Research Article

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To Evaluate the Effect of Aluminium Oxide on Flexural Strength of Heat Activated Denture Base Resin

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ABSTRACT

Background: To evaluate the effect of aluminum oxide on flexural strength of heat activated denture base resin. A standard stainless-steel mold measuring 65mm x 10mm x 2.5mm was made for the fabrication of 180 samples which were then divided into 6 groups of 30 samples each. The 6 groups were as follows, Group A (Control Group): the unmodified denture base resins; Group B, Group C, Group D, Group E and Group F were the modified denture base resins with varied particle size such as, 5μ, 10μ, 15μ, 20μ, 25μ and varied concentration such as 5%, 10%, 15%, by wt. Aluminum oxide powder respectively. It was found that increase in the particle size of aluminum oxide in PMMA resin increases the flexural strength of heat polymerized PMMA linearly. Flexural strength has also shown a linear increase, when the concentration of aluminum oxide was increased from 5 to 10% but a decline in flexural strength was seen when the concentration was further increased to 15%.

Keywords: Denture base resin, Aluminum oxide, Flexural strength.

INTRODUCTION

Edentulism is defined as the loss of permanent teeth which may be partial (loss of some teeth) or complete (loss of all teeth) and is the outcome of multi factorial process involving biological process (dental caries and periodontal disease, trauma) as well as non-biological factors related to dental procedures (access to care, affordability, patient preferencesetc).[1]Tooth loss can impair one's ability to chew, speak and it can even change the shape of a patients face. Everyone has seen older people with faces that appear vertically "compressed". There is less space between the tip of the nose and the chin than there should be and the lips tend to pucker inward. These abnormalities are most likely due to tooth loss and jaw bones that have become shrunken over time. Some of the inherent problems related to conventional dentures are loose or falling dentures, soreness of mucosa, inability to eat food and clicking in the mouth.[1]Such problems reduce the patient's comfort and wellbeing. Further, the process of continuous resorption of the natural bone underneath a complete denture may deteriorate over time changing the appearance of smile and face.[2] The denture bases are subjected to various stresses during function; these include compressive, tensile, and shear stresses. Some of the factors responsible for denture fracture include stress intensification, increased ridge resorption leading to an unsupported denture base, flexural fatigue of acrylic due to cyclic stress, deep incisal notching at the labial frenum, sharp changes at the contours of the denture base, deep scratches, and induced processing stress.[3]

MATERIALS AND METHODOLOGY

This study was conducted in the Department of Prosthodontics &Crown and Bridge. Inderprastha

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Dental College and Hospital, with the prior approval of Institutional ethical committee with IEC reference no. 03. This study was done to evaluate the effect of different particle size and concentration of Aluminium oxide on flexural strength of heat activated denture base resin.

Fabrication of stainless steel mold

The stainless steelmold was prepared with ADA Specification number 12/ISO 1567:1999. The dimension of the mold was 65mm x 10mm x 2.5mm. It had two compartments, one was upper compartment with locking keys and the other was a lower compartment with a detachable wall. This wall had a key at both the ends and the corresponding keyholes at the other segmented part (Fig. 1).

Fabrication of Specimen

Modelling wax was melted in the wax water bath under a controlled temperature. It was then poured into stainless steel mold and was allowed to cool. After the wax solidified, the upper compartment was removed followed by removal of the wall of the lower compartment, then the specimen was retrieved from the stainless steel mold and checked for proper margins and dimensions with the help of vernier caliper (Fig.2). After the mold was prepared,the specimens were invested in processing flask. The upper portion of the selected denture flask was then positioned a top the lower portion of the flask. After that, the surface of the investing medium in the lower half was covered with a separating medium to prevent it adhering with the plaster mix. The lid of the flask was gently tapped into place, and the plaster was allowed to set[5] (Fig.3)

After the final poured layer was sufficiently hardened, the flask was submerged into boiling water for 5 to 10 minutes to liquefy the wax inside the mold. Next the flask was opened and thoroughly flushed with boiling water.[6] (Fig.4)

Application of separating medium

An appropriate separating medium (Orthoplast heat cure, cold mold seal, India) was applied onto the walls of the mold cavity. This medium prevents direct contact between the denture base resin and mold surface. Failure to place an appropriate separating medium may lead to water being transferred from gypsum to resin may effect the polymerization of resin.

