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Original article

COMPARATIVE EVALUATION ON THE INFLUENCE OF DIFFERENT CURING CYCLES ON THE MECHANICAL PROPERTIES OF THREE COMMERCIALLY AVAILABLE DENTURE BASE RESINS: AN IN-VITRO STUDY

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ABSTRACT

Aim: The aim of the study was to evaluate and compare the influence of different curing cycles on the mechanical properties of three commercially available heat cured acrylic denture base resins.
Methodology: A total of 120 samples were fabricated with the help of a customized 3 piece aluminium mould. Three brands of heat-cured acrylic denture base resins (DPI, TREVALON, and VERACRIL) were selected for the study. These materials were polymerized using 2 different curing cycles – Short Curing Cycle (74^0C for 2 hours followed by 100^0C for 1 hour) and Long Curing Cycle (74^0C for 8 hours followed by 100^0C for 1 hour). The cured samples were then stored in water for one month to ensure full saturation. Once the immersion time had elapsed, each group of samples are subjected to a 3 Point Bending Test and Pendulum Impact Test. The data obtained were subjected to statistical analysis.
Results: The mean flexural strength and impact strength values of all 3 brands of commercially available denture base resins were higher in the long curing group when compared to the short curing group ($p < 0.05$). Trevalon heat-cured acrylic denture base resin was found to have superior flexural and impact strength values as compared to other two denture base resins when cured using long and short curing cycles.
Conclusion: The type of polymerization cycle played an important role in influencing the flexural and impact strength of heat cured acrylic denture base resin.

Introduction

The loss of teeth and associated structures by trauma or disease had plagued mankind throughout the ages. In order to re-establish a degree of function and appearance, it has been necessary, always to fabricate prosthesis by adapting to the contemporary materials that were available at that period of history.[1]

Before eighteenth-century materials like wood, bone and ivory were used for denture fabrication. Dentures were carved out of a single piece of wood and natural teeth were held to it with the help of screws. These materials posed aesthetic and hygienic concerns. Polymethyl methacrylate was introduced in 1937 by Dr. Walter Wright and since then it has been successfully used for the fabrication of denture bases and artificial teeth. In addition, it has many other applications in the field of aesthetic dentistry. It has excellent aesthetic properties, adequate strength, low water sorption, low solubility, lack of toxicity and can

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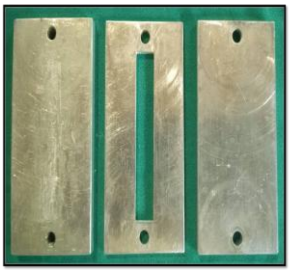

Figure 1: Customized 3 piece Aluminium mould

Figure 2: Samples obtained after Long and Short Curing Cycles

be constructed by simple moulding and processing technique.[2,3]

Mechanical properties including flexural strength and impact strength are affected by the processing technique. Flexural strength is especially important since acrylic resin prosthesis is susceptible to fracture over long periods of clinical use.[4] The two variables, time and temperature are important in the curing of heat cured acrylic denture base resins. Curing cycles that last more than six hours, with or without a terminal boil are found to have lower residual monomer leading to its improved mechanical properties. Polymerization using longer curing cycles with a terminal boiling point resulted in almost complete conversion of monomer which significantly improved the flexural and impact resistance.[5-7]

Shorter curing cycle of about 74^0C for 2 hours with a terminal boiling was introduced to shorten the polymerization process as it saved considerable laboratory time. Porosity and high residual monomer content were found to be a frequent problem with this curing cycle.[8] Residual methyl methacrylate concentration is found to be high, if the polymerization process is incomplete or if the terminal boiling is avoided in the polymerization process. This residual methyl methacrylate leaches out from the denture base resin and is the cause for adverse effect on the oral mucosa.[5] Polymerisation cycle that includes a terminal boiling period is preferred, as almost complete conversion of monomer is achieved.[9]

Long curing cycle of 8 hours at 74^0C with a terminal boiling for 1 hour and a short curing cycle for 2 hours at 74^0C with a terminal boiling for 1 hour was proposed for this study. Thus, the aim of this study was to evaluate and compare the effect of two curing cycles on the mechanical properties of three commercially available brands of heat cured acrylic denture base materials.

