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Effect of Storage Media on the Flexural Strength of Heat and Self Cure Denture Base Acrylic Resins – An Invitro Study

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ABSTRACT

Various dental prostheses and appliances show failure due to fatigue that is inherited as a result of decreased flexural strength. They need to function in wet environments like saliva and during non function, they need to be stored in water. This study was aimed to assess the influence of water sorption on flexural strength of two heat and self cure denture resins and to evaluate any difference between storage in artificial saliva and water on its flexural strength. A digitally designed stainless steel die was used to fabricate molds for making samples from heat cure (Trevalon HI, Colto Cure H) and self cure (Colto Cure C,Dentsply RR) denture base acrylic resins. Samples were tested immediately after processing (Group (GP) A – control), immersed in water (GP B) and artificial saliva (GP C). After storage of samples at four different time intervals (1 day, 1 week, 2 months, 4months), flexure test was performed on a universal testing machine. Various levels of variables were tested using Kruskal -Wallis H test ($p<0.001$) while differences between groups was tested using Mann Whitney test ($p<0.05$). Trevalon demonstrated highest dry strength. All samples demonstrated decline in flexural strength with heat cure showing less than self cure denture base resins. Reduction of flexural strength observed at 2 and 4 month time, showed a statistical difference between groups. Reduction of flexural strength was also significant when self cure resins were stored in artificial saliva. Flexural strength tends to decrease as water sorption within the denture polymer increases. Both saliva and water show pronounced effect on flexural strength.

Keywords : water sorption, flexural strength, acrylic resin, saliva, polymethylmethacrylate

Introduction

The current practice of using synthetic resins in constructing dental prosthesis and appliances started in 1937 and still continues to make significant contributions in patient rehabilitation especially completely edentulous patients. The resin type most commonly used in the fabricating denture prosthesis is the polymethyl methacrylate which is available commercially as powder and liquid form. when mixed and processed under specified conditions, the material becomes hard but

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with a relatively low flexural fatigue resistance [1]. While, most commonly, dentures tend to fracture due to sudden impact (falling from hand on hard floor), the failure which is as a result of low flexural strength occurs as a result of prolonged denture use [2]. Clinically, it presents as the midline fracture of the denture (mostly maxillary) that occurred while in use and with no history of previous fall. The flexural fatigue failure that results in a midline fracture of the denture results as a result of repetitive stress, which can be either low or suddenly become high to very high [3]. The changes in stresses are directly related to the amount of bone resorption that takes place under the complete denture prosthesis. With bone resorption, the denture movements increase vertically towards the tissue in the midpalatine area becoming a fulcrum where forces from either side concentrate leading to a flexural fatigue failure that is initiated by cyclic deformation of the base and it commonly occurs in the midline [4].

While bone resorption is inevitable irreversible outcome of wearing complete denture prosthesis, most of the attempts have been mainly focussed on improving the flexural fatigue strength (FFS) of the polymer. Methods like minimizing stress intensification in the midline of the denture [5], use of alternative resins like grafted resins [6], light cure resins, incorporation of reinforcement fibers (aramid, nylon, kevlar, polyethelene) [7-10], and use of repair resins [11]. Earlier studies also saw a shift towards the possible role of water sorption since various studies reported deterioration of properties of denture base resin due to the effects of absorbing water [12], [13]. With advances in both heat cure and self cure denture base resins and refinements of simulating oral conditions like newer formulations of artificial saliva, this study was objectively aimed to analyze the influence of water sorption on the flexural strength of two different denture bases acrylic resins (heat cure and self cure) over both short term and long term time periods. The study would also analyze the individual influences of water sorption on each material and determine the differences between the materials.

Methodology

Ethics and study design: This comparative invitro study was conducted between the December 2019 and June 2019. The study was conducted in one of the recognized dental college of north india, affiliated to a recognized university, as part of post graduate requirement. The ethical approval for conducting the study was obtained by the ethical committee of the college/university. The study was accomplished in three different stages. First stage involved fabrication of die in terms of dimensions, material and design. Second stage included preparing and storing of the specimens followed by the last stage of specimen testing and data collection.

