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Comparative Evaluation of Strength of Flexible Denture Base Material: In Vitro Analysis

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ABSTRACT

Background: To compare and evaluate the flexural strength, flexural modulus, impact strength and hardness between three injection-moulded flexible denture base materials and a conventional compression heat polymerized acrylic denture base material.

Materials and methods: Two injection-moulded flexible denture base materials were investigated in this study - Valplast, and iFlex. A conventional compression-moulded heat polymerized PMMA was used as a control. With the help of machine-made aluminium dies of dimensions 65 x 10 x 3.5 mm, 20 specimens were fabricated for each type of denture base material and divided into 3 groups; Group 1 - Valplast; Group 2 - iFlex and Group 3 - Acralyn-H. The specimens were further subdivided into 2 groups containing 10 specimens each for evaluating flexural strength and hardness, respectively. Prior to testing, all the specimens were stored in artificial saliva at room temperature for 50 hours. The data obtained were subjected to a one-way analysis of variance (ANOVA).

Results and Conclusion: Polymethyl methacrylate (acrylic resin) in the field of prosthetic dentistry is the most indispensable and versatile material. Results showed that all the three flexible denture base materials had significantly lower flexural strength compared to the control PMMA. The Vickers hardness test of Valplast, IFlex and iFlex exhibited lower values and showed that the rigidity of these materials was inferior to the conventional PMMA but comparable with each other. Thus, it was observed that each of the materials possessed moderately similar and/or differing properties.

Keywords: Flexible Material, Flexural Strength, Hardness, Denture Base.

INTRODUCTION

Loss of teeth is a matter of great concern to a majority of people worldwide. The replacement of the lost teeth by artificial substitutes such as complete and partial denture prostheses is imperative to the continuance of normal life. Over the years, several types of denture base materials have been used for denture fabrication. The aim has always been to replace or restore the lost or damaged tooth structure to satisfy both the aesthetics and functional requirements.[1] Thus, an ideal denture base material must have sufficient strength and rigidity, be biocompatible, have good aesthetics, be easy to handle and allow the minimal

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release of residual compounds in order to serve for a reasonable length of time.[2, 3]

Polymethyl methacrylate (PMMA), since its introduction in 1937, is still the most commonly used material for denture fabrication due to its easy processing, accurate fit, adequate strength, superior aesthetics, low water sorption, low toxicity and stability in the oral environment.[4] Nonetheless, drawbacks such as polymerization shrinkage, residual monomer allergy, weak flexural strength, lower impact strength and low fatigue resistance created a need to invent another material which could overcome these limitations and have better properties. Thermoplastic resin or flexible denture base material was one such invention, in the 1950s, that had the potential to be used as an alternative to conventional PMMA.[5] Its improved properties and flexibility are perfectly suited to a variety of natural conditions in the mouth, simplifying the design and enabling the resin to act as a built-in stress breaker that provides superior function and stress distribution.[6]

Over the centuries, a variety of materials have been used for denture construction. The historical developments of these materials have to lead it to the times when the dentures were carved from stone, ivory, bone and wood to the latest polymers.[7] The ideal denture base material should possess several key attributes, like biocompatibility, good esthetics, high bond strength with available denture teeth, radio-opacity, ease of repair, and should possess adequate physical and mechanical properties. The flexibility of the material also allows the shifting of the burden of force control from the design features of the appliance to the material properties of the base material.[8] This led to their usage in special circumstances where increased flexibility, higher resistance to flexural fatigue and high impact strength is a requisite as in unyielding undercuts, pronounced tuberosities, tori and bulging alveolar ridges. It is also considered in patients who are allergic to monomer as it has very little or almost no free monomer and in whom aesthetics is the main concern.

At present, flexible denture base materials are predominantly used for the Fabrication of removable partial dentures (RPDs) in patients with severe undercuts or as a solution to overcome the esthetic problems caused by the visibility of the metal clasps.[9] Yet, their use is limited in clinical practice because not much information is provided by the manufacturers. In addition, due to fewer studies, not enough data is available in the literature regarding the properties of these materials and their potential for denture base construction in comparison to conventional acrylic resin. Therefore, the purpose of this in vitro study was to evaluate and compare the mechanical properties such as the flexural strength and hardness of three commercially available injection-moulded flexible denture base materials with the conventional compression moulded thermal polymethyl methacrylate denture base material.