MATERIALS AND METHODS

This comparative in-vitro study involved a total of 120 samples consisting of 12 groups, each with 10 samples. Three brands of heat-cured acrylic denture base resins (DPI, TREVALON, and VERACRIL) were selected for this study. These materials were polymerized using 2 different curing cycles – Short Curing Cycle (74^0C for 2 hours followed by 100^0C for 1 hour) and Long Curing Cycle (74^0C for 8 hours followed by 100^0C for 1 hour).

A customized 3 piece aluminium mould of dimensions 64 mm long, 10 mm width and 3.3 mm height (BS EN ISO 1567:2001) was fabricated [Figure 1]. Two screws present at the corners of the mould helped in assembling the 3 pieces. This customized mould helped in the fabrication of polyvinyl siloxane strips. Polyvinyl siloxane putty material was adapted to the mould space and fastened by the screws. The material

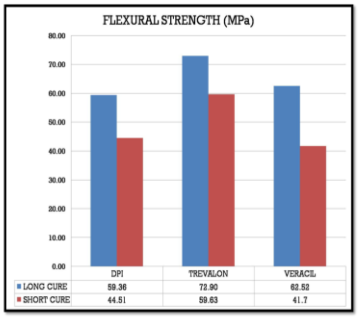

Figure 3: Mean Flexural Strengths (MPa) values of test materials after Long Curing Cycle and Short Curing Cycle

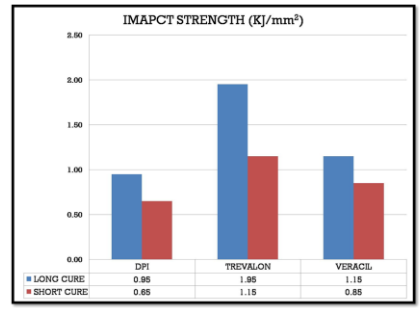

Figure 4: Mean Impact Strengths (KJ/mm^2) values of test materials after Long Curing Cycle and Short Curing Cycle

was allowed to set and excess material was cut off. The dimensions were cross-checked using a vernier calliper.

Type II dental plaster was mixed according to manufacturer's instructions and the polyvinyl siloxane strips were then placed on the partially set plaster in the base of the flask. The body of the flask was placed into position on the base and care was taken to see that no plaster remained on the rim as this could prevent complete seating of the two halves of the flask. Two coats of the cold mould seal were painted on the plaster surface of the base of the flask and were then allowed to dry. With the body in position, the flask assembly was then kept on a vibrator. Type II dental plaster was then mixed and poured to fill the body and the lid were placed and tapped to ensure that the flask was completely filled. After 30 minutes the flask was opened and the polyvinyl siloxane strips were removed, and two coats of the cold mould seal were applied into this mould space.

The polymer and monomer were mixed in a ratio of 3:1 by volume in a ceramic mixing jar. When the dough stage was reached, it was kneaded thoroughly and packed into the mould space. The flask was then closed and kept under bench press for one hour. Then it was transferred by a conventional clamp and immersed in an acrylizer. The same procedure was followed for all the 3 brands of heat polymerizing acrylic denture base resins respectively. The long curing group includes 60 samples and the curing procedure involves, keeping the samples at 74^{0}C for 8 hours followed by a terminal boil for 1 hour in the water bath. 60 samples were included in the short curing group and these were polymerized at 74^{0}C for 2 hours followed by a terminal boil for 1 hour. After curing, it was allowed to bench cool slowly from water bath temperature to room temperature for three hours. The flask was opened and the samples were retrieved and hand finished using a 320 grit silicone paper to a final dimension of 65 ± 0.2 mm in length, 10 ± 0.2 mm in width and 3.3 ± 0.2 mm in height [Figure 2]. The finished samples were then stored in water for one month to ensure full saturation. Once the immersion time had elapsed, each group of samples are subjected to a 3 Point Bending Test (MPa – Mega Pascal) and Pendulum Impact Test (KJ/mm^2 – Kilojoule per square millimeter). The data obtained from the test results were tabulated and subjected to statistical analysis using Independent-*t*-test and ANOVA (Analysis of Variance) after adjusted for multiple comparisons using Bonferroni Correction. Statistical tests were carried out using SPSS 21.0 (Statistical Package for Social Science; IBM Statistics, 2012) for which the level of significance was fixed at 5%.

