

Experimental Comparison of Hygroscopic Expansion in Three Different Composite Resins

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Abstract

Background and Aim: These days dental composites are very popular because they look good and are similar to human teeth regarding color. Hygroscopic expansion is one of the physical properties of dental composites. A dental composite may lose its efficiency as a restoration material because of water absorption. The objective of this study was to compare the hygroscopic expansion of three dental composites.

Materials and Methods: In this experimental study, to assess the effective factors of hygroscopic expansion, we used three different dental composites (Kalore, P90 and Z250). The length of these composites in water and saliva were measured eighteen times in a three-month period. For analyzing the data, we used the marginal modeling technique in which the correlation between response data can be accounted for.

Results: The results of marginal modeling showed that the type of composite is significantly related to hygroscopic expansion ($P < 0.05$); demonstrating the highest hygroscopic expansion for P90 and the lowest for Z250. In addition, time as an independent variable had a statistically significant effect on hygroscopic expansion ($P < 0.05$). However, we found no significant difference between the hygroscopic expansion of saliva and water ($P > 0.05$).

Conclusion: Overall, our findings showed that hygroscopic expansion is significantly related to the type of composite and time. Therefore, we should utilize the composites with lower hygroscopic expansion (such as Z250) for filling the patients' teeth.

Key Words: Composite resin, Hygroscopic expansion, Longitudinal studies

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Introduction

In the past years, research has been conducted towards finding an ideal substance from the esthetics and strength point of view leading to improvement in dental restorative methods. This process has resulted in the production of composite resins using the acid etch technique [1]. In the last decades, there has been remarkable progress in dental composites, one of

which is the big revolution in composites in 1960, in which demethacrylate as BisGMA, TEGDMA or UDMA were used in composites [2]. Despite these improvements, methacrylate-based composites have restrictions such as shrinkage after polymerization due to closeness and adhesion of the monomer molecules during polymerization. This matter may cause nonconcurrent margins leading to

microleakage, sensitivity after restoration and finally decrease in the longevity of the composite [3, 4].

From the late 1950s, resin composites were introduced as dental restorative materials [5]. In addition to esthetic properties, these materials have the ability to bond to the dental structure without the need to remove the normal tissue. As a result of the ability to bond to the dental structure by the bonding system, the use of composites has increased conservatively in dentistry. Therefore, composites are used in different and static fields such as anterior and posterior caries, occlusion, cementation of indirect restoration, sticking orthodontic brackets and static changes in the teeth [6, 7].

In general, composite resins are a combination of hard non mineral particles that are attached by soft composite resins. They consist of three main parts:

1- Non mineral filler that is formed of particles such as glass, quartz or attached silica.

2- Monomer system including the starter system for beginning polymerization through the free radical reaction and stabilizer for the maximum stabilizing of the non cured composite and chemical stabilizing of the cured composite.

3-The adhesion factor which is usually organosilane chemically bonds the filler and the matrix resin.

The function of the composite depends on the consisting components. Some of the properties depend on the filler and the adhesive factor and other properties depend on the composite resin. Properties such as strength, hardness, resistance against grinding and the thermal expansion index depend on the type of filler and the adhesive factor. The color stabilizing and predilection to softness are related to the resin. Properties such as polymerization shrinkage and water absorption are related to both the resin matrix, and the type of filler and adhesive factor [8-10]. As a result of polymerization and the pressure due to that destruction, the composites are sealed marginally, causing distance, sensitivity after resto-

ration, color change of the restoration margins and even secondary decay. One other complication due to polymerization shrinkage is displacement of the cusps which may lead to dental sensitivity, cracks or even dental fracture [11, 12].

Water absorption and hygroscopic expansion is one of the physical properties of the composites. After water absorption, the quality of the composite may change and its efficiency as a restorative material may not exist. In addition, if the hygroscopic expansion does not destruct the structure of the composite, it may compensate the polymerization shrinkage. On the other hand, there have been limited studies regarding hygroscopic expansion and dimensional changes in low-shrinkage composites. Since these composites have been introduced with the claim of decreasing polymerization shrinkage, evaluating the hygroscopic expansion and comparing it with the polymerization shrinkage in these material is of great importance [13].

Regarding the high variety of the number of available composites, there have been several articles published based on comparison of the different properties such as microhardness, microleakage and thermal expansion. In none of these studies, the shrinkage or the hygroscopic expansion of the three mentioned composites have been compared with each other. Martin et al. and Rutterman et al. have compared shrinkage and hygroscopic expansion between different composite resins. They reached the conclusion that these composite resins have different shrinkage and hygroscopic expansions which are mostly due to the base resin used in these composites. They also showed that in the evaluated composites, the hygroscopic expansion does not have the ability to compensate the shrinkage [14, 15].

