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ORIGINAL ARTICLE

Influence of Different Beverages on the Flexural Strength of Two Composite Restorative Materials: An *In Vitro* Study

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ABSTRACT
Dental composites are the preferred material for restorative procedures involving cosmetic restoration. The growing consumption of various beverages and their harmful effects on the mechanical performance of composite resins underscores the urgent need for further investigation. This study aims to analyze beverages' impact on composites' flexural strength. Two types of composite resins i.e., nanohybrid (Synergy D6, Coltene) from group 1 (n=30) and microhybrid (3M ESPE P60) from group 2 (n=30) were tested under the effect of beverages, i.e., distilled water (control group- subgroup 1), sprite (subgroup 2) and tea (subgroup 3). A total of 60 specimens (25mm × 2mm × 2mm) were prepared using a steel device. All composite specimens were immersed in beverages for seven days. After seven days of immersion, flexural strength was calculated with a universal testing machine. Intergroup comparison of the flexural strength of two composite resins within each solution was done using Independent t-test. Comparison of the flexural strength of each composite resin immersed in three different solutions was done using one-way Analysis of Variance (ANOVA) test, followed by Post-hoc Tukey test for pairwise comparisons. Statistical significance was considered at p-value 0.05. A statistically significant difference in flexural strength was seen with higher flexural strength for 3M ESPE P60. The average flexural strength of nanohybrid composite in tea was 68.25 MPa, 71.44 MPa in Sprite and 72.56 MPa in distilled water. For the microhybrid composite, the mean flexural strength was 131.62 MPa in tea, 144.75 MPa in Sprite and 149.43 MPa in distilled water. Microhybrid composites showed better flexural strength as compared to nanohybrid composites in all beverages.
Keywords: *Distilled water, flexural strength, microhybrid, nanohybrid, sprite, tea, universal testing machine*

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INTRODUCTION

Composite resins are extremely adaptable restorative materials in the realm of dentistry because of the synergistic qualities of the constituents—the polymer matrix and fillers [1]. An activator-initiator system, optical modifiers, fillers made of glass, quartz, or silica, and a polymer matrix made up of monomers all affect how they work.[2]. Since their inception, dental composites have become more and more popular due to ongoing improvements in their properties. They are a popular option for many dental restorations because of their ability to provide both aesthetic appeal and useful benefits. The need for premium composite materials in contemporary dentistry has been further stimulated by the move towards more conservative and aesthetic dental procedures. Significant developments in dental technology and material research have shaped the history of dental composites.

The introduction of acrylic resins in 1940 improved aesthetics compared to silicate cements but exhibited overall poor wear resistance and high rate of polymerization shrinkage. To overcome these drawbacks, filler particles were incorporated which reduced thermal expansion, polymerization shrinkage and improved mechanical and physical properties [2]. Research and evolution of composite resins have advanced significantly over the past decade, resulting in the formation of a variety of restorative materials. These include microfilled, macrofilled, microhybrid, nanofilled and nanohybrid composites. Because of unique benefits, different needs for dental restorations can be met by different types of composites [3]. Nanofilled and nanohybrid composites, in addition to traditional microhybrid and microfilled composites have been introduced lately to improve performance. These innovations aim to combine high initial polish with superior polish, retention and gloss. Nanohybrid composites combine nanosized fillers with conventional filler particles, similar to microhybrid composites [4]. A comprehensive understanding of the mechanical properties of composite resins under various oral conditions is crucial for effective selection of the most appropriate ones for patients. The oral environment is dynamic, with temperature variations caused by the consumption of warm and chilled diet which significantly impacts the mechanical properties [5]. Flexural strength is one of the essential characteristics of composites that is impacted by food and beverage consumption. The maximum stress a substance can bear in bending before undergoing failure is known as flexural strength, or bending strength. It is measured by applying load to a specimen and recording the stress at the point of fracture [6]. Due to the forces applied during biting and chewing, high flexural stress in teeth is frequently seen in the occlusal aspect of molars and premolars. This is particularly true in cervical regions, where mechanical forces can cause abfractions that result in the loss of tooth structure at restorative margins and in cracked teeth. By adopting the proper dental treatments and preventative measures, it is easier to diagnose and stop additional damage. The premise behind this study was that there would be no discernible change in the flexural strength of nanohybrid and microhybrid composites when submerged in drinks.

