: total number of 18 denture base was fabricated (six conventional base, six nylon denture base and six modified PMMA denture base), retention of the maxillary dentures was measured before and after thermocycling, 30 rectangular samples were fabricated from each material for flexural strength test. Data ware calculated, tabulated and statically analyzed.

Results: results showed significant differences appeared between both polyamide and modified PMMA in comparison to conventional PMMA in both retention and flexural strength.

Conclusion: modification of PMMA with nano-zirconia filler improved both fracture resistance and retention of denture bases.

KEYWORDS: Polymethyal methacrylate, Polyamide, Nylon, Thermocycling , zirconia nano-filler

INTRODUCTION

Among the several treatment options for edentulous patients, conventional complete dentures are known as the best option for edentulous people. Denture materials and methods have evolved over the last century, with the primary goal of overcoming the absence of accurate fit between denture bases and underlying tissues which affects the retention of dentures, Conventional complete denture treatment continues to fabricate high-quality dentures to improve function and patient comfort. [(1)]

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Retention is critical factor which affects the entire denture success, though each step of denture fabrication has to be prioritized. The intimate mucosal contact of the denture base results in effective retention. Thickness of the salivary film, cohesion, adhesion, surface tension, and air pressure are the physical parameters that govern total denture retention. Increase in surface tension and reducing the fluid film, will increase the denture retention. The denture base's dimensional stability and accuracy will result in good adaptation to the oral tissues. [2,3]

Polymers for denture base resins were introduced in the field of dentistry in 1937, polymethyl methacrylate (PMMA) is still the golden choice for mostly all denture technician and prosthodontists today. Throughout the polymerization process, the resin shrinks in dimension. As a result of polymerization, shrinkage caused by changes in the monomer and polymer densities leads to the lifting away denture base from the area of the post dam (posterior palatal seal). [4]

Polymethylmethacrylate (PMMA) based heat-cured acrylic resin for denture base is the most commonly material used in complete denture construction in the field of removable prosthodontics. Its popularity due to its excellent working properties, acceptable physical, mechanical, and esthetic characteristics, and ease of manufacture with low-cost. But still same drawbacks exits that affect its service such as shrinkage due to polymerization, low flexural, reduced impact strength, and weak fatigue resistance, which may cause failure of denture retention. [5]

Several attempts have been carried out such as inclusion of plates or wires made of metal, metal inserts, fibers, and alteration of chemical structural. Polyamide resin was introduced in the field of dentistry as a denture base material. Nylon term is used as a general term for types of thermoplastic polymers in the polyamide category. Advantages of nylon materials include increased elasticity than standard heat-polymerized acrylic resins, biocompatible with patients who suffer from resin monomer allergy or metal allergies, and utilization of heat-molding rather than chemical polymerization to regulate the degree of shrinkage due to polymerization reaction and other related deformation that may occur. [6]

Many efforts have been made to achieve more improvement in denture base material's characteristics. The inclusion of nanoparticles as a reinforcing agent has been discovered to improve the characteristics of acrylic resins, previous research reported that PMMA nanoparticles had great impact over the ordinary PMMA. [7]

Recent research has investigated the effect of adding inorganic different nanoparticles into PMMA in order to enhance its characteristics. The characteristics of a polymer nanocomposite mixture are determined by the form and size of these nanoparticles, in addition to their concentration percentage and linking with a polymer grid. [8]

Nanomaterials are well-known for their exceptional properties; zirconium oxide nanoparticles which commonly known as (nano- zirconia) usually used mechanically to strengthen polymers and reinforce the matrix of PMMA. [9]

Because of its high biologically acceptance and white color, it is unlikely to interfere with aesthetics. When compared to other metal oxide nanoparticles, nano-zirconia has attracted a lot of attention, also due to its superior mechanical qualities, nano- zirconia can endure cracking. [10] nano-zirconia also has the highest hardness between most of the nan-oxide. This beacuse of its crystalline form, moreover it has a high degree of opacity. [11]

Denture prostheses are typically subjected to heat fluctuations in the oral cavity as a result of hot or cold liquids consumption. Denture polymer degradation may occur due to thermal cycling in a wet environment, and heat stress may also occur none the less, water sorption increasing due to the polymer chains separation. Water absorpation can function as a plasticizer causing increase in denture softness and lowering the material's mechanical properties. [12] On the other hand, heating the acrylic resins, may accelerate additional polymerization reactions, resulting in an improvement in mechanical properties. As a result the temperature cycling possible effect on the mechanical characteristics of acrylic resins must be examined, as this aspect may affect the performance of relined detachable prostheses. [13], [14]