As a sample, in the national studies, Sadaghiani et al. evaluated the effect of the distance of the LED and halogen light curing machine on the microleakage of Z250 composite and reached the conclusion that the microleakage of all the sam-

ples hardened in zero distance was significantly higher than the samples hardened in 5 mm distance. Besides, the findings in this study showed that the ratio of the surface microleakage to the depth in the LED machine is higher than halogen [16]. Another important point in the mentioned studies is that in the majority of them single variable statistical tests such as analysis of variance was used to compare different properties of the composite. Based on the above mentioned matters, the objective of this study was to use an appropriate statistical method to analyze the longitudinal data in order to evaluate the change in the hygroscopic expansion of three Z250, P90 and Kalore composites in a three-month period in two saliva and distilled water environments.

Materials and Methods

This experimental study was conducted to evaluate the effective factors on the hygroscopic expansion of three Z250, P90 and Kalore cylindrical composites and the details of the composite properties are demonstrated in Table 1. Of each composite, ten 6×4 mm (length 6 mm and diameter 4 mm) cylindrical samples were made and were then placed in normal saliva and distilled water for three months. The length of these cylindrical samples were measured 18 times—24 hours, 48 hours, 5 days, one week, 9 days, 11 days, two weeks, 18 days, 20 days, three weeks, one month, 6 weeks, two months, ten weeks, 78 days, 80 days and three months after preparation. For each condition (environment-composite), five samples were considered and in order to increase the accuracy in each measurement step, each sample was measured twice. In this study, to evaluate the linear hygroscopic expansion, a digital micrometer with a measurement accuracy of 1 micron was used.

For describing the data, the mean and standard deviation of hygroscopic expansion for each composite in the two environments together with the appropriate linear graphs have been used. Besides, for simple comparison of the composites, the one way analysis of variance (ANOVA) and for comparison of the two maintaining environ-

ments, t test for two independent samples was used. Since multiple measurements on each composite lead to dependent response; therefore, analysis of these data needs methods that consider these dependencies [17, 18]. Thus, in order to define the simultaneous effect of the three independent variables; namely, the type of composite, the maintaining environment and time on hygroscopic expansion in 18 described times, the the marginal modeling approach which is one of the most common and efficient methods for the analysis of longitudinal data was used.

[19,20]. SPSS 16 for Windows (SPSS Inc., Chicago, Il) was used for statistical analysis. P value less than 0.05 was considered statistically significant.

Results

In Table 2, the mean and standard deviation of each composite's hygroscopic expansion is displayed in distilled water and oral saliva environments. The reported statistics are the mean of the measurements in 18 repeated times. Therefore, to understand the difference between the studied composites, we have demonstrated graphs 1 & 2 in which the change in the mean hygroscopic expansion regarding the maintaining environment and time may be observed more clearly. It may be deduced that Z250 composite has the least and P90 composite has the highest hygroscopic expansion. The results from t student test show that there is a significant difference statistically between distilled water and saliva environments ($p=0.001$).

The results from variance analysis show that the difference between the three composites is statistically significant ($p<0.001$). As mentioned before the main reason for the significant difference in these two tests is the high number of observations—18 times measurement for each sample.

Although the data were measured repeatedly in a period of time and subsequently had internal dependence, using such tests may not obtain accurate results because in single variable tests such as t test or one way analysis of variance we are

Table 1: Properties of the Studied Composites

Composite	Type	Manufacturer	Batch No.	Color Shade	Monomer	Filler (Wt %)
Filtek Z250	Micro-Hybrid	3M ESPE, St Paul, MN, USA	N132502	A3	Bis-GMA, UDMA, Bis-EMA	Silicon dioxide, Zirconium dioxide (82%)
Filtek P90	Micro-Hybrid	3M ESPE, St Paul, MN, USA	N146379	A3	Silorane (3,4-epoxycyclohexylethyl cyclopolydimethylsiloxane, Bis-3,4-epoxycyclohexylethylphenylmethylsilane)	Silicon dioxide, ytterbium Trifluoride (76%)
GC Kalore	Nano-Hybrid	GC-International Tokyo-Japan	0906021	A3	DuPont monomer, UDMA, Dimethacrylate comonomers	Perpolymerized filler (lanthanoid fluoride), fluoroaluminosilicate glass, strontium/barium glass, Silicone dioxide (82%)

Table 2: Mean and standard Deviation (mm) of Hygroscopic Expansion of Composites in Saliva and Distilled Water

		Environment	
		Normal Saliva	Distilled Water
Type of Composite	Z250	5.96 ± 0.013	5.97 ± 0.010
	P90	5.98 ± 0.021	6 ± 0.027
	Kalore	5.98 ± 0.021	5.97 ± 0.014