MATERIAL AND METHODS

Two types of composites (Table 1) were evaluated to compare their flexural strength under the influence of tea, Sprite, and distilled water (control). Tested composites included 3M ESPE P-60 (microhybrid composite), Synergy D6, COLTENE, and Whaledent Pvt. Ltd. (nanohybrid composite). The beverages that were used were tea and Sprite (The Coca-Cola Company, United States).

Table 1: Types of Composites used with their details.

Composite	Filler composition	Matrix composition	Batch No.	Manufacturer	Type
Synergy D6 [9]	65 v% Amorphous silica, barium glass, prepolymerized filler (0.6-20) µm	Bis-GMA, UDMA, TEGDMA	0089437	Coltene, Whaledent AG, Altstätten, Switzerland	Nanohybrid
Filtek P60 [10]	61 v% Zirconia/silica (0.01-3.5) µm	Bis-GMA, UDMA, Bis-EMA	N511095	3M /ESPE, St Paul, MN, USA	Microhybrid

UDMA: urethane dimethacrylate, Bis-GMA: bisphenol-A glycidyl dimethacrylate, TEGDMA: triethyleneglycol dimethacrylate, Bis- EMA: ethoxylated bisphenol-A dimethacrylate.

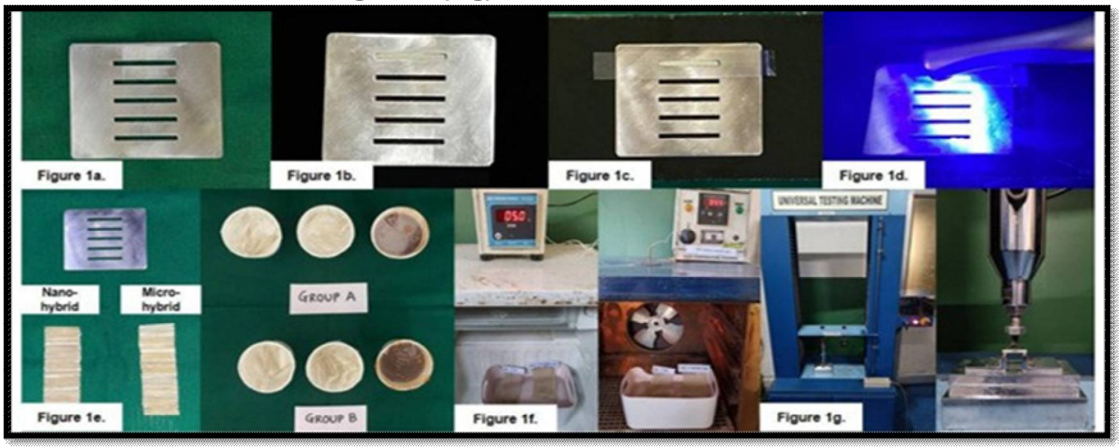
Tea solution was formulated by immersing five premade tea bags in 500 ml of boiling water for 10 minutes. A digital pH meter measured the acidity of each solution. The recorded pH readings for sprite were 3.3 and for tea were 4.9, both being less than the critical pH 5.5. The study included 60 samples, with 30 of each type of composite. A total of 60 rectangular specimens, each measuring 25 mm in length, 2 mm in depth and 2 mm in height, were prepared using a custom steel device (Fig. 1a). The device was then positioned on a coloured glass slab to achieve an even surface. Small increments of composites were compacted using standard dental pluggers (Fig. 1b). After compaction of the composites, a mylar sheet was utilized to abstain formation of oxygen layer and to have an even sample surface (Fig. 1c). Subsequently, each specimen was subjected to light-curing for 20 seconds with a light-emitting diode device (Woodpecker iLED Plus Light Cure Unit) following the manufacturer's guidelines (Fig. 1d). The prepared specimens were then examined to discard those with air bubbles or problems associated with compaction and polymerization. The prepared samples were then randomly divided into two groups, which were further divided into subgroups (Table 2). The samples were immersed for seven days in their respective beverages (Fig. 1e). Thermocycling was carried out for all the samples to simulate oral conditions. According to the ISO TR 11450 standard, thermocycling process of 500 cycles ranging from +5ºC to +55ºC is a suitable method for simulating artificial aging (Fig. 1f) [7]. Szalewski *et al* (2015) provided an algorithm determining the sevenday period suggesting that consuming one cup of coffee (around 150 mL) equates to one minute of contact with the oral cavity. For an average individual consuming roughly five cups of drinks per day (around 750 mL), immersing samples for one week simulates nearly five years of oral exposure [8]. All samples were stored in dark conditions to replicate the oral environment. After seventh day the samples were dried and evaluated for flexural strength using a universal testing machine.