MATERIALS AND METHODS

The present study was conducted to assess the flexural strength, flexural modulus, impact strength and hardness between three commercially available injection-moulded flexible denture base materials and a conventional compression-moulded heat polymerized acrylic denture base material.

Methodology

Two commercially available injection-moulded flexible denture base materials were selected for this study: Valplast, and iFlex. Control group was used as conventional compression-moulded heat polymerized polymethyl methacrylate (PMMA). Based on the type, the selected materials were divided into three groups.

Three rectangular-shaped aluminium dies measuring 65 x 10 x 3.5 mm were fabricated for making specimens to test the flexural strength and hardness. Similarly, three rectangular-shaped aluminium dies of dimensions of 50 x 6 x 4 mm were made for preparing specimens for impact strength.

Preparation of specimens

a. Fabrication of flexible denture base material specimens using an injection moulding technique

Using the fabricated aluminium dies of dimensions 65 x 10 x 3.5 mm and 50 x 6 x 4 mm, condensation silicon moulds were prepared. Wax patterns of specimens were prepared in these moulds. The wax patterns were then invested in the lower part of the specially designed flask for injection process using dental plaster (White gold, Asian chemicals, India). The plaster was allowed to set, and a wax sprue was attached to the side of the wax patterns to serve as an inlet for the flow of the material. A thin coat of separating medium (Cold Mould Seal, Dental Products of India, Mumbai) was painted on the investment, and the upper portion of the flask was positioned over the lower portion. Subsequently, type III dental stone (Goldstone, Asian chemicals, India) was poured till the top, and the lid of the flask was pressed into place. When the stone investment had set, the flask was placed in boiling water for 4 to 6 minutes for de-waxing.

Following this, the flask was opened, and the residual wax was flushed out with boiling water. A thin layer of separating medium was applied to the mould space and allowed to dry. The cartridge of the injecting material was sprayed with silicone and inserted into the pre-heated electric cartridge furnace using a cartridge sleeve. The material was melted as per the manufacturer's instructions. The two halves of the flask were assembled, fastened with screws and positioned under the press of the injection unit. After the meeting time, the heated cartridge was withdrawn from the furnace and placed in proper alignment over the flask.

The levers of the press were turned rapidly, applying firm pressure for 3 to 5 minutes to compress the cartridge. The soft, fluid material was forced into the flask. Thereafter, the pressure was relieved, and the flask was disengaged and allowed to bench cool for 15 to 20 minutes. After bench cooling, the flask was opened, and the specimens were retrieved. Any gross irregularities were corrected, and sprues were removed using tungsten carbide burs (DFS, Germany). In this manner, a total of 90 specimens were fabricated for each type of injection moulded flexible denture base materials.

b. *Fabrication of heat cured acrylic denture base resin specimens using a compression moulding technique*

Using the fabricated aluminium dies of dimensions 65 x 10 x 3.5 mm and 50 x 6 x 4 mm, condensation silicon moulds were prepared. Wax patterns of specimens were made in these moulds. The wax patterns were then invested with dental plaster in the regular brass denture flask. De-waxing was carried out with boiling water to obtain plaster moulds. A thin layer of separating medium was applied to the mould space. The mould was packed with heat cure acrylic resin, proportioned and manipulated according to the manufacturer's instructions. The flask was closed tightly and placed under 1500 psi pressure using a hydraulic bench press to force the material into the mould. Two trial closures were carried out to remove the excess material followed by the final closure.

After the final closure, the flask was placed in the traditional clamp and allowed to bench cure for 30 minutes at room temperature. Following bench curing, the clamped flask was immersed in an acrylizer containing water at room temperature. The material was heat cured or polymerized with short curing cycle, i.e. 74o C for 90 minutes and at 100o for 30 minutes. The flask was left to cool to room temperature, after which the specimens were retrieved from the flask, trimmed, finished and polished in the same way as flexible denture base material specimens. In this manner, 30 specimens were prepared for compression-moulded heat cured acrylic denture base resin.