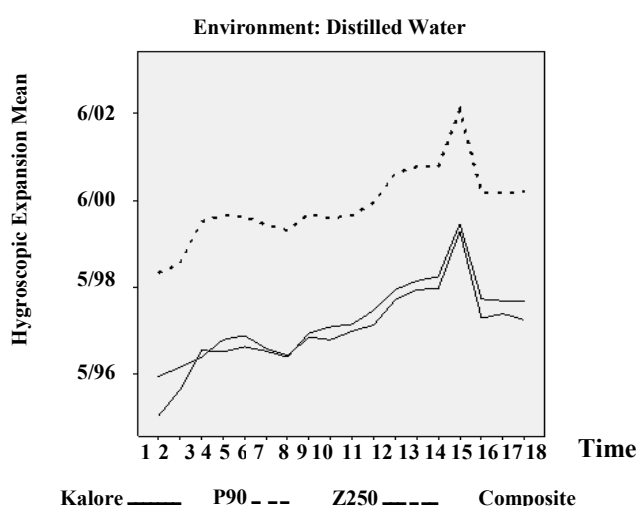
not able to evaluate the effect of time. In order to adjust this defect, applying complicated statistical models to analyze the data and to measure the dependence structure of the collected measure. Although the data were measured repeatedly in a period of time and subsequently had internal dependence, using such tests may not obtain accurate results because in single variable tests such as t test or one way analysis of variance we are not able to evaluate the effect of time. In order to adjust this defect, applying complicated statistical models to analyze the data and to measure the dependence structure of the collected measurements in the time period seems necessary. For the purpose of evaluating the type of composite, time and the maintaining environment on the hygroscopic expansion simultaneously, we used the marginal modeling approach which is one of the most prevalent methods used for analysis of longitudinal dependent data. In this model, the internal dependence structure of the data is considered as a parameter in the model. The marginal model used is:

$$Y_{it} = \theta + \beta_1 \text{Time}_{it} + \beta_2 \text{Composite}_i + \beta_3 \text{Environment}_i \\ i = 1, 2, \dots, 30; t = 1, 2, \dots, 18$$

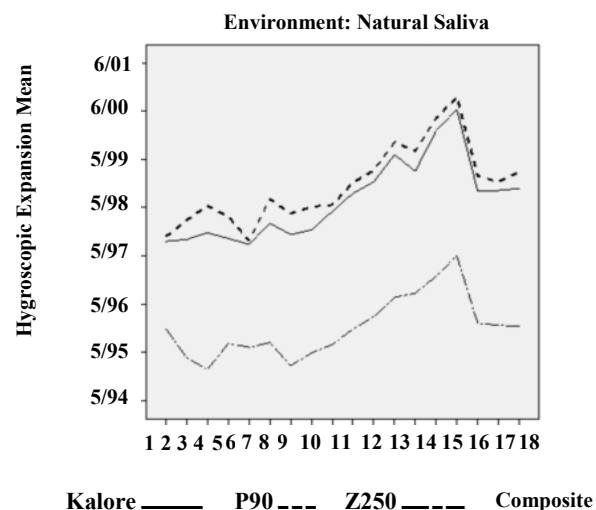
In which Y_{it} stands for the hygroscopic expansion of the i^{th} composite in t^{th} time [21-23].

The results of this fitting have been demonstrated in Table 3.

The results show that pass of time has a significant effect on hygroscopic expansion of the composite ($p < 0.001$). In addition, the type of composite has a significant effect on the hygroscopic expansion statistically; this is to say that the difference between Z250 composite and P90 composite was significant ($p = 0.008$), but this model did not show a statistically significant difference between P90 composite and Kalore composite ($p = 0.085$). On the other hand, there was no significant difference statistically between the two maintaining environments of distilled water and normal saliva regarding hygroscopic expansion ($p = 0.777$).



Graph 1: Comparison of the mean hygroscopic expansion of the composites in distilled water in 18 different times



Graph 2: Comparison of the mean hygroscopic expansion of the composites in normal saliva in 18 different times

Table 3: The Results of Marginal Model Fitting to Hygroscopic Expansion of the Composites

Variable	Category	Estima- tion	Standard Deviation	P	Odds ratio
Intercept	--	5.980	0.0077	--	--
Type of Composite	Z250	-0.022	0.0083	0.008	0.978
	Kalore	-0.017	0.0099	0.085	0.983
	P90		Reference category	Reference category	
Maintaining Environment	Distilled water	-0.002	0.0069	0.777	0.998
	Normal saliva		Reference category	Reference category	
Time	--	0.001	0.0001	<0.001	1.001