Incorporation of aluminium oxide powder in PMMA

For each particle size of aluminium oxide (5, 10, 15, 20, 25 micron) 3 different concentration (5%, 10%, 15%) were taken and then were mixed with polymer of PMMA. Concentration was calculated in weight %, where

$$\text{Weight } \% = \frac{\text{Weight of solute (aluminiumoxide powder)}}{\text{Weight of powder (polymer of PMMA)}}$$

Table 1: Division of sample according to particle size and concentration.

S. No.	Groups	Particle size of aluminium oxide (micron)	Subgroups concentration of aluminium oxide powder (%)
1	Group A(Control)	-	-
2	Group B	5	B_1-5, B_2-10, B_3-15
3	Group C	10	C_1-5, C_2-10, C_3-15
4	Group D	15	D_1-5, D_2-10, D_3-15
5	Group E	20	E_1-5, E_2-10, E_3-15
6	Group F	25	F_1-5, F_2-10, F_3-15

Packing and curing of samples

The polymer and monomer were mixed in ratio of 2.5:1 by weight for all the 6 groups (Fig.5). When the resin reached dough stage, it was packed into the mold and sheet of polyethylene was placed over the resin. The two halves of the flask were placed together and subjected to pressure on hydraulic press (Sirio, Itlay), with a minimum pressure of 1100 pascal. The halves of the flask were separated, the polyethylene sheet was removed and excess resin or flash was carefully removed. The flask was then closed and was kept on bench press unit for

Fig 1: Stainless steel mold measuring 65mm x10mm x2.5mm.

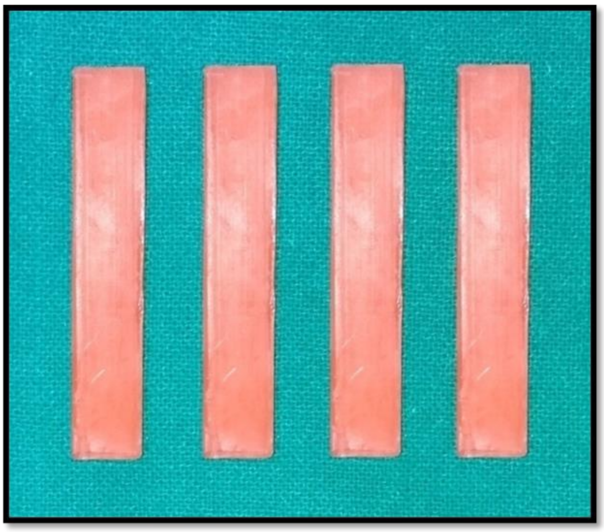

Fig 2: Wax Mold (65mm x10mm x2.5mm).

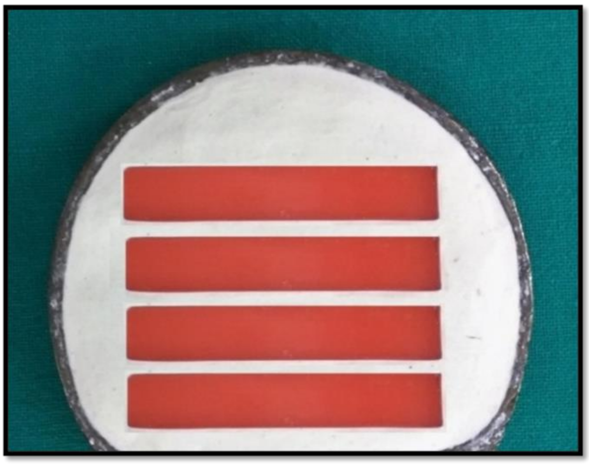

Fig 3: Wax molds flasked with plaster in the flask.

