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Effect of Food Stimulating Liquids on The Flexural Strength of Direct and Indirect Composite -An Invitro Study

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Abstract

Background: *The oral cavity is frequently exposed to exogenous substrates, and composites are known to be vulnerable to the impacts of physical and chemical agents. The study evaluated the effect of food simulating liquids on the flexural strength of direct and indirect composite on exposure to 500ml Artificial saliva 0% Heptane, 2% Citric acid and 2% Aqueous ethanol. 60 rectangular specimens with prescribed dimensions of 25x2x2mm were constructed. They were then tested for flexural strength using a universal testing machine. Flexural strength of direct composites was significantly affected by food simulating liquids, while no significant effects were noted on indirect composites. In direct composites, heptane was found to be the most effective, followed by 50% ethanol, while in indirect composites, 2% citric acid was found to be the most effective, followed by 50% heptane. Thus, food-imitated liquids, notably 50% heptane, 50% ethanol, and 2% citric acid, affect the flexural strength of composites, putting composite restorations at jeopardy in the mouth.*

Keywords: *Composites, Ethanol, Citric Acid, Artificial Saliva, Heptane*

Introduction

When teeth are discoloured, misshapen, or cracked, there is often a conscious effort to avoid smiling. Alternative restorative materials can restore the tooth's form, function, and aesthetics. Dental composites have been deemed the most appropriate restorative material for anterior application due to their highly cross-linked polymer reinforced with a dispersion of glass, crystalline, resin filler particles and/or short fibers related to the matrix by a silane coupling agent.1.

The inorganic filler ingredient in the dispersion phase of composite resins determines the physical and mechanical properties of composite materials. These filler particles are introduced to the organic phase to improve the organic matrix's physical, mechanical, and chemical properties, as well as its electrical and optical properties.2 Flexural strength is a material parameter defined as the stress in a material shortly before yielding in a flexure test. It is also known as modulus of rupture, bend strength, or transverse rupture strength.3

As we know that, oral cavity is continuously subject to changes in its environment in terms of temperature, pH, and so on, as a result of food and fluid intake of various temperatures and pH, as well as internal gastrointestinal diseases such as acidic reflux. As a result, by exposing resin-based composites to chemical agents orally, they weaken the matrix, resulting in the hydrolytic breakdown of the binding between the silane and filler particles and the filler-resin matrix, and the plasticizing action of water causes debonding and softening of dental resins.4 Therefore, a strong and stable resin bind to metal is required for the clinical application of composite veneered metal crowns.

Flexural bond strength is a crucial quality in terms of the restoration's resistance to deformation or fracture caused by occlusal loads, as well as the maintenance of the marginal seal.5 Direct composites have a number of clinical drawbacks, including polymerization shrinkage and poor shape. To counteract this, the indirect composite system was developed. They have properties like improved contour, interproximal contacts and potential for decreased postoperative sensibility.

As a result, a good understanding of how dietary acids affect hardness requires further inquiry and evaluation to add to the already available knowledge on composite qualities.6 Therefore, this study was carried out to assess the impact of various food imitating liquids on the flexural strength of direct and indirect composites.

Aim

To investigate the effect of food simulating liquids on the flexural strength of direct and indirect composite.

Objective

1. To evaluate the flexural strength of direct and indirect composite on exposure to Artificial saliva.
2. To evaluate the flexural strength of direct and indirect composite on exposure to 50% Heptane.
3. To evaluate the flexural strength of direct and indirect composite on exposure to 2% Citric Acid.
4. To evaluate the flexural strength of direct and indirect composite on exposure to 50% Aqueous Ethanol.