Table 2: Groups and Sub-groups.

Group A Nanohybrid composite (n=30)		**Group B** Microhybrid composite (n=30)	
Subgroup A1(n=10)	Distilled water (Control)	**Subgroup B1**(n=10)	Distilled water (Control)
Subgroup A2(n=10)	Sprite	**Subgroup B2**(n=10)	Sprite
Subgroup A3(n=10)	Tea	**Subgroup B3**(n=10)	Tea

The specimens were placed on a steel jig at a crosshead speed of 1 mm/ min (Fig. 1g). The maximum load was recorded when the specimen fractured. The formula 3FL/2BH was used to determine bending strength [7]. Where, F = Maximum load (Newton), L = Span of 20 mm between the supports, B = Width of the specimen, H = Height of the specimen. The flexural strength mean and standard deviation were analyzed statistically. The data was compiled using Microsoft Excel software using Statistical package for Social Sciences (SPSS) version 26 considering statistical significance at p-value ⍰ 0.05. Intergroup comparison of flexural strength of two composite resin within each solution was done using Independent t-test. Comparison of flexural strength of each composite resin immersed in three different solutions was done using one-way Analysis of Variance (ANOVA) test, followed by Post-hoc Tukey test for pairwise comparisons.

Figure 1 (a-g): Materials and methods.



RESULTS

The nanohybrid composite's average flexural strength was 68.25 MPa in tea, 71.44 MPa in Sprite, and 72.56 MPa in distilled water. The microhybrid composite's mean flexural strength was 149.43 MPa in distilled water, 131.62 MPa in tea, and 144.75 MPa in Sprite. (Table 3). Distilled water, Sprite, and tea came in order of increasing strength for both nanohybrid and microhybrid composites (p-value < 0.001) (Tables 3, 4 and 5; Fig. 2). For both nanohybrid and microhybrid composites, significant differences were observed when comparing values from tea and Sprite to those from distilled water. The difference in flexural strength for nanohybrid composite between distilled water and Sprite was 0.990 and between Sprite and tea was 0.923 (p- value = 0.867). The difference in flexural strength for microhybrid composite between distilled water and Sprite was 0.963 and between Sprite and tea was 0.745 (p-value = 0.593). However, between distilled water and tea, the results were less pronounced, with a difference of 0.864 for nanohybrid composites and 0.585 for microhybrid composites.

Table 3: Comparison of flexural strength (in MPa) between two composites.