Table 1: Comparison of Flexural strengths (MPa) between DPI, Trevalon and Veracril after Long and Short Curing Cycle

Long Curing Cycle			
Materials		Mean Difference	*p*-value
DPI	TREVALON	13.54	< 0.001*
	VERACRIL	3.16	0.140
TREVALON	VERACRIL	10.38	< 0.001*
Short Curing Cycle			
DPI	TREVALON	15.12	< 0.001*
	VERACRIL	2.81	0.075
TREVALON	VERACRIL	17.93	< 0.001*

p-value based on ANOVA (Analysis of Variance) after adjusted for multiple comparisons using Bonferroni Correction

* = Statistically Significant ($p < 0.05$)

Table **2:** Comparison of Impact Strengths (KJ/mm^2) between DPI, Trevalon and Veracril after Long and Short Curing Cycle

Long Curing Cycle			
Materials		Mean Difference	*p*-value
DPI	TREVALON	1.00	< 0.001*
	VERACRIL	0.20	0.33
TREVALON	VERACRIL	0.80	< 0.001*
Short Curing Cycle			
DPI	TREVALON	0.50	< 0.001*
	VERACRIL	0.20	0.23
TREVALON	VERACRIL	0.30	< 0.030*

p-value based on ANOVA (Analysis of Variance) after adjusted for multiple comparisons using Bonferroni Correction

* = Statistically Significant ($p < 0.05$)

RESULTS

Long curing group showed maximum mean value when compared to short curing group in terms of flexural strength ($p < 0.001$) [Figure 3] and impact strength ($p < 0.05$) [Figure 4]. There was a statistically significant difference in the flexural strength (Table 1) and impact strength (Table 2) in long and short curing groups between DPI – TREVALON and TREVALON – VERACRIL group, but no statistically significant difference was found between DPI – VERACRIL group.

DISCUSSION

Polymethyl methacrylate resins are extensively used as the material of choice for the fabrication of removable complete and partial dentures. It continues to be the material of choice for denture fabrication because of its acceptable dimensional stability, ease of processing, low water sorption, the accuracy of fit and improved aesthetics.[10,11] Poor resistance to force of impaction, bending and fatigue are few of the inherent drawbacks of this material making them susceptible to failure due to fracture.[12]

Fractures in denture result from two different types of forces, impact and flexural fatigue. Repeated flexing from chewing ultimately fatigues majority of dentures in the mouth, thus, the resin should have a good ability to resist plastic deformation within the oral cavity.[13] Acrylic resins capable of sustaining high flexural strength and impact strength are thus less prone to clinical failure.[14] Flexural strength of a material is a combination of compressive, tensile and shear strength. As the tensile and compressive strengths increases, the force required to fracture the material also increases.[15]

There are various factors that can affect the mechanical properties of the polymerized resin. According to Harrison and Huggett (1992)[16], long water bath cycles without a terminal boil showed approximately 3 times higher values of residual monomer, when compared to long curing cycle with a terminal boil. Acrylic resin cytotoxicity is associated, with the presence of residual monomer after the polymerization process. Residual monomer can induce changes in basic cell structure and function, loss of membrane integrity, alteration of enzyme activities and synthesis of macromolecules, reduction of antioxidants, cessation of cell growth, reduction of viability and inhibition of cell proliferation and differentiation, gene mutation, delay of cell cycle, induction of cell apoptosis and necrosis.[5]

Bural C et al (2011)[4] evaluated different polymerization cycles of heat polymerized resins and observed an increase of methyl methacrlylate residual monomer in specimens that were not immersed in water. Residual monomer content was minimal when the resin was immersed in room temperature water for a period of 7 days. However, the flexural strength decreased when the acrylic resin was immersed in water for a period of about 30 days or more. Water has a plasticizing effect on the resin thereby leading to its fracture under loading.[17]