Materials and Method

A- Materials

1. **INDIRECT COMPOSITE** (CERAMAGE®, Shofu Dental India Private Limited) **[**According to the manufacturer, this micro- ceramic polymer system contains 73% zirconium silicate fillers (PFS-Progressive Fine Structured Fillers) evenly distributed in an organic polymer matrix. Flexural strength of CERAMAGE® is about 146 MPa.**]** as shown in figure 1.
2. **DIRECT COMPOSITE** (CERAM X® Sphere TECTM, Dentsply Sirona) **[**according to manufacturer, in ceram.x, the Sphere TEC fillers (≈15 µm) are combined with non- agglomerated barium glass fillers (≈0.6 µm) and ytterbium fluoride (≈0.6µm). Furthermore, the composite contains highly dispersed, methacrylic polysiloxane nano-particles, which are chemically similar to glass or ceramics. Flexural strength of CERAM X® is about 100 MPa**]** as shown in figure 2.
3. **Artificial saliva, 50% Heptane, 2% Citric Acid, 50% Aqueous Ethanol** as shown in figure 3,4,5,6 respectively**]**.

Figure 1: Indirect Composite (Ceramage)

Figure 2: Direct Composite (Ceram x)

Figure 3: Artificial Saliva

Figure 4: 50% Heptane

Figure 5: 2% Citric Acid

Figure 6: 50% Aqueous Ethanol

The food simulating liquids were bought from Lab supplies India Private Limited.

B- Method

1. Sample Size

A total of 60 specimens were generated, with 30 direct composites, 30 indirect composites respectively (as shown in figure 9a & b).

The relevant sample size in each group is n=6 with a 95% confidence level and 80% power. 95% confidence level and 80 % power.**[7]**

Using the formula

$$n = \frac{2(Z_{\alpha} + Z_{1-\beta})^2 x \sigma^2}{d^2}$$

$Z\alpha = 1.96$ at 95% confidence level

$Z_{1-\beta} = 0.84$ at 80% power

σ = Combined standard deviation

d = mean difference

2. Preparation of Specimens

Konkan Specialty Polypropylene Private Limited created an ad hoc stainless-steel mould to construct 60 specimens of direct (CERAM X® Sphere TECTM, Dentsply Dentsply Sirona) and indirect composites (CERAMAGE®, Shofu Dental India Private Limited) of size 25×2×2mm7(As shown in figure 7). This mould had six slots with predefined dimensions of 25×2×2mm. Every time a new set of composite material was placed into the mould, it was lubricated from

the inside with Vaseline petroleum jelly. A single set yielded a total of six specimens. Excess material on the slot's top was removed by pressing a glass slab on it. Following that, the composites were cured using the composite curing gun (Curing Light LED.D, Woodpecker©) and composite curing unit for direct composite and indirect composite, respectively. (As shown in figure 8a and b). The specimens were retrieved once the

mould was opened. Each specimen was measured precisely with a Vernier calliper. Lab Supplies India Private Limited in Bangalore, Karnataka, provided food stimulating liquids such as fake saliva, 50% heptane, 2% citric acid, and 50% aqueous ethanol. All group D and group I specimens were then immersed in the relevant meal simulating liquids (6 per liquid) in an incubator for 7 days, according to their subgroups, while the sample specimens exposed to air were retained in an open glass beaker as a control. (As shown in figure 10 and 11).

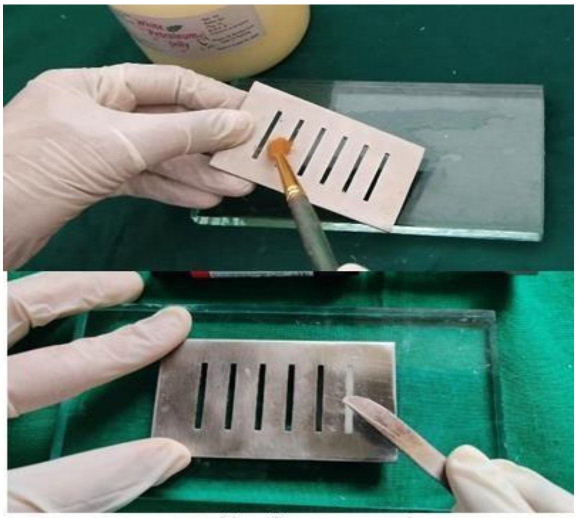
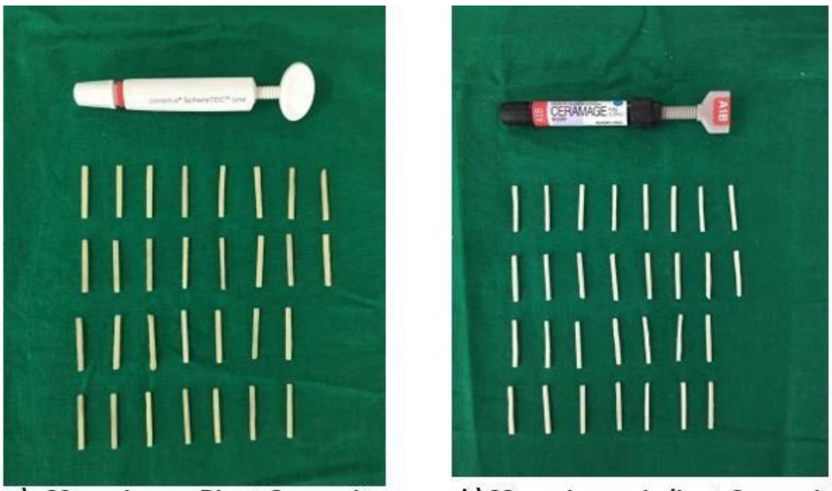