MATERIAL AND METHODS

Total number of 18 denture base was fabricated (n=18), 6 denture base of each group and 30 rectangular samples from each material for flexural measure test (a.PMMA, b. Polyamide C. nano zirconia filler modified PMMA)

Fabrication of denture base

PMMA denture base fabrication: Denture bases were constructed traditionally according to manufacturer's instructions from (ACROSTONE, Egypt), the mixture was packed in flasks, and sealed for denture processing using (hot water bath at 74 degrees for nine hours according to long cycle processing technique). **Fabrication** of **Thermoplastic Polyamide (nylon) denture base material base** material is mixed according to the instruction on the package from (Dentiflex, Roko dental system, Poland) following the elimination of the wax, a brush was used to coat the mould surface with separating medium. After that Polyamide capsule was placed in the injection machine's metal ring, the temperature was raised to 288°C under 0.1 MegaPascal (MPa) pressure and heated for 12 minutes to prepare the polyamide for injection. At the meantime, the metal flask was sealed tightly and put in hot oven at the degree 75°C for 12 minutes. [15]

Nano zirconia fillers modified PMMA

(Nano-tech Egypt for photo electronics, city of 6th October, Egypt) developed nano-zirconia powder for the current investigation. A reaction of 3 Trimethoxysilylpropyl methacrylate (TMSPM), (SIGMA-ALDRICH, Germany) and 99.5% purity nano-zirconia was used to add reactive groups onto the filler surface. This procedure was performed to ensure proper adherence between the nanoparticles and the resin matrix.

The silanized nano-zirconia powder was separately mixed into acrylic resins using same process. Nano-zirconia and PMMA was weighed using an electronic balance (Scaltec, SBC series, India), yielding nano-zirconia concentrations of 3%, by weight. Separately, the powder of Nano-zirconia was added to acrylic resin powders and carefully mixed with a mortar and pestle to ensure even dispersion of all particles before powder was blended with the liquid.

After removing the dentures from the molds, excess margins were cut using tungsten carbide burs, then polished using pumice powder and preserved in water. **Figure (1)**

Each denture group was divided into subgroups I; before thermocycling and II after thermocycling, all II subgroups were displayed for thermocycling 5000 cycles (at 5°C and 55°C, 2 cycles/min)

Retention testing:

A metal chain attached from three sites (between two centrals between and between the second premolar and first molar on each side) and was collected in a single metal ring at the top to hold each denture in place. .

Each cast was placed in the machine (Instron 5567 compression tension tensile meter) **Figure (2)** , each model received five pulls to dislodge the denture from its model, force applied vertically at center of acrylic block, Joining the three metallic chains that held the denture , the force used was displayed on the digital indicator which was recorded.. The test was performed both before and after thermocycling. **Figure (3)**

Samples for flexural strength test

30 rectangular specimens were constructed according to each material technique (10 specimens according to each material group and then subdivided before and after thermocycling).

A metallic flask was used for Specimens fabrication using a stainless-steel mold of the necessary dimension and invested in a Type III gypsum product (Dental Stone-Zhermack elite rock type 4 extra hard stone, ITALY). A wax pattern with dimensions of 65x13x5 mm was constructed to create the mould into which the resin was applied. **Figure 4 (a, b, c)** Subgroups were thermocycling for 5000 cycles (5°C and 55°C, 2 cycles/min)**.**

Test for flexural strength

A universal testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) was used for the Three-point flexural test at force of 5mm/min and the crosshead speed of 5mm/min. a rig with integrated supports spaced at 50 mm apart was used for Specimens placement **Figure (5)**

Computer software (Instron Bluehill Lite Software) was used for data recording. Flexural strength was determined using 5 specimens from each subgroup (n = 15) before and after thermocycling. Each specimen center was noted. Force application was done on the specimen's crosshead center at a speed of 5 mm/min until it fractured. A digital monitor on the machine displays the amount of force applied to the test specimen. When the specimen breaks, the digital scale reading instantly stops, indicating the fracture load.

Statistical analysis:

Data were collected, tabulated, and SPSS program version 21 was used for statical analysis. An one-way ANOVA test was conducted in order to compare the effect of thermocycling on the flexure strength and denture base retention for Acrylic, Polyamide and Zirconia filler in denture base specimens.

Fig. (1) Finished maxillary denture

Fig. (2)

Fig. (3)

Fig. (2) Retention test using universal.