Grouping of specimens

A total of 60 specimens were fabricated, which were divided into 3 groups with 20 specimens for each type of denture base material. The specimens were further subdivided into 2 groups containing 10 specimens each for evaluating flexural strength and hardness, respectively. All specimens were stored in artificial saliva at room temperature for 50 hours and were subjected to testing immediately after removal from the artificial saliva without drying. Specimens were labelled on each end before testing so that fractured pieces could be reunited.

Testing of specimens

a. Flexural strength testing

The flexural strength of the specimens was measured with a computerized universal testing machine using a 3 point bending test. Each specimen was placed on two supporting wedges separated by a span of 50 mm. A vertical load was applied from zero at the midpoint of the specimen at a crosshead speed of 5 mm/min until it fractured. The values were recorded and the flexural strength and flexural modulus were computed using the formula;

Flexural strength (S) = 3PL / 2bd2

Where, S = Flexural strength, P = maximum load exerted or load at fracture (N), L = span distance (50 mm), b = width of the specimen (10 mm), d = height/thickness of the specimen (3.5 mm).

Flexural modulus (E) = FL3 / 4ybd3

Where, E = flexural modulus, y = deflection corresponding to load F, F = maximum load exerted or load at fracture (N), L = span distance (50 mm), b = width of the specimen (10 mm) and d = thickness of specimen (3.5 mm).

b. Hardness testing

The surface hardness of the specimens was determined using the Vickers hardness tester. The testing was conducted using a load of 25g with a 30 sec contact time on the polished surface of the specimen. Two measurements were made on each specimen along a straight line, and an average of two readings was calculated as a final surface hardness value for the specimen. The values were recorded, and the hardness was computed using the formula;

VHN = 1.854 F / d 2

Where, 1.8544 is a constant geometrical factor for the Vickers pyramid, F = Load in Kgf, d = Length of the diagonals in mm. The results of each test were tabulated and statistically analyzed by one-way analysis of variance (ANOVA)

RESULTS

The aim of the vitro analysis was to evaluate and compare the mechanical properties such as the flexural strength and hardness of three commercially available injection-moulded flexible denture base materials with the conventional compression moulded thermal polymethyl methacrylate denture base material.

To check the flexural strength, the mean strength was calculated in each of the groups. The mean flexural strength in group 3 was found to be highest as compared to group 1 and group 2. In between group 1 and 2, a specimen of group 2 had more strength as compared to group 1. The difference in mean flexural strength was found to be statistically significant between Group 1 (Valplast) and Group 2 (iFlex) (P<0.05), Group 1 (Valplast) and Group 3 (Acralyn-H) (P<0.05), as well as Group 2 (iFlex) and Group 3 (Acralyn-H) (P<0.05).

Table 1: Comparison of flexural strength between different groups.

Group comparison	Flexural strength difference	P value
Group 1 & Group 2	- 12.30	< 0.005
Group 2 & Group 3	- 17.30	< 0.005
Group 1 & Group 3	- 3.85	< 0.005

The hardness measurement was done on the blocks of the group. The highest value of hardness was measured in group 3 as compared to group 1 and group 2. The difference in mean hardness was found to be statistically significant between Group 1 (Valplast) and Group 3 (Acralyn-H) (P<0.05). The difference in mean hardness was not found to be statistically significant between Group 1 (Valplast) and Group 3 (iFlex) (P=0.772).