Figure 7: Mold and Specimen Fabrication

a) Direct Composite b) Indirect Composite

Figure 8: Curing of Specimen illustrated above (Direct and Indirect composite methods)



a) 30 specimens: Direct Composite b) 30 specimens: Indirect Composite

Figure 9: A total sixty specimens were developed (above)

Figure 10: Immersion of specimens in 'Food Simulating Liquids'.

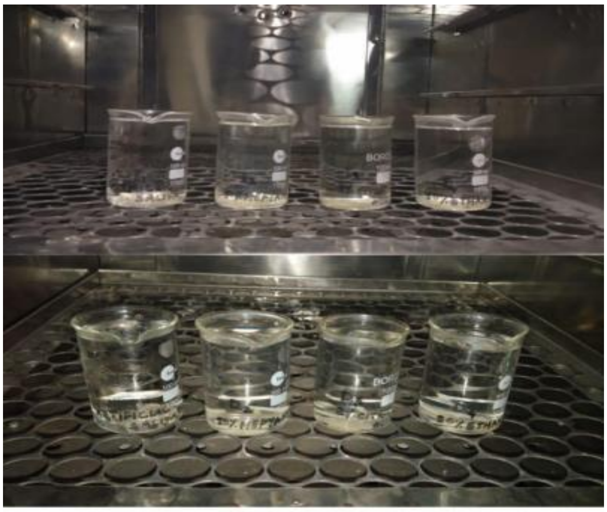


Figure 11: Specimen Preserved in Incubator at 37°C for 7 Days

3. Grouping of Samples

Out of the total 60 specimens, 30 were direct composite and 30 were indirect composite, labelled as groups D and I, respectively. Furthermore, the specimens in both groups were classified into 5 subgroups each, having 6 specimens in each subgroup, as shown below. These five subgroups were made up of four food stimulating liquids and one control to which the specimens were subjected, where control (Air) was 0 and artificial saliva was 1, Heptane was 2, 2%. Citric acid was 3 and 50% Aqueous ethanol was 4. However, group D0, D1, D2, D3, D4 and group I0, I1, I2, I3 and I4 are subgroups of group D and group I, respectively.

4. Specimen Testing

The Control samples (D0 and I0) were kept at room temperature for a week. The remaining subgroups, (D1, D2, D3, D4) and (I1, I2, I3, I4), were submerged in four different liquids that simulated food (1, 2, 3, 4) and incubated for a week (7 days) at a temperature of 37. These specimens were removed after a week of immersion and incubation, dried by air and ten tested for flexural strength by being aligned so that the load was placed in the middle using a universal testing machine. (As shown in figure 12). Flexural strength testing was conducted at a crosshead speed of 1 mm per minute up until the specimen fractured. The flexural strength (S) will be computed in MPa using the following formula after the greatest force exerted till the fracture of the specimens was recorded: 3FL/2BH2 (F is the greatest force applied in Newton, L is the distance between the supports, B is the sample width, and H is the sample height. Following that, the mean and standard deviations were computed.)

