Original Article

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Dentistry Section

Effect of Hot and Cold Beverages on the Flexural Strength of Nanofilled and Nanohybrid Composites: An In-vitro Study

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ABSTRACT

Introduction: Nanocomposites is the latest development in the field of dentistry. It has improved mechanical properties. The clinical success is dependent on the effect of changes in the oral temperature due to consumption of various beverages.

Aim: To evaluate and compare the effect of hot and cold beverages on the flexural strength of nanofilled and nanohybrid composites.

Materials and Methods: This in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics at Bharati Vidyapeeth Dental College and Hospital, Sangli, Maharashtra, India, from March 2021 to December 2021. Two types of nanocomposites (nanofilled and nanohybrid) were tested for flexural strength under effect of hot (like tea) and cold (like carbonated drink) beverages. All composite specimens were immersed in tea, carbonated beverage and distilled water thus the present study included six groups. A total of 60 specimens (25 mm in length, 3 mm in width, 2 mm in thickness were prepared using teflon moulds with 10 samples for each combination. Maximum load for distortion of the sample was measured after seven days of immersion and flexural strength was calculated. One-way Analysis of Variance (ANOVA) test, Post-hoc Tukey test and Independent t-test were utilised to compare the differences in flexural strength among study groups. Statistical significance was fixed at p-value ≤0.05.

Results: The flexural strength of nanohybrid composite immersed in tea was 85.78 MPa, in aerated drink was 95.55 MPa and in distilled water was 126.78 MPa. The flexural strength of nanofilled composite immersed in tea was 73.66 MPa, in aerated drink was 85.35 MPa and in distilled water was 120.54 MPa. Nanohybrid composite compared to nanofilled composite showed higher flexural strength in all beverages.

Conclusion: Nanohybrid composites were found to have greater mechanical properties as compared to nanofilled composites when subjected to both hot and cold temperatures.

Keywords: Carbonated drink, Distilled water, Immersion, Storage, Thermocycling, Universal testing machine

INTRODUCTION

Dental composites are mixture of two materials in which one of the material, the reinforcing phase, is in the form of fibres, sheets or particles and are embedded in the other material called the matrix phase. The resin matrix consists of monomers, an initiator-activator system, stabilisers and pigments. The inorganic filler consists of particles such as glass, quartz and colloidal silica. The resin matrix and fillers are bonded together with the help of coupling agent [1].

They have different applications in dentistry such as filling the tooth cavities, veneering to mask discoloration and correcting contour and alignment. Their clinical behaviour is dictated by their mechanical strength. During the 1970's and 1980's the main reasons of failure of composite restorations were insufficient wear resistance, loss of anatomic form, proximal contacts and degradation of the restoration. The improvement in filler technology resulted in more resistant composites and changed the reasons for failure and restoration replacement. As the composites improved their wear resistance through the incorporation of filler, they also became more brittle materials, increasing the prevalence of bulk fractures [2,3].

In the past few years, one of the most important advancements in dental materials is related to application of nano-technology to dental restorative composites. Currently, nano-sized composites are categorised as nanofilled and nanohybrid composites. Nanofilled composites consist of nano-meter sized particles clustered to form larger secondary particles which are embedded in the composite matrix whereas nanohybrid composites consist of nano-meter and micro-meter sized fillers. However, a good knowledge of the mechanical properties of new dental materials in various oral conditions would help clinicians to compare behaviour of different dental materials and selecting appropriate one [2].

The variation of temperature in oral environment can affect the mechanical properties of dental restorative materials. Intake of hot or cold food and beverages are the causes of most extreme temperature variation in oral cavity. Typical minimum and maximum temperatures of tooth surface during the consumption of food stuffs are 1ºC and 50ºC. The mechanical properties of dental composites are often sensitive to temperature variations. Therefore, it is important to evaluate effect of oral conditions on mechanical properties of dental restorative composites [2]. Limited literature is available which compare effect of temperature change and mechanical properties of the composite [2]. Till date, no study was found comparing the effect of high and low temperature on flexural strength of composites.

Therefore, the present in-vitro study was undertaken to evaluate and compare the effect of hot and cold beverages on the flexural strength of nanofilled and nanohybrid composites. This study was based on the hypothesis that there is no significant difference in flexural strength of nanocomposites after immersion in hot and cold beverages.