Sample preparation, storage and grouping: Four commercial and commonly used denture base resins, 2 heat cure (Trevalon HI, Colto Cure H) and 2 self cure (Dentsply-RR, Colto Cure) were selected for this study. All samples were to be stored in groups in two different immersion media, commercially available artificial saliva and distilled water [14]. A stainless steel die was machined utilizing computer designing and cutting. Metal strips of the dimensions: length (60mm) x breadth (10mm) x thickness (5mm) were coated with separation media and invested in large denture flasks (Hanau, USA) using, the type 3 dental stone (Elite Model; Zhermack, Badia Polesine, Rovigo, Italy). Once the investing material was set, the flasks were opened and the metal strips removed, thus leaving a mold for preparing test specimens of various denture base resins. The manufacturer's recommendation was strictly adhered for all four types of denture base resins. For heat cure denture base resins, the test specimens were processed using the short cycle (74°C for 2 hours followed by 100°C for 1 hour). The chemical cure denture base material was packed and processed in a pressure pot at 30 psi pressure for 30 minutes. In total, 180 test

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specimens were prepared, finished and polished like conventional denture base resins are done. All samples were further divided into three groups, namely Group (GP) A (dry weight) (control), GP B (distilled water) and GP C (artificial saliva). The samples in GP A were 20 (5 for each four resin types) while the other two groups had 80 samples each [(5 for each resin type for 4 different time intervals (1 day, 1 week, 2 months, 4months)]. All the samples were placed in their respective immersion media in controlled temperature of 37 degrees centigrade.

Testing of the specimens: All wet samples were first air dried before undergoing the flexure test. Each specimen was mounted on a custom jig that secured it firmly at its ends while a three – point flexural test was carried out by loading the center of each sample at 5mm per minute crosshead speed using a digitally controlled universal testing machine (FIE Digital HGFL). The specific reading at which each specimen in the concerned group fractured was noted automatically within the machine. The procedure was repeated for all specimens in all three groups. The values of the fracture load were calculated in kg/meter square. To calculate the flexural strength the formula used was $3PI/2BD^2$ (where P = fracture load, I = distance between the supports, B = width of the specimen, D = thickness of the specimen).

Data Analysis

Collected data were evaluated, refined and finally summarized before coding them for statistical analysis. Since the independent variable in this study had more than two levelpairwise comparison was tested by Kruskal -Wallis H test while the differences between two independent groups was tested by Mann Whitney test ($p<0.05$). Statistically significant differences between the means of the studied groups were calculated by one way analysis of variance (ANOVA) test. Values of p were considered to be statistically significant at the values of $p<0.001$.

Results

The results of the flexural fatigue strength test were calculated in terms of the mean (average of all samples in particular subgroups within a group). Results show that the flexural strength of two heat cure (91.6 to 103) denture base resins were comparatively higher than the self cure (58 to 64) denture base resins when tested immediately which served as GP A (control).Less change in term of change in flexure strength after water sorption at 1 day was observed in heat cure samples of GP C (saliva) (Colto Cure H) while all samples in other subgroups of the same group demonstrated less decrease in FS than the samples in GP B (water) **(Table 1)**. Within the heat cure specimens, the samples that were stored and tested after 2 and 4 months, respectively demonstrated statistically significant differences in FS when compared with the control group (GP A). Although there was a decrease in the mean FS among other subgroups, none demonstrated statistically significant differences ($p<0.001$). However, within the self cure group samples in both groups at the time interval of 1 week, 2 and 4 months showed statistically significant differences when compared with the control group. For heat cure resins, the effect of the storage medium (saliva or water) does not seem to affect its FS. Only Trevlon HI samples of subgroup (2 month) demonstrated differences that were statistically significant ($p<0.05$). However, the samples of subgroup 1 week, 2 and 4 months for self cure material (Colto cure C) showed statistically significant differences between GP B and GP C while the other material (Dentsply RR) showed differences only that of 1 week samples. Irrespective of the medium in which the denture base resin was stored, results show that the FS decreased with time. The reduction in FS is gradual and is more pronounced within the first week **(Graph 1 and 2)** while the reduction of FS declines in term of intensity. On average a decrease of approximately 2 Mpa

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decline in, FS was observed among all groups at designated time intervals. The only exception being that of heat cure resins at 1 day intervals where there was minimal reduction of FS.

Table 1: Comparative Flexural strength and their relative differences in means of various denture base resins at various intervals of time immersed in water and artifical saliva.