	Control (Air)	Artificial Saliva (500ml)	50% Heptane	2% Citric Acid	50% Aqueous Ethanol
Direct [D] composite (30 samples)	D_0 (6 each)	D_1 (6 each)	D_2 (6 each)	D_3 (6 each)	D_4 (6 each)
Indirect [I] composite (30 samples)	I_0 (6 each)	I_1 (6 each)	I_2 (6 each)	I_3 (6 each)	I_4 (6 each)

Figure 12: Testing of Specimens for Flexure Strength via Universal Testing Machine

Stastical Analysis

The tabulated data was subjected to statistical analysis using the following formula and Kruskal Wallis test. A statistical package SPSS version 17.0 was used to do the analysis where P < 0.05 was considered as significant.

$$n = \frac{2(Z_{\alpha} + Z_{1-\beta})^2 x \sigma^2}{d^2}$$

$Z\alpha$ = 1.96 at 95% confidence level

$Z_{1-\beta}$ = 0.84 at 80% power

σ = Combined standard deviation

d = mean difference

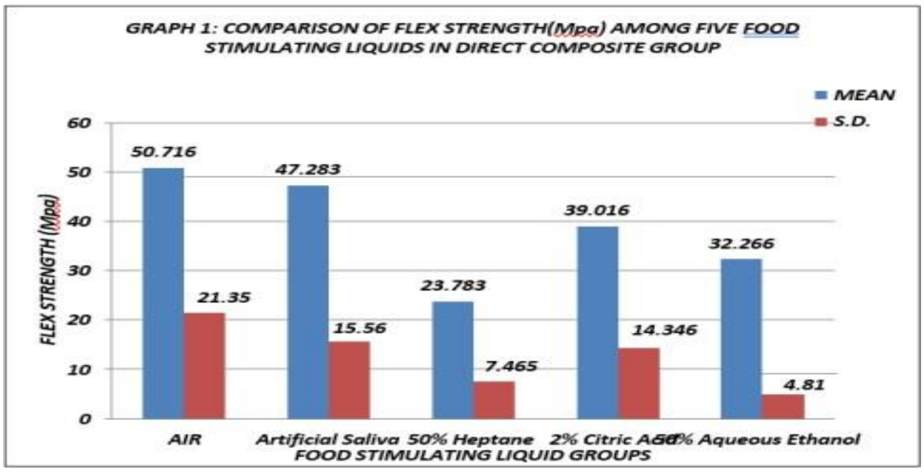
Results

In the present study, the flex strength was evaluated for the 6 specimens of direct (CERAM X® Sphere TECTM, Dentsply Sirona) and indirect composite (CERAMAGE®, Shofu Dental India Private Limited) in the five-food stimulating (Control group), artificial saliva, 50% heptane, 2% citric acid and 50% Aqueous ethanol.

Table 1 = Mean & standard deviations for the flex strength for the above mentioned specimens, with indirect composites having higher flex strength than direct composites. It was higher for 50% aq. ethanol subgroup (75.733 ± 22.055) and lowest for 2% citric acid subgroup(60.650 ± 33.326) as compared to highest for the control82.533 ± 15.622) while in the direct composites group, it was higher for artificial saliva (47.283 ± 15.560) with lowest for 50% heptane subgroup (23.783 ± 7.465) as compared to highest for the control (50.716 ± 21.350). (Graph 1, Graph 2)

Table 1: Descriptive Statistics of Flex strength for different liquids in Direct and Indirect composites

MEDIUMS	GROUPS	N	Mean ± S.D.
AIR (control)	Direct	6	50.716 ± 21.350
	Indirect	6	82.533 ± 15.622
Artificial Saliva	Direct	6	47.283 ± 15.560
	Indirect	6	64.866 ± 28.384
50% Heptane	Direct	6	23.783 ± 7.465
	Indirect	6	63.250 ± 24.780
2% Citric Acid	Direct	6	39.016 ± 14.346
	Indirect	6	60.650 ± 33.326
50% Aqueous Ethanol	Direct	6	32.266 ± 4.810
	Indirect	6	75.733 ± 22.055