Solution	**Nanohybrid composite**		**Microhybrid composite**		**Difference**	**p-value**
	Mean	**SD**	**Mean**	**SD**		
Distilled water	72.56	12.60	149.43	46.28	-76.87	<0.001*
Sprite	71.44	24.02	144.75	34.67	-73.31	<0.001*
Tea	68.25	17.59	131.62	38.06	-63.37	<0.001*

Statistical test used: Independent t test; * indicates a significant difference at $p \leq 0.05$

Additionally, the difference between tea and Sprite was greater for nanohybrid composites (Tables 4 and 5). Comparing microhybrid composites to nanohybrid composites submerged in the identical beverages, the former showed higher flexural strength in every beverage (Fig. 2).

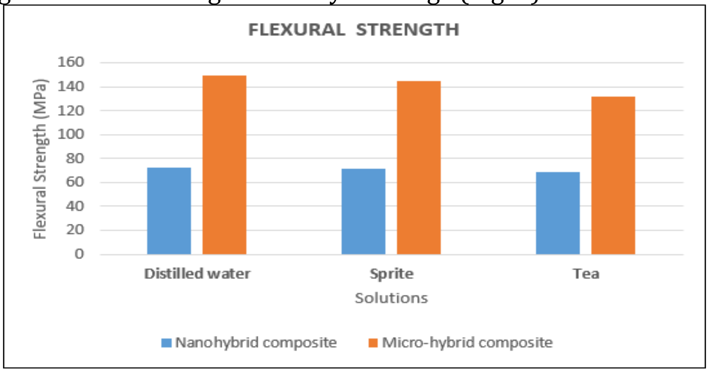


Figure 2: Graphical representation of flexural strength of nanohybrid and microhybrid composites in three different solutions.

Table 4: Comparison of flexural strength (in MPa) of nanohybrid composites in three solutions.

Solution	Mean	SD	p-value	Multiple comparisons
Distilled water	72.56	12.60	0.867	Distilled water vs Sprite: 0.990
Sprite	71.44	24.02		Distilled water vs Tea: 0.864
Tea	68.25	17.59		Sprite vs Tea: 0.923

Statistical test used: One-way ANOVA test; Post hoc Tukey test

Table 5: Comparison of flexural strength (in MPa) of microhybrid composites in three solutions.

Solution	Mean	SD	p-value	Multiple comparisons
Distilled water	149.43	46.28	0.593	Distilled water vs Sprite: 0.963
Sprite	144.75	34.67		Distilled water vs Tea: 0.585
Tea	131.62	38.06		Sprite vs Tea: 0.745

Statistical test used: One-way ANOVA test; Post hoc Tukey test

DISCUSSION

The purpose of this study was to assess the flexural strength of two distinct composite resins, namely nanohybrid and microhybrid composites, following seven days of storage in three distinct beverages: tea, Sprite, and distilled water. In order to demonstrate continuous exposure to liquids in the oral cavity, the immersion in the beverages was maintained [7]. The diet of today typically consists of consuming a lot of foods and drinks that are high in caffeine and have a low pH [8].

Exposure to low pH conditions can adversely affect composite resins. Specifically, under acidic conditions, the filler particles within the resin are prone to falling out which cleaves the matrix leaving it prone to fragmentation and disintegration. This degradation process is significant because it impacts both the filler and the resin matrix, leading to compromised structural integrity of the restoration. Research has indicated that both enamel and restorative dental composites dissolve at a pH value of 4 or below. This acidic environment accelerates the breakdown of these materials, highlighting the importance of maintaining a neutral pH in the oral cavity to ensure the longevity and durability of dental restorations [11]. Distilled water used in this study represents control group to imitate the moist oral environment provided by saliva and water [12]. Distilled water was used to mimic the flushing action of saliva as the artificial saliva does not replicate a clinically appropriate environment [10]. To meet the high standards of modern dental restorations, minimum filler size and maximum filler load is being achieved [7]. Coltene Synergy D6 is a nanohybrid universal composite resin with an average filler particle size 0.6 µm that offers a simplified and aesthetically pleasing material, raising the bar for dental restorations. Nanohybrid composites are preferred for their superior aesthetics, making them ideal for anterior restorations and some posterior restorations requiring high strength and wear resistance. It is an exceptional option for practitioners looking for efficiency without sacrificing quality because of its low shrinkage, and quick polishability. 3M ESPE P-60 Microhybrid composite resin with inorganic filler loading 61v% and filler size ranging from 0.01-3.5 µm performs exceptionally in anterior and posterior restorations due to its low shrinkage and superior strength and wear resistance.