Polymerization temperature and time can affect the leaching concentrations of residual methyl methacrlylate.[18] The residual monomer could affect the flexural strength because of a plasticizing effect, which effectively reduces the interchange forces. Consequently, deformation occurs more easily under load.[19] The polymerization reaction never reaches 100% conversion and monomers remain free within the denture base material which leaches into the oral cavity. Modifying the parameters – Time and Temperature could reduce the undesirable effect of unreacted methyl methacrlylate.[20] Higher values of mechanical properties were also achieved by the use of a long curing cycle with a terminal boiling. Porosity in an acrylic resin denture base is often attributed to the presence of residual monomer.[21] Beech DR (1975) indicated that residual monomer causes three principle effects: porosity, dimensional change through stress relief, and decreased physical properties.[22]

Studies have shown that porosity leads to slow influx of oral fluids through the acrylic resin and foul odours develop from the stagnation of oral fluids in these voids.[23] With regard to hygiene, the denture must be nonporous in order to resist staining, calculus deposition, and adherent substances.[24] A spongy denture tissue surface, full of nutritive substances, is an ideal incubator for species such as Candida Albicans.[25] The thickness of the prosthesis also has an effect on porosity. No porosity was found in the conventional long curing cycles in acrylic resin thickness of up to 19.5 mm. Short curing cycle should not be used for a long-term prosthesis or those requiring a thickness of more than 6 mm.[26] Jerolimov V et al (1989)[27] reported that occurrence of porosity is dependent on the rate of polymerization and the efficiency of heat dissipation. If the rate of polymerization is too high then the heat generated cannot be dissipated quickly enough, especially in the thicker regions, which causes local vaporization of monomer and gaseous porosity in the denture.

The conducted study showed that the mean flexural strength and impact strength for all three materials tested using the long curing showed higher flexural strength values which were statistically significant. These results were in concordant with previous studies done by Harrison A and Huggett R (1992).[16] Studies done by Athar Z (2009)[9] and Dixon DL (1991)[17] also supports the results on the high values of flexural strength obtained in the present study. These values indicate high flexural strength values were associated with samples cured with long curing cycles in comparison with short curing cycles. Out of three materials tested, Trevalon had the highest mean flexural strength of 72.9 MPa followed by Veracril (62.52 MPa) and DPI (59.36 MPa). There was no statistically significant difference observed in flexural strengths between DPI and Veracril group. There was a statistically significant decrease in the flexural strength values among all the three materials after short curing cycles.

Removable dental prostheses are susceptible to high impact extra-oral forces when the prosthesis is accidentally dropped. The stress concentration generated in the denture base acrylic resin can initiate or propagate existent cracks, thereby influencing the failure rate. To compensate for these problems, the ability of the material to withstand the presence of notches and crack propagation is an important factor affecting denture performance.[28]

Impact strength values of the short curing group in the present were study found to be inferior to that of the long curing group. Out of three study groups tested Trevalon (1.95 KJ/mm^2) was found to have higher mean impact strength value, followed by Veracril (1.15 KJ/mm^2) and DPI (0.95 KJ/mm^2). There was no statistically significant difference in the impact strength between DPI and Veracril. The improved mechanical properties of Trevalon may be due to the variations in the concentrations of initiator and cross-linking agent present when compared to DPI and Veracril. These results were in concordance with the results of the study conducted by Jadhav R (2013).[29] Study conducted by Foat F (2006)[28] stated that addition of cross-linking agents to the monomer improves its impact strength. Jerolimov V (1969)[30] observed that sharp contours present in the prosthesis may act as an area of stress concentration and also stated that acrylic resin processed by long curing with a terminal boil was found to have higher mean impact strength values due to greater degree of monomer conversion which supports the results of the present study.

Although the use of long polymerization cycle is time-consuming, it results in a prosthesis with improved flexural strength and impact resistance as compared with the use of short polymerizing cycle. Residual methyl methacrylate monomer content was found to be significantly less in the prosthesis polymerized using the long curing cycle with a terminal boil due to its complete conversion, thus being more biocompatible with the oral mucosa.

CONCLUSION

The following conclusions were drawn at the end of the presently conducted study:

1. The type of polymerization cycle plays an important role in influencing the flexural and impact strength of heat cured acrylic denture base resin.
2. The long curing cycle produced denture base resin with highest flexural and impact strength values.
3. Out of three study materials used, Trevalon was found to have superior flexural and impact strength values in both long and short curing cycles.

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