Discussion

Although there have been many studies in the field of water absorption, hygroscopic expansion and dissolution of composite, relating the present study to those is a difficult thing to do due to the different time spans, variety of composites and the different measurement methods [24]. The considerable matter is that in studies related to hygroscopic expansion, the evaluated samples were of different sizes because after floating in water, different sized samples need different times in order to reach equilibrium—the smaller the sample is, the shorter the time necessary for it to reach equilibrium is. Certainly the chemical

structure of the substance is important, because the more the substance has propensity to absorb water the later it reaches equilibrium [24, 25]. In this study, the samples were cylinders 6 mm in length and 4 mm in diameter. The advantage of using such sized samples are that they are similar to big dental restorations and the dimensions are comparable to many of the restorations which are performed in clinic. This finding that composites need a long duration of time to reach dimensional equilibrium has been confirmed by the present study and so many other studies. In 1994, Momoi and McCabe evaluated the hygroscopic expansion of composites for 6 months

through measurement of the entered force from the composite to the wall of the brass generator [26]. The results showed that in the course of 6 months, the force increased. This matter confirmed unsaturated areas in the samples. The mentioned study was in accordance with many studies such as the present study [27, 28]. Based on the results of the past studies, in the first days, the composites have a high speed of water absorption and hygroscopic expansion, but in order to reach equilibrium more time is necessary [29]. In 1979, Pearson on a study regarding the maintenance time of composites in a water environment, showed that the amount of water absorption and hygroscopic expansion occurs in the first two weeks and reaches equilibrium during 8 weeks [30]. Martin et al. in a 64-day study mentioned that 63% of the expansion happens in the first 10 days and after 10 days although the expansion does not reach equilibrium, it does decrease [14]. Decrease in the amount of linear expansion through time may be due to two reasons; first, saturation of the composite polymer network and second, increase in the amount of dissolution of the composite particles. Rutterman et al. mentioned that with the increase of the sample's floating time in water, the dissolution increases and the hygroscopic expansion decreases [15]. Although in our study the equilibrium time is incongruent to other studies, graphs 1 and 2 clearly show the primary increasing trend of the hygroscopic expansion and subsequently its relative decrease from the fifteenth measurement (10 weeks) to the end. In this study, the three types of composite showed dimensional changes in which the substance had a statistically significant effect on the amount of expansion. On the contrary, the environment had no significant effect on the linear expansion statistically. The highest amount of hygroscopic expansion belonged to composite P90 which is congruent to the results of their study in 2011 [29]. The present study actually showed that Z250 composite has the least hygroscopic expansion; therefore, is better than the other two

composites regarding this matter. Z250 composite has UDMA monomers (urethane hydrophilic groups), Bis-GMA (hydroxyl groups) and hydrophilesthericbonds. P90 composite has silorane monomer which is a hydrophobic monomer. Some studies have introduced this composite as a composite with low expansion and an estimated polymerization expansion of less than 1% volume [31]. Thus, the high hygroscopic expansion of P90 composite despite the existence of siloxane molecule which has a hydrophobic property may put the surrounding dental tissues under a great amount of pressure consequently leading to pain, crack and even dental fracture [26]. Some other studies on P90 composite have reported approximately similar results, although in none of these studies this composite has directly been compared with two other composites in the same environmental circumstance as this study.

Some studies have mentioned the high sealing ability of P90 composite [26, 31, 32]. In Palin et al.'s study, in which the solution containing the samples (distilled water) was changed every two weeks, the water absorption of P90 composite was significantly lower than Z250 composite [33]. Regarding Kalore composite, the present study showed that in distilled water, this composite has a low hygroscopic expansion (approximately similar to Z250 composite), but in normal saliva environment, it has a high hygroscopic expansion (roughly comparable to P90 composite).

In Wei et al.'s study, a high hygroscopic expansion has been reported for this composite [29].

The results of this study indicated that two normal saliva and water maintaining environments had no significant difference statistically regarding hygroscopic expansion. Although some studies have mentioned the decrease of water absorption and hygroscopic expansion in saliva as a result of decrease in the osmotic slope, in most of these studies artificial saliva was used as the maintaining environment [34]. For instance, Martin et al. and also Musaje et al. evaluated the

amount of water absorption and solution of the composites in distilled water and artificial saliva in a two month period and they reached this conclusion that the composites maintained in artificial saliva have a higher increase in weight and a lower solubility compared to composites maintained in water [14, 35].

Finally, we have to mention that some of the times the results of student's t test and variance analysis were not in accordance with the results of the statistical model used for this study. This was due to the fact that none of the single variable tests consider the effect and passing of time, but the marginal model considers the simultaneous effect of time, composite and maintaining environment on hygroscopic expansion; therefore, the results are more precise and valid statistically.

Conclusion

Overall, the results show that the type of composite and the passing of time have a significant effect on hygroscopic expansion statistically. So it is better to use composites with a lower hygroscopic expansion such as Z250 for dental restoration. In addition, for analysis of the data of the composites' hygroscopic expansion—usually collected as repeated measurement in a period of time—advanced statistical models, in which dependence between the data and also the effect of time is measurable, should preferably be used.

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