

SORPTION OF NANOFILLED VERSUS OTHER CONVENTIONAL COMPOSITES

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Abstract

Since composite water sorption can result in expansion of the restoration, which would be detrimental to the restoration, it is important to limit the amount of water absorbed. The aim of this study was to evaluate and compare water sorption values of various composite materials.

Seven commercial light-activated composite materials: Tetric Evo Ceram (Ivoclar, Vivadent, Schaan/Liechtenstein, Austria), Premise (Kerr, Orange, CA USA), Herculite (Kerr), Z100 (3M-ESPE, St. Paul, MN, USA), Z250 (3M-ESPE), P60 (3M-ESPE) and SupremeXT (3M-ESPE). Ten disc specimens were prepared for each composite material using a stainless steel mold with 15 mm in inner diameter and 1 mm in thickness. The curing of each composite specimen was divided into 5 segments and each segment was photo-cures for 40 seconds. Water sorption of different materials was calculated by means of weighting the samples before and after water immersion (15 days) and desiccation. Data were analyzed by one-way ANOVA at 5% level of significance.

Tetric Evo Ceram composite showed the lowest water sorption values followed by Herculite, P60, supreme XT, Z100, Z250 and Premise which exhibited the highest values.

All the composites being tested in this study exhibited sorption values within the acceptable limits and composite composition significantly influenced its water sorption value.

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Introduction

During the last few years, resin composites have been classified according to their filler particle size, as hybrid, microhybrid and microfilled. More recently, however, with the introduction of nanotechnology in dentistry¹, a new class of resin composites, the so-called nanocomposites, is available to clinicians. However, there is a lack of data about the sorption phenomena of this new class of restorative materials. The oral environment plays an important role in the properties of the dental restorative materials. Water sorption may affect dental restorative materials such as composites,

by compromising their physical and mechanical properties²⁻⁴.

Water sorption by composite materials is a diffusion-controlled process, and the water uptake occurs largely in the resin matrix⁵. The water sorbet by the polymer matrix could cause filler-matrix debonding or even hydrolytic degradation of the fillers⁶ and may affect composite materials by reducing their mechanical properties^{7,8}. The hydrolytic degradation is a result of either the breaking of chemical bonds in the resin or softening through the plasticizing action of water⁹. Sorption affects composite restoration by water uptake producing an increased weight of the composite restoration¹⁰.

The aim of this study was to evaluate and compare water sorption values of various composite materials.

Materials and methods

Seven composite materials were selected for sorption evaluation in this study: Tetric Evo Ceram (nanofilled) (Ivoclar, Vivadent, Schaan /

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Liechtenstein, Austria), Premise (nanofilled) (Kerr, Orange, CA,USA), Herculite (Kerr), Z100 3M-ESPE, St. Paul, MN, USA), Z250 (3M-ESPE), P60 (3M-ESPE) and Supreme XT (nanofilled) (3M-ESPE) forming 7 experimental groups (n = 10). The composition of the selected composites is summarized in Table 1.

Composite	Organic/inorganic Matrix	Inorganic Filler	Filler size	% in Volume (Filler)
Tetric EvoCeram	Dimethacrylates (17-18% weight)	barium glass, ytterbium trifluoride, mixed oxide and prepolymer	0.04-3 µm 0.55 APS	60-61*
Premise	The ethoxylated Bis-GMA	Non-agglomerated silica nanoparticles, prepolymerized filler, 0.4 micron barium glass	0.02 µm APS	69*
Herculite	Bis-GMA and TEGDMA	Barium glass and silicon dioxide	0.6 µm	59%*
Z100	Bis-GMA and TEGDMA	Zirconia/Silica	0.01-3.5 µm	66*
Z250	Bis-GMA, UEDMA and Bis-EMA	Zirconia/Silica	0.19 – 3.3 µm	60*
P60	Bis-GMA, UEDMA and Bis-EMA	Zirconia/Silica	0.01-3.5 µm	61*
Supreme (XT)	BIS-GMA, BISEMA, UDMA and TEGDMA	Zirconia/Silica	(clusters of 0.6 to 1.4 µm particles of 5 to 20 nm)	57.7*

* Manufacturer's information
 APS: Average particle size

Table 1. Composition of the selected composites in this study.