Fig. (3): Thermocycling machine testing machine

Fig. (4) a: Processed rectangle samples, b: Preparing closed flask for processing, c: Packing of acrylic mix in the flask

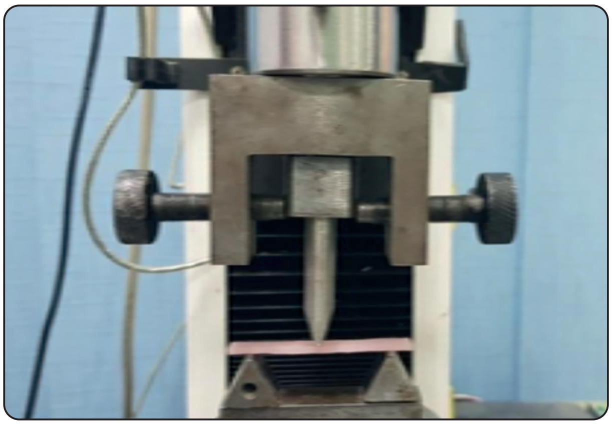

Fig. (5) Testing of flexural strength using universal testing machine

TABLE (1) Means and SD between the different groups before and after thermocycling

Retention values	pmma	Nylon	Zr 3%	p value
Means before	510.83± 76.5(Aa)	541.17± 82.2(Aa)	578.5± 71.4(Aa)	0.01 (sig.)
Means after	493.33± 74.8 (Bb)	527.83 ±81.5(Ca)	569.24± 73.1(Aa)	

Different superscript capital letters (in each column) indicates significant differences P<0.05 within each group. Different superscript small letters (in each row) indicate significant differences P<0.05 between groups

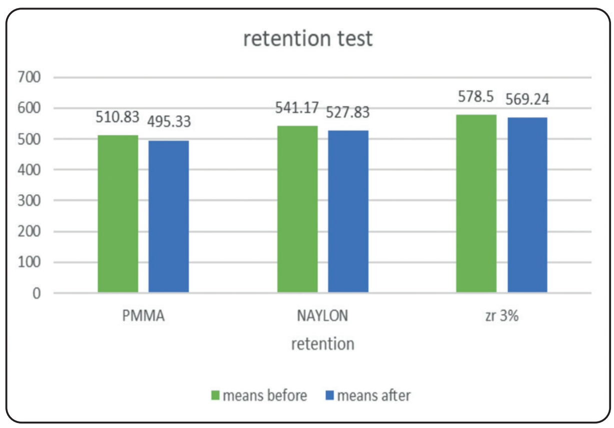

Fig. (6) Histogram showing difference in retention before and after thermocycling

RESULTS

Results showed change in retention before and after thermocycling in the three groups of material, there was a significant difference between PMMA and the two other groups. PMMA showed the least values for retention test. p value ≤ 0.01 while there was no significant difference between Polyamide and Nano zirconia group. Within the groups: in Zirconia filler group There were no significant differences while there were significant difference within groups of PMMA and Polyamide. **Table (1) & Figure (6)**

Results showed change in flexure strength before and after thermocycling in the three material groups, there was a significant difference between Zirconia nano filler and the two other groups, zirconia group showed better results than the two other group's p≤ 0.05. Within groups zirconia group showed no significant difference while there was significant difference within PMMA and nylon .**Table (2) & figure (7)**

TABLE (2) Shows means and SD between the three different groups

Flexure strength	Pmma	Nylon	Zr 3%	P value
Before thermocycling	67.15± 2.2(Aa)	70.49± 1.3(Ba)	78.32± 1.8(Ba)	0.012 (sig)
After thermocycling	58.9± 1.09 (Cb)	68.5± 1.9(Ab)	76.9± 1.3(Ba)	

Different superscript capital letters (in each column) indicate significant differences P<0.05 within each group. Different superscript small letters (in each row) indicate significant differences P<0.05 between groups

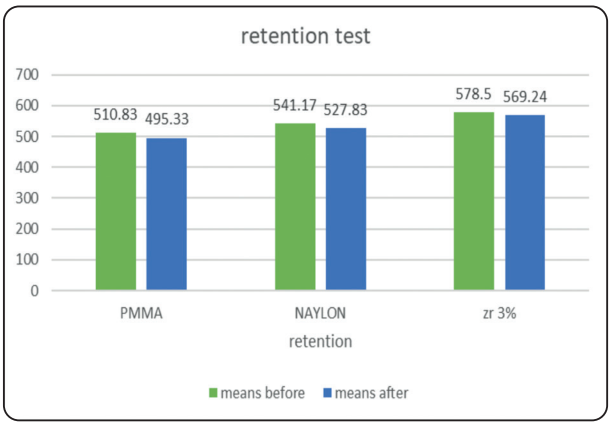

Fig (7) Histogram showing difference in retention before and after thermocycling

DISCUSSION

Popularity of PMMA in dentistry stems from its simplicity of production, low cost, light weight, Aesthetic characteristics, low water sorption, and solubility are all advantages. Other characteristics include limited strength, reduced thermal conductivity, brittleness, and an increase thermal expansion coefficient, make the material more likely to fail during clinical service. As a result, numerous attempts have been made to increase strength characteristics of acrylic denture base. [(5), (16)]

