Water Absorption of Two Different Denture Base Resins Reinforced with Dental Fiber Systems

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ABSTRACT: The absorption of water by denture base materials is important because it is directly related with dimensional stability of dental material. In this study, water absorption of denture base materials reinforced with different type of dental fiber systems was compared. The samples were prepared from heat-polymerized and microwave polymerized denture base resins and reinforced with different dental fiber systems. Five different reinforcement materials were used in this study, namely, (1) no fiber (control group), (2) plasma-treated crosslinked polyethylene fibers, (3) plasma-treated woven polyethylene fibers (4) porous polymer preimpregnated continuous unidirectional glass fibers, and (5) woven glass fibers. The water absorption calculations were done for the periods of 7, 14, 21, and 30 days of water immersion and in total 100 specimens were tested. The statistical analysis via analysis of variance and Duncan multiple comparison tests have shown that the fiber reinforcement significantly influence the water absorption. Moreover, the results have shown that water absorption of denture base polymers is higher when the specimens are reinforced with the fiber systems. © 2010 Wiley Periodicals, Inc. J Appl Polym Sci 117: 1750–1753, 2010

Key words: Water absorption; Denture Base Resin; Dental Fiber System

INTRODUCTION

Acrylic resins, based on poly(methyl methacrylate) (PMMA), have been the most popular denture base material for many years.[1–5] This material has an excellent appearance, ease of processing, and ease in repair. However, there are still shortcomings including water absorption and mechanical properties.[6–8]

Approaches to strengthen the acrylic resin prosthesis with different fibers have been studied.[9–12] The use of carbon and aramid fibers are limited for their poor aesthetic and difficulties in polishing.[12,13] Gas-plasma-treated polyethylene fibers and porous PMMA polymer preimpregnated silanized E-glass fibers are promising materials for their good adhesion to the polymer matrix, high aesthetic quality and the increased strength of the resulting materials.

Position, quantity, direction of the fibers, and degree of adhesion between the fibers and the polymer matrix affect the reinforcement.[13–17] Effects of thermocycling and the surface modification of PMMA by wetting with MMA monomer was studied by means of mechanical and dynamic mechanical test.[5] Glass and polyethylene fibers can be woven, unidirectional continuous and chopped form,[18,19] woven, and continuous fiber reinforced dentures showed encouraging results.[19–21]

The fiber reinforced denture base resins are used in wet environment in the oral cavity; when not in use, storing in water is an important factor.[22–24] Poly(methyl methacrylate) absorbs water slowly over the time period. This imbibition is primarily due to the polar properties of the resin molecules. As a result, high equilibrium uptake of water can soften the denture because the absorbed water can act as a plasticizer; hence reduce the mechanical properties of the material.[22–24] The amount of water absorption into the fiber reinforced resins is also affected by the impregnation of fibers. A few commercially available dental fiber systems are based on the use of polymer-preimpregnated glass fibers or plasma-treated polyethylene fibers, and this dental fiber fabrication system maximize fiber compaction and minimize air voids.

The purpose of this *in vitro* study is to compare the water absorption degree of a heat-polymerized and a microwave-polymerized denture base polymers that have been reinforced with different fiber systems that are commonly used in dental applications.

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MATERIALS AND METHODS

Denture base resins and dental fiber systems used in this study are shown in Table I. In total, 100

