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Effect of Glass Fibers or Metallic Filler on the Linear Dimensional Changes and Water Sorption of Acrylic Resin Denture Base Material

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Abstract

The aim of this study was to study the effect of reinforcement of acrylic resin denture base polymer with chopped glass fibers and silver filler on the linear dimensional changes, and water sorption. The dimensional changes were measured immediately after processing, after 1,2,3,7 and 14 days of water storage. Water sorption was measured after 7-days of water storage. The results revealed that both types of reinforcement affect the dimensional accuracy and water sorption of the test specimens when compared to the control unreinforced specimens. The greatest dimensional accuracy was found with the glass fibers reinforced test specimens. The lowest amount of water sorption was found with the silver-filled test specimens. It was concluded that both the tested reinforcing materials decreased the linear dimensional changes and water sorption as compared to the control group specimens.

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Introduction

Polymethylmethacrylate has proved to be the most satisfactory denture base material currently available. Although this material has several desirable features that account for its popularity, it has few but important disadvantages such as low thermal conductivity, high coefficient of thermal expansion that causes dimensional inaccuracy and relatively low modulus of elasticity[1]. The causes of the dimensional changes of resin material are well documented. However, the dimensional changes of acrylic resins are inevitable, which is caused by processing shrinkage and expansion upon water sorption[2]. All available resins used in dentistry undergo shrinkage during processing[3]. For instance, the ratio of polymer powder to monomer liquid, type of acrylic resin, curing cycle, and investment affect dimensional changes during processing[2,4]. Polymethyl methacrylate (PMMA) absorbs water slowly over a period of time, primarily because of the polar properties of the resin molecules. Furthermore, water sorption of polymethylmethacrylate after curing has an effect on the dimensions of the denture[5].

Approaches to strengthening the acrylic resin prosthesis have included modifying or reinforcing the resin. The most common reinforcing technique is the use of solid metal forms[6,7]. Another approach is the reinforcing of acrylic resin dentures with fibers. Different fiber types have been added to acrylic resin dentures to improve their physical and mechanical properties. These fibers included carbon fibers[8], glass fibers[9], kevlar fibers[10] and polyethylene fibers[11].

Fibers that used as a denture base strengtheners has three forms. namely, continuous parallel, chopped, and woven[12] Glass fibers were tested in some studies to improve the mechanical properties of denture base polymers are woven and continuous forms only[12,13]. The effect of the chopped glass fibers and the silver filler on the linear dimensional changes and water sorption are relatively few in literature. Therefore, the aim of this study was to study the effect of reinforcement ofacrylic resin denture base polymer with chopped glass fibers and silver filler on the linear dimensional changes, and water sorption. However, the dimensional changes were measured immediately after processing, after 1,2,3,7 and 14 days of water storage. Water sorption will be measured after 7-days.

Materials and Methods

Linear Dimensional Changes

A stainless steel mold containing five compartments each 65 mm long, 10 mm wide, and 3 mm thick was fabricated. With the use of a polysiloxane impression material (Coltene AG, Coltenewhaledent. ch, Switzerland) in a custom acrylic resin tray, an impression was made for the metal mold, and master casts were prepared from this impression from improved dental stone (Zeta, Zingardis.r.i. Italy). Wax was placed in each stone compartment. Two wax dimples were made in each block with a number eight round bur, one dimple near each end of the wax block. These indentations in the wax block produced a reference points in the acrylic resin specimens for measurement. A measuring microscope (Linear Microscope, Griffin and Company, London, England) was used to measure the distance from the lowest point of the upper most dimple to the highest point of the lower most dimple. The linear dimensional value for each block was recorded. The casts with the wax blocks were then invested in denture flasks[14].

Ten wax blocks were processed with acrystone heat-cured acrylic resin (Acrystone Dental Factory, England) according to manufacturer's instructions without reinforcement. The resin dough was pressed for 10 minutes at a pressure 1000 kpa (10 bars)[15]. Then the resin was processed by the short curing time at 74ºC for 1.5 hours followed by boiling for an additional one hour. The denture flask was cooled slowly to room temperature.Immediately after processing, all samples were measured by the same method described. To determine the effect of water sorption on the dimensional stability of the resin, each processed block was stored in deionized water at 37º C, and measured again after 1,2,3,7 and 14 days.