MATERIALS AND METHODS

This in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics at Bharati Vidyapeeth Dental College and Hospital, Sangli, Maharashtra, India. The duration of study was about 10 months- March to December in the calendar year 2021. Study was approved by the Institutional Ethical Committee on December 13th 2019 (Letter number- 2019-20/D-28).

Study Procedure

A customised teflon mould [Table/Fig-1] measuring 25 mm length, 3 mm width, 2 mm thickness was placed on a tinted glass slab. The dimensions were measured using digital vernier caliper (Precision measuring, 150 mm, 6”) as they ensured uniformity. Nanohybrid (Beautiful II LS, Shofu) and Nanofilled (Universal Z350 XT, 3M) were placed in the teflon mould [Table/Fig-2] and a cover slip was placed on top of the mould to prevent formation of oxygen inhibition layer [Table/Fig-3]. The samples were light cured for 20 seconds using Light-emitting Diode (LED) light with intensity of 400 mW/cm^2 according to the manufacturer’s instructions [Table/Fig-4]. A total 60 samples were prepared, 30 from each composite group [Table/Fig-5].

To simulate the oral environment conditions all the 60 samples were subjected to thermocycling. The ISO TR 11450 standard indicates that a thermocycling procedure of 500 cycles in water between +5ºC and +55ºC is an appropriate artificial aging test [2].

Samples were randomly divided into six groups as follows (10 samples each group):

Group 1: Nanohybrid (Beautifil II®LS (B), Shofu Dental Corporation, JAPAN) composite immersed in hot tea at 55ºC for seven days.

Group 2: Nanohybrid composite immersed in cold carbonated drink at 4ºC for seven days.

Group 3: Nanohybrid composite immersed in distilled water at room temperature for seven days. (Control group).

Group 4: Nanofilled (Filtek Z350 XT, 3M ESPE, USA) composite immersed in hot tea at 55±5ºC for seven days.

Group 5: Nanofilled composite immersed in cold carbonated drink at 4±2ºC for seven days.

Group 6: Nanofilled composite immersed in distilled water at room temperature for seven days. (Control group)

This period was calculated on the basis of the algorithm given by Szalewski L et. al., [4]. The algorithm assumes that drinking a cup of coffee (approximately 150 mL) means that oral cavity comes into contact with the liquid for one minute. For an average person who takes approx. 750 mL (five cups) of drinks per day, storing the specimens for seven days can be compared to about five years in the oral cavity [4].

After immersion in respective beverages for seven days, each sample was dried and subjected to flexural strength testing using universal testing machine [Table/Fig-6].

Each sample was balanced on the steel jig for a three-point bend test with a crosshead speed of 1 mm/min. The specimen had to undergo load and the end was calculated when the specimen crashed. The maximum loads were obtained and the flexural strength was calculated using formula: $3FL/2BH^2$ [4].

Where,

F=Maximum load in Newton’s.

L=Span of 20 mm between the supports.

B=Width of the specimen.

H=Height of the specimen.

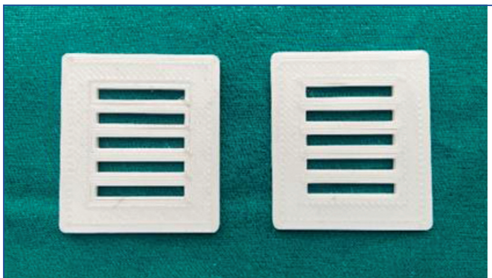
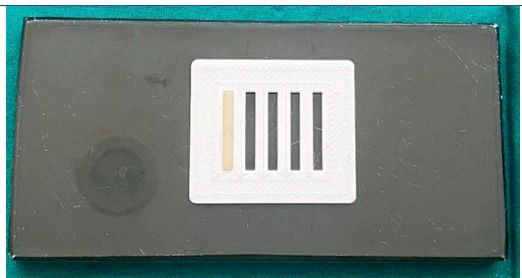
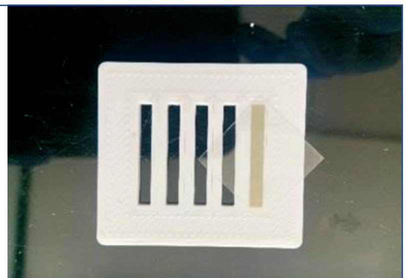
STATISTICAL ANALYSIS

Descriptive statistics were employed to measure mean and standard deviation for flexural strength. One-way Analysis of Variance (ANOVA) test, Post-hoc tukey test and Independent t-test were utilised to compare the differences in flexural strength among study groups. Statistical significance was fixed at p-value ≤0.05. Analysis was done using Statistical Package for the Social Sciences (SPSS) software version 23.0.