TABLE I
Dental Fiber Systems Used

Fiber System	Manufacturer	Physical composition	Type of surface treatment
Dyneema	DSM BV. Heerlen, Holland	Woven bi-directional Polyethylene fiber	Cold gas plasma treated
Ribbond	Ribbond Inc., Seattle, USA	Leno stitch cross-link Polyethylene fiber	Cold gas plasma treated
Stick	Stick Tech Ltd. Turku, Finland	Continuous, uni-directional E-glass fiber	Porous PMMA polymer pre-impregnated
Stick-Net	Stick Tech Ltd, Turku, Finland	Woven bi-directional glass fiber	Porous PMMA polymer pre-impregnated

specimens were used for the tests with a 10 specimens for each test group. The specimens (with dimensions of $3 \times 12 \times 20$ mm^3) were prepared from heat-polymerized (Meliodent, Bayer Dental, Newbury, Berkshire, UK) and a microwave-polymerized (Acron-MC, GC-Dental, Tokyo, Japan) denture base resins, and these resins were reinforced with four different types of dental fiber systems that are; (i) leno-stitch crosslinked gas-plasma treated polyethylene fibers (Ribbond, Ribbond Inc., Seattle, WA, USA), (ii) woven gas-plasma-treated polyethylene fibers (Dyneema, DSM BV., Heerlen, Holland), (iii) continuous unidirectional E-glass fibers (Stick, Stick Tech., Finland), and (iv) woven-form E-glass fibers (Stick-Net, Stick Tech., Finland). Stick and Ribbond fibers were cut with 15 mm length. Stick-Net and Dyneema fibers were cut with dimensions of 15×8 mm^2. Moreover, control groups were tested for each denture base resin.

All fibers were weighed with an electronic-precision balance (Bosch S-2000, Germany) with an accuracy of $\pm$0.0001 g. The reinforcement fibers were soaked–washed with the PMMA / methyl methacrylate (MMA) mixture of each acrylic resin for 10 min. Then, fibers were placed in the middle of mold. Ribbond with weight fraction of 6.6% and 6.2%, Dyneema with weight fraction of 7.1% and 6.8%, Stick with weight fraction of 18.6% and 17.3% and Stick-Net with weight fraction of 6.8% and 6.5% for heat and microwave polymerized denture base resins, respectively, were prepared.

The powder/liquid ratio of Meliodent (heat polymerized) resin was 23.49 g/10 mL and that of Acron MC (microwave polymerized resin) was 30 g/9 mL. Meliodent resin was polymerized in water bath maintained at 100°C for 20 min and microwave polymerization was carried out at 500 W for 3 min in a microwave oven (Vestel, Pekel Co., Manisa, Turkey). In total, 50 specimens were made from heat polymerized acrylic resin and the other 50 specimens were made from microwave polymerized denture base resin while 10 specimens from each group were prepared with no fiber as control groups.

After polymerization, the specimens were ground with silicon carbide abrasive papers from P 200 to P 600 (Waterproof silicon carbide paper, English Abrasives Ltd., London, UK) to the predetermined dimensions of the specimens. Samples were dried for 4 days at 37 $\pm$ 1°C under vacuum, weighted with an analytic balance and their length, width, and height were measured with a digital micrometer. The water absorption was determined according to the International Standards Organization (ISO) standards 1567 : 1999 (ISO 1567 : 1999 Denture Base Polymers). The samples were immersed in distilled water at 37 $\pm$ 1°C and removed from water by blotting with filter paper and the water immersion periods were 7, 14, 21, and 30 days. Water absorption (mg/cm^3) calculations were carried out according to the formula of $Z = Y/X$ where Z is amount of water absorbed in mg/cm^3, Y is the amount of water absorbed (mg), and X is initial volume of specimen (cm^3). Analysis of variance (ANOVA) at 5% significance level and Duncan post hoc tests were carried out.

RESULTS AND DISCUSSIONS

The mean values for the water absorption of samples are given in Table II, and the change in water absorption for each resin is shown in Figures 1 and 2. It is clear from the results that fiber reinforcement significantly influenced the water absorption. In general, the water absorption was increased with time for both of the resin types as shown in Figures 1 and 2. The rate of water absorption was relatively higher between the time periods of 0–7 and 7–14 days of water immersion for all resin and fiber systems and control groups as shown in Figures 1 and 2. The highest rate of water absorption was obtained as 0.126 mg/ cm^3/h and 0,127 mg/cm^3/h for Acron MC + Dyneema and Meliodent + Ribbond systems, respectively, within the time period of 0–7 days of water immersion, assuming the linear change of absorption of water with time.