DISCUSSION

Polymethyl methacrylate is still a popular choice of material for the Fabrication of denture bases. It is rigid, easy to use, easy to repair, offers good aesthetics, is relatively inexpensive and readily available.[4] However, due to its rigidity, it may not be a suitable option for the management of partially edentulous patients with challenging conditions such as severe soft/hard tissue undercuts, multiple paths of placement, tilted teeth and deranged occlusion, unexplained repeated fracture of dentures, compromised aesthetics caused by visible metal clasps and in those who have an allergy to monomer.[10, 11]

Flexible denture base materials or thermoplastic polymers were first introduced to dentistry by the name of Valplast and IFlex in the 1950s. These belong to the class known as polyamides and nylon is the generic name used for these types of thermoplastic polymers.[11] The material, however, has evolved over the years from a nylon-based to a more modern polyolefin thermoplastic polymer. Under high heat, these granules will soften and change shape (thermoplastic) so that it can be injection-moulded. The prostheses thus fabricated have got various advantages over the traditional rigid denture bases. They are unbreakable, flexible and do not warp or become brittle. They are thin, lightweight and resistant to fracture. The material's natural flexibility allows free movement of the prosthesis such that it can easily pass by the soft and hard tissue undercuts.[12]

During mastication, a denture base material is subjected to flexural deformation. Flexural strength (FS) is a measure to assess the resistance of a material to flexural deformation or fracture. It is basically a combination of compressive, tensile and shear strengths, all of which directly reflect the stiffness and resistance of a material to fracture.[13]

All the materials tested fractured during the FS test. Among the three flexible denture base materials, IFlex was found to have the highest FS of 47.63 MPa followed by Valplast (31.7 MPa). Compared to PMMA (48.31 MPa), they had significantly lower FS. This was found to be in agreement with the previous studies where a reduced FS was associated with the nylon-based polymers. *Yunus et al.* [14] evaluated and compared some flexural properties of a nylon denture base material to other PMMA based denture polymers using various methods of processing and polymerization modes.[15]

The results of this study showed that IFlex (1.04 GPa) and PMMA (1.02 Gpa) exhibited a higher elastic modulus compared to the other materials and that IFlex had a modulus superior to PMMA (though not significant). *Pfeiffer et al.* found that the flexural modulus of a polyethene terephthalate denture base resin (thermoplastic) was higher than that of a conventional PMMA, which was in agreement with the present result. The flexural modulus of Valplast was observed to be the lowest with a value of 0.74 GPa, and iFlex showed a modulus of elasticity of 0.90 GPa. This suggested that Valplast was less rigid and more flexible when compared to the other groups. This was in agreement with that of the study conducted by *Hamanaka et al.*,[16] where valplast showed the lowest flexural modulus. *Yunus et al.* as well reported that the flexural modulus of polyamide denture base resin was lower than that of conventional PMMA, which was similar to the results of the present study. Studies by *Stafford et al. and MacGregor et al.* also indicated that nylon was more flexible than PMMA denture base polymers.[17]

In this study, the heat cure PMMA samples showed more microhardness values than flexible denture base materials. The mean hardness values of the flexible denture base materials arranged in descending order were: Valplast (6.05 VHN) > IFlex (5.14 VHN). PMMA (Acralyn-H) demonstrated the highest microhardness value of 17.15 VHN. When the groups were compared using Tukey's pairwise test, the differences were found to be statistically significant ($p<0.05$). These results were found to be in agreement with other studies which analyzed the hardness of thermoplastic resins. *Ucar et al.* [15] compared the hardness of a polyamide-based denture material (Deflex) with another injection-moulded PMMA based material and a conventional compression moulded PMMA.

Hence, clinicians should be well aware of the properties of flexible denture base materials in order to choose one that is appropriate for each patient. Moreover, though the surface roughness of flexible denture base materials is well within the accepted norm, prosthesis fabricated from these resins requires a level of maintenance far exceeding that of conventional PMMA. Thus, strict and careful follow-up evaluation of the patients rehabilitated with flexible prosthesis is recommended.

CONCLUSIONS

Polymethyl methacrylate (acrylic resin) in the field of prosthetic dentistry is the most indispensable and versatile material. Results showed that all the three flexible denture base materials had significantly lower flexural strength compared to the control PMMA. The Vickers hardness test of Valplast, IFlex and iFlex exhibited lower values and showed that the rigidity of these materials was inferior to the conventional PMMA but comparable with each other. Thus, it was observed that each of the materials possessed moderately similar and/or differing properties.

CONFLICTS OF INTEREST

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

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