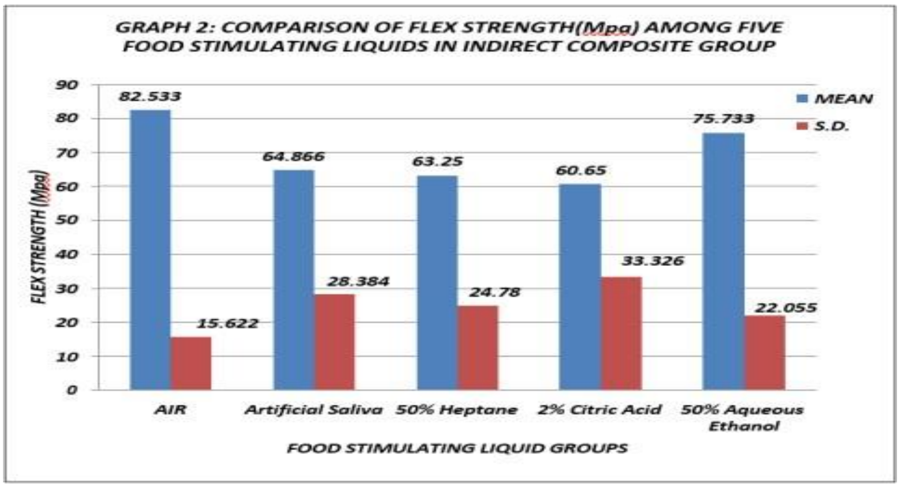


Table 2: Comparison between the Direct and Indirect composites for different liquids using Mann Whitney U test

LIQUIDS	GROUPS	N	Mean Rank	Sum of Ranks	t	P value
AIR	Direct	6	4.00	24.00	-2.402	.016*
	Indirect	6	9.00	54.00		
	Total	12				
Artificial Saliva	Direct	6	5.00	30.00	-1.44	.150
	Indirect	6	8.00	48.00		
	Total	12				
50% Heptane	Direct	6	3.50	21.00	-2.882	.004**
	Indirect	6	9.50	57.00		
	Total	12				
2% Citric Acid	Direct	6	4.83	29.00	-1.601	.109
	Indirect	6	8.17	49.00		
	Total	12				
50% Aqueous Ethanol	Direct	6	3.50	20.00	21.000	.004**
	Indirect	6	9.50	54.00		
	Total	12				

** - significant*

*** - highly significant*

Table 2=When the comparison for the direct and indirect composite groups was done using Mann Whitney U test, it was observed that the results were statistically significant for the subgroup air (p = 0.016) and highly significant for the subgroups namely, 50% heptane (p = 0.004) and50% aq. Ethanol (p = 0.004).

Table 3: Comparison of different mediums in direct and indirect composites using Kruskal Wallis test

GROUPS	MEDIUMS	N	Mean Rank	F	P value
Direct	AIR	6	20.42	12.382	.015*
	Artificial Saliva	6	21.58		
	50% Heptane	6	5.92		
	2% Citric Acid	6	16.50		
	50% Aqueous Ethanol	6	13.08		
	Total	30			
Indirect	AIR	6	20.83	3.505	.477
	Artificial Saliva	6	13.67		
	50% Heptane	6	13.00		
	2% Citric Acid	6	13.17		
	50% Aqueous Ethanol	6	16.83		
	Total	30			

* - *significant*

Table 3 =For the intergroup comparison between the food stimulating liquids, Kruskal Wallis test was used. The results were statistically significant for direct composite specimens (p = 0.015) and insignificant for indirect ones (p = 0.477) showing that the effect of liquids on the flex strength for the indirect composite group was less.Furthermore, to assess the effect of the food stimulating liquids on the flex strength for the individual subgroups, one-to-one comparison (pairwise comparison) was done using Post Hoc test.

Table 4 = In direct composite group showed statistically significant result only for air vs. 50% aq. ethanol (p = 0.031) and highly significant for air vs. 50% heptane (p = 0.003) and artificial saliva vs. 50% heptane (p = 0.008) while the results were non-significant for indirect composite group.