Each composite specimen disc was 15 ± 1 mm in diameter and 1 ± 0.1 mm thick and was prepared using a stainless steel mould (Figure 1).



Figure 1. The composite stainless steel mould used in this study.

The material was prepared in accordance with the manufacturer's instructions, by filling the mold with the material using a plastic spatula to condense, and covering it with a polyester transparent film which was placed over the mould and finally covered by a glass slide. The photocuring of each composite specimen was divided into 5 sections overlapping each other and each section was photocured with the bluephase C5 (LED) (Ivoclar, Vivadent) light curing unit for 40s. The specimens were removed from the mould and any flash if present, was removed.

The specimens were immersed in distilled water and maintained at 37 °C for 15 days. After that time, the specimens were removed, washed with water, surface water blotted away until free from visible moisture, and waved in the air for 15 seconds, then finally weighed 1 minute after being removed from the water by using an analytical balance (Precisa, TYP 205A, made in Switzerland). This mass (m¹) was recorded.

The specimens were placed in the desiccator containing silica gel, freshly dried for 2 hours at 58 °C to obtain (m²). This cycle was repeated until constant mass was obtained. These steps were carried out to evaluate water sorption (A) according to Oysaed & Ruyter⁷ formula: $A = \frac{m^1 - m^2}{V}$, where m¹ is the sample weight after immersion and m² is the sample weight after immersion and desiccation. V is the volume of the specimen in cubic millimeters. The data was analyzed by one-way ANOVA at 5% level of significance.

Results

Table (2) summarizes sorption, means and standard deviations (in parenthesis) of Tetric Evo Ceram, Premise, Herculite, Z100, Z250, P60 and Supreme XT composites in µg/mm³.

Supreme XT	P 60	Z 250	Z 100	Herculite	Premise	Tetric Ceram	Composite
20.382 (2.655)	19.023 (3.149)	22.137 (6.916)	21.064 (5.319)	18.683 (4.161)	26.666 (6.642)	18.343 (4.297)	Sorption

Table 2. Means sorption values and standard deviations of the tested composites.

Premise light activated composite exhibited the highest mean value, while Tetric Evo Ceram composite exhibited the lowest mean value (Figure 2).

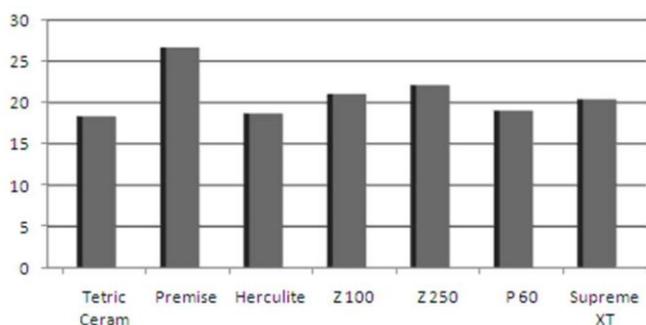


Figure 2. Mean sorption values for the composite groups in $\mu\text{g}/\text{mm}^3$.

Further statistical analysis of data by using one-way analysis of variance (ANOVA) revealed that, there was statistically significant difference ($P \leq 0.05$) in water sorption values between the seven composite groups being tested as shown in Table 3.

Source	DF	SS	MS	F	P
Factor	6	500.5	83.4	3.38	0.006
Error	63	1556.8	24.7		
Total	69	2057.4			

Table 3. One-way Analysis of Variance (ANOVA) of the sorption test.