Another 20 samples of acrylic resin were prepared with the same previous technique. Ten samples were reinforced with a prefabricated CF-140 chopped glass fibers (length 12 mm, diameter 17 micron, weight of fibers 0.16 gm). The fibers were incorporated into the center of the resin dough during packing in a loose and random distribution. The other 10 samples were reinforced with 5% by volume of silver powder (particle size 10 μm). The metal filler were added to the resin powder andthetwo powders were mixed in a mortar and then in an amalgamator (YDM, China) for two minutes to achieve a mixture with uniform color.

Water Sorption Test

Thirty acrylic resin samples were prepared according to the ANSI/ADA specification No. 12 for denture base polymer. The disk specimen of 50 ± 1 mm in diameter and 0.5 ± 0.05 mm thick was formed in a stainless steel-gypsum mold. Ten disks were prepared without reinforcement, ten disks were reinforced with glass fiber, and ten disks were reinforced with silver powder. The disks were dried in a desiccator containing thoroughly dry anhydrous calcium sulfate at 37ºC for 24 hours, removed to a similar desiccator at room temperature for one hour, then weighed using an electronic balance (Sartorius MCI Reasearch RC Z10 D, Sartorious AG, Gottingen, Germany). This cycle was repeated until a constant weight was attained (WI). The disks were then immersed in deionized distilled water at 37ºC for 7 days, after which time the disks were removed from the water with tweezers, wiped with clean, dry hand towel until free from visible moisture, waved in air for 15 seconds, and reweighed one minute after removal from the water (W2). Water sorption was calculated by the following formula:

$$\text{Water sorption (mg/cm}^3\text{)} = \frac{w2(mg) - w1(mg)}{\text{Disc volume (cm}^3\text{)}}$$

Statistical Analysis

Statistical analysis of the results was carried out with ANOVA test. LSD test was carried out when a significant difference was found by ANOVA. t-test was performed to compare the mean values ofwater sorption between the unreinforced and reinforced groups.

Results

The results of linear dimensional changes are presented in Table 1.ANOVA test revealed a significant changes in the linear dimensions of the unreinforced, fiber reinforced and silver reinforced groups. The unreinforced group showed a significant shrinkage from the start of specimens decasting up to 2-weeks ($p < 0.05$). The statistical analysis of the results of the fiber reinforced group did not show any significant changes after processing up to 2-weeks ($p > 0.05$). Silver reinforced group should significant shrinkage after 1-day, 2-days, 3-days and 1-week of water storage but it did not show a significant changes after processing and 2-weeks of water storage. Although the unreinforced specimens should expansion during water storage, this expansion did not compensate the processing shrinkage. Both types of reinforcing materials showed a significant reduction in the linear dimensional changes after 2-weeks. The fiber reinforcing material exhibited the best dimensional stability.

Table 1: Mean linear dimensions (mm) of the test specimens after processing, 1-day, 2-days, 3-days, 1-week and 2-weeks of storage in water

Time Resin type	Unreinforced resin	Fiber reinforced resin	Silver- reinforced resin
Before processing	$5.95^A \pm 0.1$	$5.92^A \pm 0.12$	$5.99^A \pm 0.05$
After processing	$5.78^B \pm 0.08$	$5.88^A \pm 0.1$	$5.94^A \pm 0.06$
1-day water storage	$5.79^B \pm 0.12$	$5.85^A \pm 0.09$	$5.90^B \pm 0.04$
2-days water storage	$5.79^B \pm 0.09$	$5.85^A \pm 0.14$	$5.91^B \pm 0.08$
3-days water storage	$5.8^B \pm 0.13$	$5.86^A \pm 0.13$	$5.92^B \pm 0.09$
1-week water storage	$5.81^B \pm 0.12$	$5.88^A \pm 0.07$	$5.93^B \pm 0.06$
2-weeks water storage	$5.82^B \pm 0.1$	$5.89^A \pm 0.12$	5.93A ± 0.1

Means with different superscripted letters are significantly different
$P < 0.05$ = significant

The results of water sorption of polymer resin materials are presented in Table 2. Both unreinforced and silver reinforced groups should a significant water sorption after water storage for 1-week ($p < 0.05$). Silver reinforced group should the least water sorption ($p > 0.05$).