		Heat cure		Self cure	
		Trevalon HI	Colto Cure H	Colto Cure C	Dentsply RR
Control (Gp A)		103.88 ± 3.01	91.66 ± 2.51	58.33 ±2.08	64.33 ± 1.52
Gp B (Distilled water)	1 day	102.0 ± 3	90.5 ± 2.78	56.33 ± 2.08	62.66 ± 1.52
	1 week	99.66 ± 2,51	88.66 ± 3.51	53.33 ± 1.52*¤	60. 66 ± 1.53*¤
	2 months	97.33 ± 2.67*¥	86.01 ± 2.88*	51.0 ± 1.13*µ	58.67 ± 1.18*
	4 months	96.33 ± 2.28*	85.00 ± 1.89*	50.33 ± 1.23*€	58.00 ± 1.13*
Gp C (Saliva)	1 day	103.66 ± 4.04	91.33 ± 2.78	56.83 ± 1.61	63.16 ± 2.02
	1 week	101.66 ± 3.51	89 ± 2.64	54.66 ± 1.52*¤	61 ± 2.08*¤
	2 months	99 ± 3.6*¥	87.01 ± 2.64*	52.67 ± 1.52*µ	59 ± 2*
	4 months	97.66 ± 4.16*	86.33 ± 3.05*	52.33 ± 1.52*€	58.3 ± 1.52*

All means are in terms of Mpa (mega pascals)
Levels of significance:
* Significance of the differences when the mean were compared with the control (dry weight). Values were considered to be significant when the value of $p<0.001$
¥, ¤, µ, € indicates significant differences observed between specimens of subgroups (time interval) within different groups [Water (Gp A) and saliva (Gp B)] . Differences were considered to be significant when the value of $p <0.05$

Graph 1: Comparison of Mean Flexural strength among four denture base resin materials at different time intervals when immersed in water.

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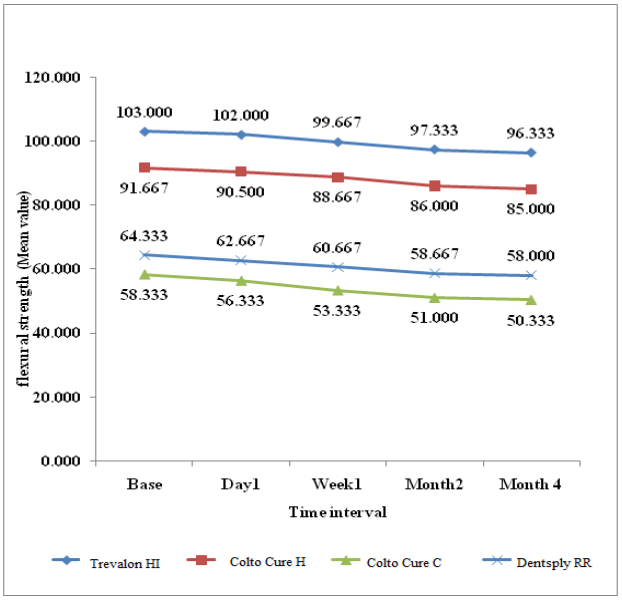
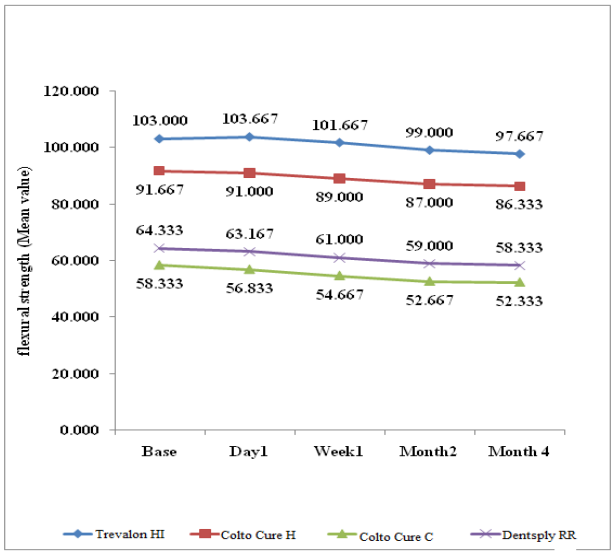


Graph 2; Comparison of Mean Flexural strength among four denture base resin materials at different time interval when immersed in artifical saliva.