Discussion

Many resin-based composite materials are Bis-GMA-based. The high viscosity of the polymer requires the addition of diluent monomers, which coupled with the presence of hydroxyl groups in the Bis-GMA molecule result in high values for sorption. Since such sorption can result in expansion of the restoration, which would be detrimental to the restoration, it is important to limit the amount of water absorbed. Higher sorption values can manifest as reduced wear and abrasion resistance of resin-based composites, as well as color instability. ADA Specification No. 27¹¹ requires that “the water sorption of all materials shall be less than or equal to $40 \mu\text{g}/\text{mm}^3$ ” within a seven day period of water storage” Resin composites indicated as restorative materials must also comply with ISO 4049 for a maximum value of $40 \mu\text{g}/\text{mm}^3$ for water sorption within a seven day period of water storage¹².

The water sorption values obtained from this study are remarkably lower than ADA and

ISO guidelines, even for a 15-day storage time which is double than the recommended time.

Several factors, such as the polymeric matrix composition¹³, filler particle type and content¹⁴ can influence sorption behavior of resin composites. Statistical significant differences were detected between the tested composites in this study. Results are probably related to the composition of the tested composites. The composites used in this study have a great similarity in the filler particle percentage by volume (Table 1) but showed differences in their filler particle size and shape and could be one of the causes that affect sorption values¹⁵.

Premise light activated composite exhibited the highest sorption values and this could be related to its highest filler loading by volume (69%) and the presence of non-agglomerated silica nano-particles and prepolymerized filler (Table 1). The sorption phenomenon in resin composite materials is mainly dependent on the hydrophilicity of their polymeric matrices¹³.

The chemistry of the monomers present in the matrix is the key to the hydrophilic nature of the polymer¹⁶. In this study, the resin matrix composition of Premise light-activated composite contains ethoxylated Bis-GMA resin matrix which can be considered a weak resin matrix in providing the composite adequate resistance against sorption. In addition to the polymeric matrix, the filler particle system may also influence the sorption phenomenon in resin composites. Analyzing several commercial resin composites and experimental dimethacrylate models, Kalachandra and Wilson¹⁷ (1992) found that Silux Plus, i.e., a microfill resin composite with a $0.04 \mu\text{m}$ silica filler (in this study Premise resin composite $0.02 \mu\text{m}$ non-agglomerated silica nanoparticles), displayed a more drastic reduction in elastic modulus after storage in water at 37°C . This result was related to the greater amount of water accumulated at the matrix-filler interface.

In conclusion, these authors claimed that the interface between the inorganic filler particle and the polymeric matrix is the most probable site for accommodation of additional water in resin composites. It seems obvious that the large total surface area of silica filler in Silux Plus resin composite contributed to the results of the above-mentioned study. The same reasoning could be used to justify the differences in sorption values

between the composites studied in the present study.

It is reasonable to assume that the theoretically larger total surface area of nanofilled composite particles, derived from the nonagglomerated 20 nm silica filler, allowed more water to accumulate at the filler particle-polymeric matrix interfaces, thus increasing its sorption value. Another possibility that could explain the greater sorption values in the Premise composite is that, the water accumulated at the aggregated silica cluster filler-organic matrix interface could have created paths for water diffusion towards the inside of aggregates, where the presence of microvoids is quite probable, due to lack of 5-20 nm-sized primary particles being impregnated in the polymeric matrix¹⁸.

It is possible that in the presented study, degree of conversion might affect the sorption values indirectly since the non-agglomerated silica nano-particles with mean size of 20 nm of Premise light activated composite (Table 1) may have caused a light-scattering effect in nanofilled composite. Thus, the light intensity might have been attenuated and the degree of conversion decreased. On the other hand, in the other composites being tested, light transmittance was probably higher, and their degree of conversion was not affected¹⁹.