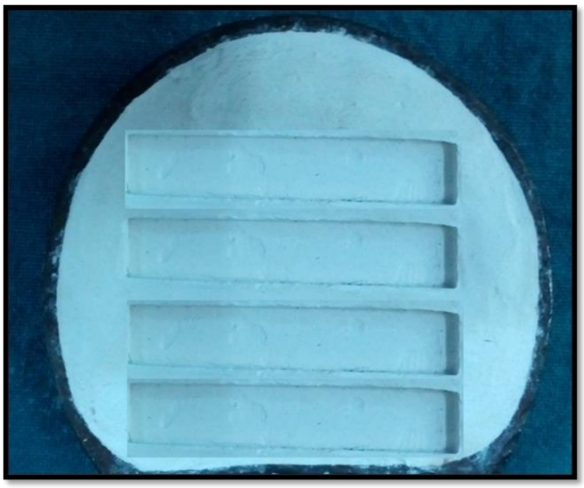

Fig 4: Wax molds dewaxed in the flask.

Fig 5: Different particle size of aluminum oxide.

Fig 6: Acrylised samples.

Fig 7: Prepared samples.

Fig 8: Universal testing machine.

Fig 9: Testing of the sample with the help of universal testing machine.

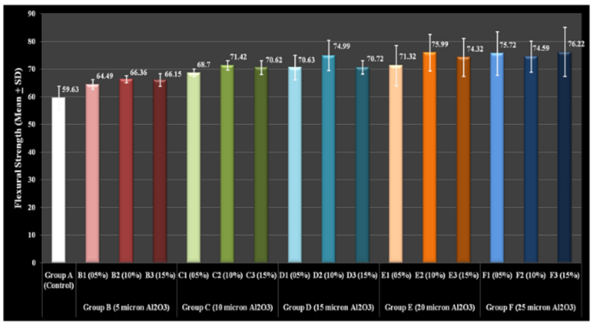

Fig 10: Graphical representation of flexural strength.

bench curing for 30 min and then cured. Curing of samples was done for 8 hours at 74^{0}C followed by 1 hour at 100^{0}C.[80]Before deflasking, the acrylised sample was allowed to cool to room temperature so as to prevent formation of internal stresses within the prepared sample. (Fig.6)

Finishing and polishing of samples

Finishing and polishing was carried out using acrylic bur followed by400 grit size silicon carbide paper. (Fig.7)

Storage of samples

Temperature of 37° C was maintained in an incubator. Samples were stored in the incubator for 7 days before testing flexural strength.

Testing of samples

The flexural strength of the specimens was tested using universal testing machine. All the specimens were marked in the center. A customized jig was positioned on the universal testing machine and the samples were loaded at that time. Load was applied at the center of the sample at a cross head speed of 5mm/min, until it fractured. (Fig.8)

3-point Flexure Test

In this test a specimen with round, rectangular or flat cross-section was placed on two parallel supporting pins. The loading force was applied in the middle by means of loading pin. (Fig.9)

The supporting and loading pins were mounted in a way, allowing their free rotation about:

- axis parallel to the pin axis;
- axis parallel to the specimen axis.

This configuration provides uniform loading of the specimen and prevents friction between the specimen and the supporting pins.

Calculations

The flexural strength S was calculated in (MPa) for all specimens from the Equation given below.

$$S = \frac{3PI}{2bd^2}$$

In this formula "P" is the maximum load or force (N) which is applied to the center of the specimen to fracture it. The specimens were placed on jig that were 50mm apart, which represents the space between the maxillary molar in a complete denture. 'I' is the span length (50mm). "b" is the width of specimens (10mm) and "d" is the height of the specimen (3mm).