Table 4: Pairwise comparison between the medium subgroups for Direct and Indirect composite groups for using Post Hoc test

GROUPS	(I) Liquids	(J) Liquids	Mean Difference (I-J)	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Direct	AIR	Artificial Saliva	3.433	.675	-13.23	20.102
		50% Heptane	26.933*	.003	10.263	43.602
		2% Citric Acid	11.700	.161	-4.969	28.369
		50% Aqueous Ethanol	18.450	.031	1.780	35.119
	Artificial Saliva	AIR	-3.433	.675	-20.102	13.236
		50% Heptane	23.500	.008	6.830	40.169
		2% Citric Acid	8.26	.317	-8.402	24.936
		50% Aqueous Ethanol	15.0166	.075	-1.652	31.686
	50% Heptane	AIR	-26.933	.003	-43.602	-10.263
		Artificial Saliva	-23.500	.008	-40.169	-6.830
		2% Citric Acid	-15.233	.072	-31.902	1.436
		50% Aqueous Ethanol	-8.483	.305	-25.152	8.186
	2% Citric Acid	AIR	-11.700	.161	-28.369	4.969
		Artificial Saliva	-8.266	.317	-24.936	8.402
		50% Heptane	15.233	.072	-1.436	31.902
		50% Aqueous Ethanol	6.750	.412	-9.919	23.419
	50% Aqueous Ethanol	AIR	-18.450	.031	-35.119	-1.780
		Artificial Saliva	-15.016	.075	-31.686	1.652
		50% Heptane	8.483	.305	-8.186	25.152
		2% Citric Acid	-6.750	.412	-23.419	9.919
Indirect	AIR	Artificial Saliva	17.666	.242	-12.699	48.033
		50% Heptane	19.283	.203	-11.083	49.649
		2% Citric Acid	21.883	.150	-8.483	52.249
		50% Aqueous Ethanol	6.80	.649	-23.566	37.166
	Artificial Saliva	AIR	-17.66	.242	-48.033	12.699
		50% Heptane	1.616	.914	-28.749	31.983
		2% Citric Acid	4.216	.777	-26.149	34.583
		50% Aqueous Ethanol	-10.866	.468	-41.233	19.499
	50% Heptane	AIR	-19.283	.203	-49.649	11.083
		Artificial Saliva	-1.616	.914	-31.983	28.749
		2% Citric Acid	2.600	.861	-27.766	32.966
		50% Aqueous Ethanol	-12.483	.405	-42.849	17.883
	2% Citric Acid	AIR	-21.883	.150	-52.249	8.483
		Artificial Saliva	-4.216	.777	-34.583	26.149
		50% Heptane	-2.600	.861	-32.966	27.766
		50% Aqueous Ethanol	-15.083	.316	-45.449	15.283
	50% Aqueous Ethanol	AIR	-6.800	.649	-37.166	23.566
		Artificial Saliva	10.866	.468	-19.499	41.233
		50% Heptane	12.483	.405	-17.883	42.849
		2% Citric Acid	15.083	.316	-15.283	45.449

Discussion

In modern dentistry, dental composites are the most widely used and accepted tooth-colored restorations. However, they, like any other dental restorative material, have downsides. This involves shrinkage during polymerization as well as low fracture and wear resistance.[8] The contents of the oral cavity, as well as its organic acids, tend to impair the physical qualities of composites such as hardness, flexural strength, and flexural modulus.[9] Flexural strength, also known as transverse strength, is the strength of a rod supported by two parallel supports while subjected to static stress.[7] Flexural strength is critical for composite restorations, especially those that are stressed and subjected to tension and compression pressures, such as posterior restorations.[10] In the current investigation, indirect composites outperformed direct composites in terms of overall maximum flexural strength. This finding contradicts a 2019 study by Marcia, which found that direct composites have much higher flexural strength than indirect composites.[11] This is due to the varying filler content in the composites evaluated, which may alter the hardness and strength. The findings of the current investigation are consistent with a 2017 study by Mohammadi et al. who found that ethanol drastically reduced the flexural strength of composite resins based on methyl and silorane. Heptane and citric acid, on the other hand, had no effect on the same resins.[7]

1. Effect of Air

The influence of air on the composites was retained in the current investigation as a comparative control for evaluating the flexural strength of the materials employed. When exposed to air, the mean flexural strengths of the direct and indirect composites were 50.716 (±21.350) and 82.533 (±15.622), respectively, and these values were statistically significant (As shown in Table 1&2). Due to air exposure, the flexural strength of direct composites was generally impacted more than indirect composites tested. (As shown in Table 3) Additionally, it was noted that, in the direct composite group, the results were non-significant for the indirect composite groups except for the air vs 50% aq. ethanol ($p = 0.031$) and the air versus 50% heptane ($p = 0.003$). (As shown in Table 4). However, when conditioned with air, bulk-fill composite demonstrated the highest flexural strength when compared to distilled water, citric acid, and ethanol in a study done by Ahmed in 2018.