For the same resin type and same time period of water immersion, different small letters in the same row of Table II shows the difference in mean values of water absorption is statistically significant regarding to the fiber system ($p < 0.01$). Fiber system does not affect the water absorption for the Meliodent resin with any of fiber reinforcement for the 21 and 30 days of water immersion time period. However,

TABLE II
Mean and Standard Deviation Values for Water Absorption (mg/cm^3) Samples and Statistical Analysis Results

	Acron-MC (Control) (n=10)	Acron-MC +Ribbond (n=10)	Acron-MC +Dyneema (n=10)	Acron-MC +Stick (n=10)	Acron-MC +Stick-Net (n=10)	Meliodent (Control) (n=10)	Meliodent +Ribbond (n=10)	Meliodent +Dyneema (n=10)	Meliodent +Stick (n=10)	Meliodent +Stick-Net (n=10)
7 Days	C bc 20.17±0.209 1	C c 19.63±0.466 2	B a 21.39±0.618 1	C bc 20.55±0.406 1	C bc 20.16±0.20 2	C a 20.32±0.445 1	C a 21.24±0.452 1	B a 21.07±0.392 1	C a 21.02±0.360 1	B a 21.16±0.772 1
14 Days	B c 21.62±0.285 2	B bc 22.28±0.499 2	A a 24.15±0.496 1	B b 23.10±0.541 1	B b 22.56±0.163 2	AB b 23.12±0.497 1	B ab 23.38±0.982 1	A a 24.29±0.338 1	B ab 23.85±0.344 1	A a 24.19±0.811 1
21 Days	AB c 22.05±0.306 2	A b 23.39±0.455 2	A a 24.79±0.486 1	A ab 23.98±0.395 1	A b 23.60±0.225 2	A b 23.70±0.484 1	A a 25.26±0.465 1	A a 24.61±0.395 1	A a 24.97±0.298 1	A a 24.68±0.836 1
30 Days	B c 22.65±0.459 1	A b 23.68±0.457 2	A a 24.71±0.442 1	A ab 24.55±0.389 1	A ab 23.92±0.278 2	A b 22.66±1.222 1	A a 25.37±0.489 1	A a 24.63±0.384 1	A a 25.20±0.332 1	A a 24.89±0.792 1

fiber systems affect the water absorption for the Acron MC case for the 21 and 30 days of water immersion time period.

For the same resin type and same fiber system, different capital letters in the same column of Table II shows the difference in mean values of water absorption is statistically significant regarding to the time period of water immersion ($p < 0.01$). In general, the difference in water absorption between 21 and 30 day period was insignificant. That means, the resin and fiber system reaches saturation in the long term regarding water absorption.

For the same fiber system and same water immersion period, different numbers in the same row of Table II shows the difference in mean values of water absorption is statistically significant regarding to resin type ($p < 0.01$). All fiber systems have statistically insignificant difference in mean values of water absorption for the Meliodent resins for each of the time periods of water immersion. Dyneema and Stick fiber systems have statistically insignificant difference in mean water absorption values of water absorption for the Acron MC resin for all the time periods of water immersion.

Meliodent resin without fiber system has higher water absorption values than Acron MC resin without fiber. In addition, Meliodent resin reinforced with fiber system for all cases except for the Dyneema fiber case has higher water absorption values then Acron MC.