Table 2: Amount of water sorption (mg/cm^3) of unreinforced and reinforced resins after 7 days.

Resin type	Unreinforced resin	Fiber reinforced resin	Metal reinforced resin
Mean ± SD	0.42 ± 0.017	0.40 ± 0.003	0.39 ± 0.01
t. value	2.23	3.35	1.58
P-value	< 0.05*	< 0.01**	> 0.05$^+$

*P < 0.05 = significant
**P < 0.01 = high significant
+p > 0.05 = not significant

Discussion

Several fibers can be added in the form of continuous parallel, woven or chopped glass fibers to PMMA[16]. Chopped fibers were selected here because this type of fibers not studied before regarding to dimensional stability and water sorption. The short fibers seemed to be evenly distributed in the polymer matrix and no voids around the fibers were observed[17]. Woven or continuous glass fiber needs greater amount of monomer to be incorporated as a bundles in the acrylic resin. Polymerization shrinkage of acrylic resin inside the fiber roving was high because of the excess plain monomer liquid[15]. Chopped glass fibers can be used in a loose form without pure monomer liquid, so the dimensional stability was observed in the fiber reinforced specimens. Also, silver powder was selected because of its good thermal conductivity, low cost and ability to attain high polish. Studies have demonstrates that physical properties of denture base affect patient satisfaction and acceptance. Thermal conductivity is among the most important properties of denture base influencing the sense of taste and gingival health. The conventionally used acrylic resin has a low coefficient of thermal conductivity. This study aimed to improve the thermal conductivity of acrylic resin by adding small concentrations of nanosilver[18].

In the present study, the addition of chopped glass fibers and silver fillers decreased the linear dimensional changes and water sorption of the heat-cured acrylic resin. This was because by the addition of glass fibers and silver particles, the actual number of PMMA molecules available on the surface of the specimens for water sorption to occur decreases as compared to the control specimens. Glass fibers reinforced acrylic resin showed less dimensional changes andgreater water sorption than that of the silver reinforced acrylic resin. The silver filler particles decreased the potential sites of water exchange to occur[19].

The results of the water sorption and linear dimensional changes of heat-cured PMMA, either with or without reinforcement, were in accordance with the ANSI/ADA specification No. 12 and the ISO standard 1567. This study showed that all resin types, either reinforced or unreinforced expand during storage in water for 2 weeks. Expansion of acrylic resin as a results of water sorption may compensate the thermal shrinkage encountered during polymerization process. Water is absorbed into polymer by the polarity of the molecules in the polymers by unsaturated bonds of the molecules or unbalanced intermolecular forces in the polymers[1].

Ladizesky, et al.[20] studied the water sorption and dimensional changes of denture base acrylic resin reinforced with woven, highly drawn linear polyethylene fibers. The high fiber loading, namely, fiber content, reduced the water sorption of the resin by about 25%. However, the fiber content used in this study was 0.16 gm. Thus effect of fiber inclusion on the water sorption is obviously minor, as noted for the test results of the heat-cured test specimens. From the clinical stand point, the difference in water sorption between glass fiber reinforced and unreinforced PMMA is slight, but type of acrylate used in dentures is more important than glass fiber reinforcement[5]. Significant decrease in water sorption, modification of heat-cured acrylic resins with certain amounts of silver particles, may be useful in preventing undesirable physical changes of dentures resulting from oral fluids clinically.

Conclusion

Within the limits of this study, the following conclusion can be drawn. Since glass fibers and silverfillers resulted in significant decreased linear dimensional changes and significant decrease in water sorption, modification of heat-cured acrylic resins with certain amounts of glass fibers and silver particles, may be useful in preventing undesirable physical changes of dentures resulting from oral fluids clinically.

Conflict of Interest: No potential conflict of interest relevant to this article was reported.

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