2. Effect of Artificial Saliva

When exposed to artificial saliva in the current investigation, the mean flexural strength for direct and indirect composite was 47.283(±15.560) and 64.866(±28.384), respectively. This result was not statistically significant (p=0.015). (As shown in Table 1&2) In comparison to the indirect composite evaluated, the effects of Artificial saliva were statistically significant (p=0.015) for the direct composite group (As shown in Table 3). In the direct composite group, it was also noted that the result was statistically significant only for artificial saliva vs. 50% heptane (p = 0.008) and not for any other food stimulating liquid examined. (As shown in Table 4). In 1994, Lee SY conducted research on the effects of synthetic saliva on composite bond strength and found that storage time had no bearing on the bond strength.**[**12**]**

3. Effect of 50%Heptane

The mean flexural strength for direct and indirect composite in the current investigation was 23.783(±7.465) and 63.250(±24.780), respectively, when exposed to 50% heptane, which was statistically highly significant (p=0.004). (As shown in Table 1&2). When compared to the indirect composite group, the effects of 50% heptane were statistically significant (p=0.015) for the direct composite group (As shown in Table 3). Additionally, it was noted that the results for air versus 50% heptane (p = 0.003) and artificial saliva versus 50% heptane (p = 0.008) were extremely significant in the direct composite group (As shown in Table 4) A Similar to the current investigation, U Yap et al. in 2000 reported that immersion in heptane increased the flexural strength of every composite and polyacid-modified composite evaluated significantly compared to citric acid, ethanol and deionized water.**[**13**]**

4. Effect of 2% Citric Acid

When subjected to 2% citric acid in the current investigation, the mean flexural strength for direct and indirect composite was 39.016 (±14.346) and 60.650 (±33.326), respectively. However, this result was not statistically significant (p=0.109) (AS shown as Table 1 and 2) When compared to the indirect composite group, the effects of 2% citric acid were statistically significant (p=0.015) for the direct composite group (As shown as Table 3). Additionally, it was noted that the outcome for the citric acid direct and indirect composite groups was inconsequential (As shown in Table 4). According to A U Yap et al. in 2000, when subjected to aqueous solutions of citric acid, significant differences were found between the flexural strengths of several composites and their polyacid counterparts.**[**14**]** It is well known that citric acid considerably reduces the microhardness of materials used in tooth-colored restorations.

5. Effect of 50% Aqueous Ethanol

When exposed to 50% aqueous ethanol in the current investigation, the mean flexural strength for direct and indirect composite was 32.266(±4.810) and 75.733(±22.055), respectively. This result was very significant (p=0.004) (As shown in Table 1 and 2) In comparison to the indirect composite examined; the effects of 50% aqueous ethanol were statistically significant (p=0.015) for the direct composite group (As shown in Table 3). Additionally, it was noted that the results for the ethanol-infused direct and indirect composite groups were negligible (As shown in Table 4). According to A U Yap et al. in 2000, when composite and polyacid-modified composite materials were tested after conditioning with a 50% ethanol-water solution, substantial changes were found in their flexural strength14.The flexural strength of composites was dramatically decreased by an ethanol solution, as demonstrated by Yesilyurt in 2009 and Mohammadi in 2017.**[**7**]**

Conclusion

All the dental restorations in the oral cavity are affected by the products that are consumed by the patient. Foods, beverages, candies and mouthwashes are the most common things a human oral cavity is exposed to. The present study concluded that food simulating liquids compromise the flexural strength of composite restoration. More investigations need to be carried out in order to study and manufacture newer composite materials which can withstand attacks by chemicals in food.

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