Conclusions

- 1- All the composites being tested in this study exhibited sorption values within the acceptable limits by the ADA and ISO.
- 2- Composite composition is significantly influences its water sorption values of the tested composites.
- 3- The polymeric matrix composition, filler particle type and content can influence sorption behavior of resin composites.
- 4- Nanofilled composites being tested in this study exhibited comparable sorption values with other conventional composites except for Premise light-activated composite which exhibited higher values.
- 5- Tetric Evo Ceram composite showed the lowest water sorption values followed by Herculite, P60, supreme XT, Z100, Z250 and Premise which exhibited the highest values.

Declaration of Interest

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References

1. Mitra SB, Wu D, Holmes BN. An application of nanotechnology in advanced dental materials. *J Am Dent Assoc.* 2003;134:1382-90.
2. Roulet IE and Walti C. Influence of oral fluid in composite resin and glass-ionomer cement. *Prosthet Dent*1984; 52: 182-187.
3. Yap AU, Teoh SH and Tan KB. Influence of water exposure on three body wear of composite restoratives. *J Biomed Mater Res* 2000; 53: 547-553.
4. Sarkar NK. Internal corrosion in dental composite wear. *J Biomed Mater Res* 2000; 53: 371-80.
5. Braden M. and Clarke R.L.: Water absorption characteristics of dental microfine composite filling materials. *Biomaterials.* 1984; 5: 369-372.
6. Söderholm K.J. Zigan M, Ragan M., Fischlschweiger W. and Bergman M., Hydrolytic degradation of dental composites. *J Dent Res.* 1984; 63: 1248-1254.
7. Oysaed H. and Ruyter I.E., Composites for use in posterior teeth: mechanical properties tested under dry and wet conditions. *J Biomed Mater Res.* 1986; 20: 261-271.
8. El-Hadary A. and Drummond J.L., Comparative study of water sorption, solubility, and tensile bond strength of two soft lining materials. *Prosthet Dent.* 2000; 83: 356-361.
9. Mohsen N.M and Craig R.G, Hydrolytic stability of silanated zirconia-silica-urethane dimethacrylate composites. *J Oral Rehabil* 1995; 22: 213-220.
10. Peutzfeldt A and Asmussen E, Influence of ketones on selected mechanical properties of resin composites. *J Dent Res.* 1992; 71: 1847-1850.
11. The ADA division of science on behalf of the ADA council on scientific affairs: Resin-based composites. *J Am Dent Assoc.* 2003; 4; 510-13.
12. International Organization for Standardization. ISO 4049: Dentistry polymer – based filling, restorative and luting materials. Switzerland, 2000.
13. Sideridou I, Tserki V, Papanastasiou G. Study of water sorption, solubility and modulus of elasticity of light-cured dimethacrylatebased dental resins. *Biomaterials.* 2003;24:655-65.
14. Söderholm KJ, Zigan M, Ragan M, Fischlschweiger W, Bergman M. Hydrolytic degradation of dental composites. *J Dent Res.* 1984;63:1248-54.
15. Berger SB, Paliolol AR, Cavalli V, Giannini M: Characterization of water sorption, solubility and filler particles of light-cured composite resins. *Braz Dent J.* 2009; 4:314-318.
16. Malacarne J, Carvalho RM, Goes MF, Svizero N, Pashley DH, Tay FR, et al. Water sorption/solubility of dental adhesive resins. *Dent Mater.* 2006; 22: 973-80.
17. Kalachandra S, Wilson TW. Water sorption and mechanical properties of light-cured proprietary composite tooth restorative materials. *Biomaterials.* 1992;13:105-9.
18. Santos C, Clarke RL, Braden M, Guitian F, Davy KWM. Water absorption characteristics of dental composites incorporating hydroxyapatite filler. *Biomaterials.* 2002;23:1897-1904.
19. Da Silva EM, Almeida GS, Poskus LT, Guimarães JG: Relationship between the degree of conversion, solubility and salivary sorption of a hybrid and a nanofilled Resin composite: influence of the light-activation mode. *J App Oral Sci.* 2008; 2:161-6.