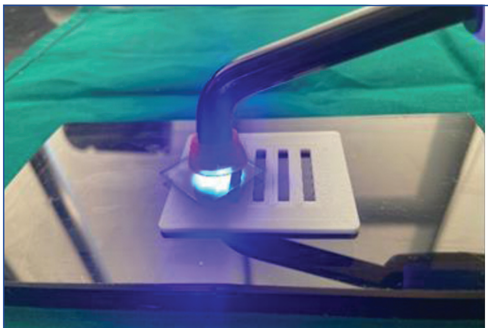
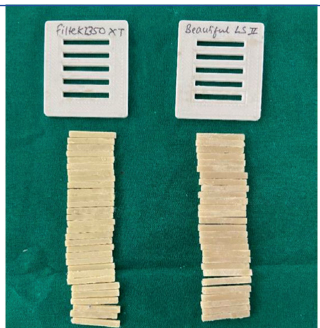
RESULTS

The mean flexural strength of nanohybrid composite immersed in tea was 85.78 MPa, in aerated drink was 95.55 MPa and in distilled water was 126.78 MPa. The mean flexural strength of nanofilled composite immersed in tea was 73.66 MPa, in aerated drink was 85.35 MPa and in distilled water was 120.54 MPa. When comparison of mean values was done within each composite group both nanofilled and nanohybrid composites showed higher strength in distilled water followed by aerated drink and tea. (p-value=0.001) [Table/Fig-7].

In case of both nanohybrid and nanofilled composite when both tea and aerated drink values were compared with distilled water significant difference was seen. The difference for nanohybrid among distilled water and tea was -41.00 whereas for aerated drink was -31.32 (p-value=0.001). In case of nanofilled composite the difference with distilled water for tea was -46.88 and for aerated drink was -35.19 (p-value=0.001). Whereas, when comparison was done between tea and aerated drink values the difference seen was less. Difference was -9.77 (p-value=0.046) for nanohybrid and -11.69 (p-value=0.014) for nanofilled. Between nanohybrid and nanofilled composites the difference of tea vs aerated drink was larger than nanofilled composite [Table/Fig-8].

[Table/Fig-1]: Teflon mould. **[Table/Fig-2]:** Placement of composite resin on mould. **[Table/Fig-3]:** Placement of cover slip over composite. (Images from left to right)


[Table/Fig-4]: Curing of sample. **[Table/Fig-5]:** Samples for flexural strength. **[Table/Fig-6]:** Testing of sample under universal testing machine. (Images from left to right)

When comparison was done between nanohybrid and nanofilled composites immersed in same beverages, nanohybrid composite showed higher flexural strength in tea and aerated beverages. (p-value for tea=0.001, aerate drink=0.029, distilled water=0.148) [Table/Fig-9].

Composite	Solution	Mean	SD	F-value	p-value
Nanohybrid	Tea	85.78	6.81	61.026	0.001*
	Aerated drink	95.55	8.98		
	Distilled water	126.78	9.92		
Nanofilled	Tea	73.66	6.84	80.092	0.001*
	Aerated drink	85.35	10.20		
	Distilled water	120.54	8.50		

[Table/Fig-7]: Comparison of flexural strength within each composite group.
SD: Standard deviation. *p-value ≤0.05 was considered statistically significant (One-way ANOVA test)

Composite	Solution	Difference	p-value
Nanohybrid	Tea vs aerated drink	-9.77	0.046*
	Tea vs distilled water	-41.00	0.001*
	Aerated drink vs distilled water	-31.23	0.001*
Nanofilled	Tea vs aerated drink	-11.69	0.014*
	Tea vs distilled water	-46.88	0.001*
	Aerated drink vs distilled water	-35.19	0.001*

[Table/Fig-8]: Pairwise comparison of flexural strength within each composite resin group.
*p-value ≤0.05 was considered statistically significant (Post-hoc tukey test)