The intimate contact between denture base and cast results in improved adaptation of the denture's tissue surface to the oral tissues, resulting in a more retentive denture. In clinical usage, the dental prosthesis temperature can change significantly due to the intake of various foods and beverages temperate, as well as warm or hot water usage for prosthesis cleansing. [(17)]

In this study, retention and flexure of denture bases from different materials (PMMA, Polyamide and Nano zircon fillers PMMA) was measured before and after thermocycling, the flexural strength of PMMA, polyamide, and Nano zircon is reduced by temperature variations and immersion in water during thermocycling. Bases denture base materials, can be concluded. The difference was significant between the PMMA and both Polyamide and Nano zirconia group. PMMA showed the lowest results in the two tests.

This is may be due to fact that states addition of chemical ingredients alters the molecular resin chain (changes the amount of interpolymeric gaps) and hence changes water sorption, also the fact that the cumulative effect of shrinkage and expansion caused by temperature changes causes strain or stress in the material, lowering its fitness accuracy which affect the retention . [(18)]

Other studies reported that many commercial varieties of acrylic resin had significant variation in residual monomer, water consumption, and water sorption and rate of solubility, which can affect denture base adaption. [(19)]

One of explanation for decrease of thermal cycling PMMA fitness and modified samples compared to those without thermal cycling is the continuous polymerization reaction in which residual monomer molecules are progressively absorbed, leading to more complete polymerization. Another possible explanation is that thermal changes are responsible for biodegradation (release of unbound/uncured monomers or and additives). [4,20, 21]

Heat-induced interaction between amide and amine terminal groups can produce denture base contraction, or polyamides exposed to heat and oxygen can modify their physical and chemical properties due to thermal oxidative degradation. [22]

Polymide denture and Nano Zicronia fillers denture bases showed better results in comparison to PMMA (significant difference) in both retention or flexural strength measures, this is contrast with results stated that the flexural strength of denture base materials is reduced by water sorption and temperature changes. [23] In many studies, PMMA materials showed increased water sorption ratios than polyamide denture base materials. Immersion of PMMA in water solutions causes Plasticizers and other soluble components to seep out after prolonged exposure in water or saliva. The physical and mechanical qualities of the resin denture base material are distorted by water sorption. [24] acrylic resin can be soften by water over time, mostly due to the polar characteristics of the resin molecules, by acting as an acrylate plasticizer and diminishing the material's strength .The amide groups, on the other hand, are responsible for polyamides' low water sorption and solubility; the more concentration of the amide group, the greater will be the water sorption. [25]

Other researchers adviced that the concentration of amide group of polyamide denture base materials should be decreased to a level as low as concentration of conventionally used industrial materials such as nylon. [26]

Also these findings in agreement of studies reported that PMMA thermocycled for 5000 cycles between 5 and 55°C showed a considerable loss in flexural strength. This is due to an elevation in temperature, that enabled water molecules to diffuse fast between the polymer chains, serving as plasticizers and causing slip of the chains more easily over one other under load. [27]

Studies also showed that adding between 3% to 5% of nano zirconia fillers increased the flexure strength of PMMA denture bases, on the contrary increasing the percentage 7% reduced it. This due to the excellent dispersion of the fillers. [28] Because their very fine size allows the particle to enter between the polymer's linear macromolecular chains and occupy spaces between chains, segmental movement of the macromolecular chains is limited, resulting in an increase in the resin mechanical strength and rigidity, leading to improvement of resistance to fracture and flexural strength. [29]

Hameed et al., reported that the nano fillers fine size allows them to enter in-between the polymer's linear macromolecular chains and occupy chains spaces, segmental movement of the macromolecular chains is limited, resulting in an increase in the strength and rigidity of the resin, which improved fracture resistance and flexural strength. [30]

CONCLUSION

With the limitation of this study, adding zirconia to PMMA improved both retention criteria and flexural strength in comparison to PMMA and Polyamides.

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