RESULTS

The mean flexural strength for control group was found to be 59.63 MPa with standard deviation of 4.2307 MPa. The mean flexural strength and standard deviation in group B_1 was found to be 64.49 MPa and 1.7610 MPa respectively. The mean flexural strength and standard deviation in group B_2 was found to 66.36 MPa and 1.7610 MPa respectively. The mean flexural strength and standard deviation in group B_3 was found to be 66.15 MPa and 2.2540 MPa respectively. The mean flexural strength and standard deviation in group C_1 was found to be 68.70 MPa and 1.4322 MPa respectively. The mean flexural strength and standard deviation in group C_2 was found to 71.42 MPa and 1.7119 MPa respectively. The mean flexural strength and standard deviation in group C_3 was found to be 70.62 MPa and 2.4652 MPa respectively. The mean flexural strength and standard deviation in group D_1 was found to be 70.63 MPa and 4.4982 MPa respectively. The mean flexural strength and standard deviation in group D_2 was found to 74.90 MPa and 5.5897 MPa respectively. The mean flexural strength and standard deviation in group D_3 was found to 70.72 MPa and 2.4119 MPa respectively. The mean flexural strength and standard deviation in group E_1 was found to be 71.32 MPa and 7.2911 MPa respectively. The mean flexural strength and standard deviation in group E_2 was found to 75.99 MPa and 6.6033 MPa respectively. The mean flexural strength and standard deviation in group E_3 was found to be 74.32 MPa and 6.9034 MPa respectively. The mean flexural strength and standard deviation in group F_1 was found to be 75.72 MPa and 7.9252 MPa respectively. The mean flexural strength and standard deviation in group F_2 was found to 76.12 MPa and 5.5912 MPa respectively. The mean flexural strength and standard deviation in group F_3 was found to be 74.62 MPa and 8.8698 MPa respectively. (Fig.10)

DISCUSSION

Complete edentulism is the state of having lost all of one's natural teeth. Alveolar resorption is a gradual process affected by multiple factors categorized as anatomic, mechanical and metabolic. This leads to an irregular resorption pattern of the residual alveolar ridge, resulting in an unevenly supported prosthesis (complete dentures)[1]. Fatigue is a phenomenon that includes loss of strength due to certain loading conditions applied over a period of time. It includes cyclic loading that result in fracture of dental prosthesis due to low and repetitive stress. There are two types of denture fractures (failures) which are commonly reported outside the mouth caused accidently by the high impact forces (due to high stress rate) and inside the mouth usually under normal masticatory function (fatigue failure).An example of the latter is "midline fracture" which appears in form of concentric curved ridges originating from a spot at the junction of the tooth and the base material. This center is known as origin of the fracture[2].

Despite many innovations in the field of dental materials, the search for an ideal denture base material remains a challenge. Acrylic resin & rubber reinforced acrylic polymers have ruled the denture base materials. Out of all the polymeric materials, poly-methyl-methacrylate (PMMA) is documented to be the most promising denture base material presently available. Although, PMMA is not an ideal denture base material, it has several merits that makes it a material of choice. It has remarkable aesthetic appearance, light weight, low solubility, ease of processing and cost effective. It can replicate surface details quite accurately and is easy to repair. However, it has certain demerits like low strength, brittle on impact, poor conductivity, high coefficient of thermal expansion and comparatively low modulus of elasticity that leads to the deformation of the material at low stresses.[4]

In spite of the material's popularity, fractures of PMMA dentures are quite common. Strength of PMMA resin is not enough to maintain long-term durability of denture fabricated with them. Assessments of the clinical longevity of dentures fabricated with poly- methyl-methacrylate concluded that nearly two-third (64-68%) of PMMA dentures fracture after a few years of service in the patient's mouth.[5] Fractures in the conventional dentures can occur due to many reasons like improper fit of acrylic dentures with the supporting tissues, poor bilaterally balanced occlusion, high impact forces, fatigue failure & stresses borne by denture base materials while processing. Fractures are primarily due to two reasons: impact failure, when the denture drops accidentally on some hard surface or due to fatigue failure, where it is repeatedly undergoing deformation under functional forces.