Nanohybrid and microhybrid composites are exposed to various sources of flexural stress in dental restorations, including chewing and biting forces, thermal cycling, occlusal forces and bruxism. The International Standards Organisation recommends the 3-point bending test for assessing polymer-based restorative material strength. Flexural tests are frequently used to measure the strength of composites [13]. This study revealed that microhybrid composites showed significantly greater flexural strength than nanohybrid composites after immersion in distilled water for seven days. This can be attributed to water sorption which is a primary factor causing formation and growth of microcracks, exacerbation of surface deficiencies, filler dissociation, unreacted monomer release and plasticization. Furthermore, the hydrophilic nature of common resin monomers like Bis-GMA, UDMA and Bis-EMA causes reduction in surface toughness of specimens when stored in distilled water. These monomers tend to absorb water, leading to further softening and degradation of the composite material [10]. Composites after exposure to acidic beverages have revealed matrix decomposition, dissolution and erosion of the surface [10,14]. The acids within these beverages penetrate the resin matrix, softening components such as Bis-GMA and facilitating the release of unreacted monomers [10,15]. The present study discovered that when composites were immersed in sprite and tea for seven days, microhybrid composites showed significantly greater flexural strength than nanohybrid composites.

However, the samples that were immersed in sprite revealed greater reduction in strength when compared to distilled water. These results were in agreement with Abouelmagd *et al* (2022) and Al-Shekhli and Aubi (2019) [10,16]. As per the previous studies, exposure to acidic solutions results in the deprivation of restorative materials and a consequent decrease in their hardness. The erosive potential of acidic solutions is influenced by factors beyond low pH, including titratable acidity, concentration, type, storage time and beverage composition [17]. The samples that were immersed in tea showed even greater decrease in flexural strength when compared to sprite and distilled water. Rapid changes in temperature result in the formation of layers in composite resins, likely due to microcracking. This phenomenon occurs due to differential expansion and contraction rates between the resin matrix and filler particles [18]. Dental restorations are commonly exposed to abrupt temperature variations in the oral environment as a result of eating warm and cold food. Microcracks may develop as a result, and the restoration may eventually deteriorate. The bending strength of nanohybrid and microhybrid composite resins immersed in the three distinct solutions did not significantly differ, according to this investigation. However, the components of composites and the type of storage media are important factors in composite deprivation [19]. Although it may not accurately mimic the oral environment, this in-vitro study offers a controlled setting for evaluating the flexural strength of composite resins.

The performance and endurance of the material can be greatly impacted by variables including saliva, temperature changes, curing time, and polymerisation shrinkage in the oral cavity. Therefore, additional research and validation through clinical studies may be required if the clinical results diverge from these in-vitro results.

CONCLUSION

While the findings provide valuable insights, it is important to acknowledge the limitations of in vitro studies. This study was conducted under controlled, artificial conditions and may not have fully replicated the complexities of the oral environment, such as the dynamic nature of human saliva, the influence of temperature fluctuations, and the mechanical forces encountered during chewing. Therefore, while the results of this study are significant, further clinical studies are needed to confirm how these materials perform over longer periods and in real-life conditions. Considering the limitations of this in vitro investigation, it can be said that tea had the least flexural strength among all storage medium. When it came to resistance to degradation, the microhybrid composite outperformed the nanohybrid composite.

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