Discussions

This in vitro study was performed on four commonly used denture base resins with two different initiation processes (heat and cold cure). Among various physical properties of denture base resins, the property of biocompatibility and esthetics are key for patient acceptance. Long term use depends more on mechanical properties which include strength to withstand functional and parafunctional masticatory forces. Flexion of the denture during function, apart from causing a mid-line fracture, also causes damage to the underlying soft structures leading to resorption of the residual alveolar ridge [15]. Polymethylmethacrylate resin is commonly used for the fabrication of removable complete and partial dentures. More than 60% of dentures fabricated with polymethyl methacrylate resin, fracture within 3 years of fabrication due to poor physical and mechanical properties. A fracture may occur due to impact (dropping of the denture) or due to

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fatigue failure [16]. Reinforcing of multiple materials within the resin, although has definitely improved resin strength [17].

While studies have been conducted to know the effects of either water or saliva on the flexural strength of denture base resins, at different intervals of time, we selected both media since all prosthesis that are worn clinically by patients have to stay in natural saliva during a function in oral cavity and in water while not being worn at night. The purpose of this study was to determine the flexural strength of high impact, heat and self cure denture base resin when immersed in artificial saliva and water for different time intervals. These time intervals also correspond to the clinical requirements of correcting occlusion during follow up visits. Zappini et al [3], stated that most studies primarily investigate strength that is based on impact value, which could not be the reliable test in predicting clinical function that are related to fatigue failure. Impact tests are also affected by loading protocols, and specimen geometry, that can be dimensions of the specimen, configuration of notches and presence of stress concentration areas. Accordingly, other studies that utilized materials like light cure denture base resins have also concluded that the fatigue test is more reliable for determining long term effect of the storage medium on the mechanical properties [18]. In the present study two heat cure denture base resins (Colto cure H and Trevalon HI) were analyzed and the results suggest that the heat cure denture base resins have a higher flexural strength than the other two autopolymerizing resin used in the study (Colto cure C and Dentsply RR). Our results are thus in agreement with the general belief that heat cure denture base resins have more flexural strength than self cure denture base resins [2],[6]. The influence of storage in water/artificial saliva on the flexural strength was gauged by testing the samples at different intervals of time. Both types of resins showed a decrease in the FS with maximum impact being within the first 1 week. The results are in agreement with a study done by Dandekeri et al, who concluded that the flexural strength of heat and self cure denture base resins decreases after storage in water. However, both heat cure materials at 2 and 4 months intervals in both GP B and GP C demonstrated differences from GP A which were statistically significant. For self cure material at 1 week, 2 month and 4 months time intervals in both GP B and GP C differed statistically from the control GP A. As the denture base polymer is immersed in water, leaching of water soluble constituents likes unreacted monomers, initiators and plasticizers takes place [19]. Microvoids are thus formed that with time are replaced with surrounding water molecules through inward diffusion. Both of these processes are time dependent and continues till equilibrium is reached. At a given time the flexural strength of a denture base polymer after immersion in water is thus dependent on the relative amount of previously polymerized molecules [20]. Unreacted monomer is present more in self cure resins and when a short cycle of denture processing is used for processing. Kanchanvasita et al in her study on effect of curing cycles on the flexural strength concluded that the long curing cycle results in less decrease of flexural strength than short curing cycle [21]. This also was the basis of preparing the samples for this study using a long curing cycle to minimize the confounding effect.

The role of different immersion medium may have little impact on the overall changes in the flexural strength. Between saliva and water, our results show that,one heat cure denture base resin (Trevalon HI – 2 months) differed significantly while for self cure resin, both (Colto Cure C – 1 week, 2 and 4 months and Dentsply RR – 1 week) differed significantly. This implies clinically that orthodontic appliances which are generally made of self cure denture base resins can have its flexural strength altered depending on the storage media. Our results are also in agreement with an early study by Koda et al, who concluded that leachability of self cure was more in artificial saliva, while leachability of heat cure and microwave cure were insignificant [22].

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Conclusion

Within the scope and limitations of the present study, it may be concluded that among the four different materials which were tested for flexural strength, Trevalon HI had highest flexural strength when dry. Decrease in flexural strength was observed at all intervals of time, although more decrease in, FS was observed during the initial first week.

Limitations and Future Studies

This study is limited by being an invitro study, since the invivo conditions are always difficult to be created in the laboratory despite best efforts by the researchers. The study also is limited by the fact that each individual patient is different and behaves differently at different times, therefore different patients will store and wear dentures differently. It may also be stated that the role of immersion medium (artificial saliva or water) seems to have an influence on self cure for which further studies need to be conducted with appropriate methods.

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