The flexural strength (also called transverse strength or modulus of rupture) of a material reflects its potential to resist catastrophic failure under flexural loads. As a foundation, the denture base material (PMMA) should exhibit a high proportional limit to resist plastic deformation under masticatory forces and also exhibit fatigue resistance to endure repeated masticatory loads. A denture base material exhibiting higher flexural strength to resist cyclic loads is usually less prone to clinical failure.[6] The maximal biting forces with natural dentition ranges from 500N to 700 N, whereas a force of 250N to 300N is reported in patients restored with fixed partial dentures (FPD). However, these values are reduced to 100N to 150N for patient's wearing conventional complete dentures.

Various mechanical tests are used to determine the strength of denture base material. For clinical utility, flexural and impact strength are of more relevance with denture base material. While determining these two strengths, it is difficult to simulate the clinical situation for the test for impact strength as there are factors which can modify the outcome such as the angle at which the denture falls, the surface characteristics of the opposite surface etc.[11]

Flexural strength gives better prediction regarding the clinical success of acrylic dentures as the cyclic or static loads can be easily simulated in the testing labs. The ultimate flexural strength of the resin reflects its capacity to withstand the catastrophic failure under flexion. High flexural strength is important for clinical success of denture, as ridge resorption is a continuous & irregular process that makes the tissue borne prosthesis inadequately supported leading to bending or flexing forces in the midline causing fracture of denture.[13]

The main objectives of this study were therefore to bring about an improvement in clinically relevant parameters such as flexural strength of PMMA, as it generally affects the durability and the longevity within the functional range of forces of the dentures. Impact strength is defined as the energy required to fracture a material under an impact force, whereas the flexural strength is the material's ability to resist deformation under load (static or cyclic) or the highest stress experienced within the material at its moment of rupture.[15]

Flexural strength of a denture base resin is important; therefore, many approaches have been used to strengthen it. Commonly there are three ways to improve the mechanical properties of PMMA: replacing PMMA with an alternative material (thermoplastics polymers) such as nylon e.g. polycarbonates and polyamides; chemically modifying it by adding rubber phase like butadiene styrene; and reinforcing the PMMA with other materials like fibers, oxides, inserts and wires. Some of the resin materials from such developments exhibit an enhanced impact strength and flexural strength.[16]

As far as the substitution of PMMA is concerned, various polymer substitutes such as vinyl acrylic, polystyrene and acrylic styrene were tried. However, most of them resulted in dentures with poor accuracy, high cost, and disappointments from the patients. As a substitute for PMMA, Polycarbonate has been used quite successfully to produce dentures with increased strength and good clinical performance; but it has to be injection molded and therefore it requires more complex processing technique and equipment which increases the fabrication cost.[18]

Reinforcement of PMMA has also been tried through chemical modification to produce graft co-polymers of rubber methacrylate, also known as high impact resin. The objective of the high impact resin is to absorb greater amount of energy at a higher strain rate before fracture than the standard resin. By contrast, this material has comparatively low flexural strength & long-standing fatigue failure. Moreover, the high costs of these materials restrict their widespread use.[20]

CONCLUSION

Within the limitations of this in vitro study, the following conclusions can be drawn:-

1. It was found that flexural strength increased with increase in particle size (5-25μ) of aluminum oxide.

2. Also, it was found that 10% concentration of aluminium oxide gave the highest flexural strength, thus it can be concluded that flexural strength increases as the concentration increases from 5 % to 10% and then decreases on further increase in concentration.

Thus, it can be concluded that 10% wt of 25-micron aluminium oxide increases the flexural strength of PMMA significantly.

The search for still higher strength polymer continues, as high strength polymers would allow dentist to fabricate removable dentures in thin sections, which would enhance patient's acceptance of the prosthesis.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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