Stick and Stick-Net fibers are manufactured as glass fibers impregnated with a highly porous polymer matrix that requires the additional process of wetting with a liquid-powder resin mixture. In clinical practice, the fiber polymer preimpregnation process used for Stick and Stick-Net, which is partly controlled by the user, might have resulted in more defects and correspondingly accounted for higher water sorption.[25] Water is absorbed into the methacrylate resin by

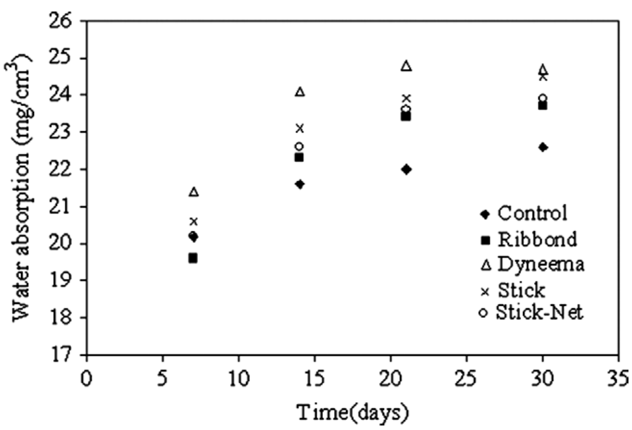

Figure 1 Water absorption (mg/cm^3) for microwave polymerized resin with different fiber systems.

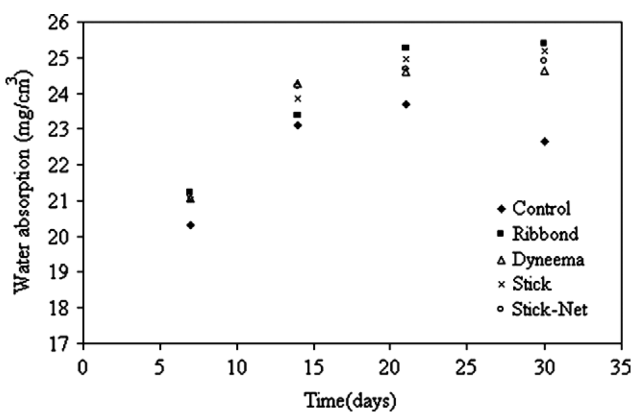

Figure 2 Water absorption (mg/cm^3) for heat polymerized resin with different fiber systems.

diffusion. Water molecules ingress into the vacancies between the polymeric chains and push the chains further apart to cause an expansion and decreases the mechanical properties of acrylic polymers.[26]

In the wet environment of the oral cavity, corrosion effects can be induced in the surface of glass fibers resulting from water that diffuses through the polymer matrix. This can lead to a reduction of the mechanical properties and changes in the fiber-polymer interface, as the surface of the glass fiber is affected by the hydrolysis of alkali and earth alkali oxides in the glass and leaching of ions.[27,28] The silanization used to brand the fibers to the polymer matrix influences the hydrolytic stability of the fiber-resin matrix.

It was suggested that when the water content in the monomer system was oversaturated, the water was likely to form clusters that functioned like micro voids, which deteriorate mechanical properties.[29]

In general, heat polymerized denture base resins reinforced with fiber systems has higher water absorption than that of microwave polymerized denture base resins reinforced with fiber systems, this might partly be attributed to the presence of soluble materials in the denture base resins that transfer to the water phase during the heat polymerization and might partly be attributed to relatively lower particle size of microwave polymerized denture base resin than that of heat polymerized denture base resins.

Stick fiber has relatively higher water absorption values for both of the heat polymerized and microwave polymerized denture base resin cases and this might be attributed to the presence of relatively higher micro voids. Stick Net has relatively lower water absorption values especially in the relatively longer time periods (21, 30 days) this might be attributed to better binding of fiber with resin due to relatively thin structure of Stick Net fiber.

CONCLUSIONS

Water absorption for nonfiber reinforced denture base system was significantly different from denture base resin reinforced with fibers. In general, the amount of water absorption into fiber reinforced denture base resin increased with time. Fiber type does not affect the water absorption of resin fiber system for the water immersion periods of 21 and 30 days for the heat polymerized and microwave polymerized denture base resins studied.

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