	Nanohybrid		Nanofilled			
Solution	Mean	SD	Mean	SD	Difference	p-value
Tea	85.78	6.81	73.66	6.84	12.12	0.001*
Aerated drink	95.55	8.98	85.35	10.20	10.20	0.029*
Distilled water	126.78	9.92	120.54	8.50	6.24	0.148

[Table/Fig-9]: Intergroup comparison of flexural strength for each solution between nanohybrid and nanofilled composites.
SD: Standard deviation. *p-value ≤0.05 was considered statistically significant (Independent t-test)

DISCUSSION

Composite resins are composed of a matrix phase, surface interfacial phase and dispersed phase. The organic matrix phase is made up of monomers. The inorganic phase consists of fillers which act as reinforcements. Each resin also included an accelerator initiator system to start and complete the polymerisation. In addition, they also include pigments and opaquer. Coupling agent is used to combine reinforcing phase and matrix phase [5-7].

Based on a study reported on the correlation between mechanical properties and filler volume, in an attempt to satisfy the requirements of dental composites the filler size is being minimised and the filler loading is being maximised [8]. Recently, there has been progress in the field by introduction of nanofilled materials by combining nanometric particles and nanoclusters in a conventional resin matrix [9].

Nanocomposites are commonly available as nano-fillers and nanohybrids. Nano-fillers are made up of 1 to 100 nm size particles mainly and nanohybrids are made up of larger particles ranging from 0.4 to 5 μm, and are called hybrids [10,11]. Composite materials used as restorations are constantly subjected to noxious factors in the oral cavity which can change their basic properties [4]. These materials clinical performance is largely determined by their resistance to degradation in the oral environment [12]. Composites come in contact with temperatures ranging from 1°C and 50°C during food consumption. These temperatures can have an effect on the mechanical properties of the material [2]. However, in the literature there are sparse studies [2,4,12-14] evaluating effect of consumption of foodstuffs affecting mechanical properties of composite.

According to Szalewski L et al., popular beverages can cause deterioration of mechanical properties of the composite material [4]. However, the effect of temperature of these popular beverages on composite was not tested. Ilday N et al., evaluated the effect of acidic beverages on composite resins and concluded that significant roughness was observed on all composite materials [12]. However both Szalewski L et al., and Ilday N et al., studied the effect of beverages alone on the composite material [4,12]. Therefore, the present study evaluated the effect of hot and cold beverages on nanohybrid and nanofilled composites. Some similar studies from the literature have been compared in [Table/Fig-10] [2,3,13-15].

Author and year of the study	Place of the study	Sample size	Objective	Conclusion
Mair LH, 1989 [13]	Liverpool, England	192	One of the experiments in the study wanted to determine the effect of high and low temperature individually.	Temperature changes caused surface degradation which caused increased depth of diffusion of fluids.
Rodrigues Junior SA et al., 2007 [3]	Pelotas, Brazil	60	Assess the filler composition effects in different commercially available resin based composites, concerning flexural strength and modulus of elasticity	Filler content affected the flexural strength of composites.
Ayatollahi MR et al., 2015 [2]	Iran	15	Effects of thermocycling and immersion in two types of beverages on the mechanical and tribological properties of several dental restorative composites.	Filler loading affects the microvoids and available free volume for water sorption. Since nanohybrids have higher filler loading they showed better flexural strength.
Szalewski L et al., 2016 [14]	Poland	35	Determine how composite materials change their properties under the influence of various energy drinks	Samples immersed in distilled water showed higher strength than samples immersed in any energy drinks and that the flexural strength of composite resins was influenced by energy drinks.
Papadogiannis DY et al., 2008 [15]	Greece	20	Determine the viscoelastic properties of nanofilled and conventional composite resins under different temperatures and conditions of storage.	The effect of temperature was extremely significant and was the same on all materials, while the medium and the time of storage affected each material differently.
Present study, 2022	Maharashtra, India	60	Evaluate and compare the effect of hot and cold beverages on the flexural strength of nanofilled and nanohybrid composites.	Nanohybrid composite showed higher flexural strength in all beverages and all temperatures than nanofilled composite.

[Table/Fig-10]: Comparative table for results of previous studies and present study [2,3,13-15].

Limitation(s)

This study being an in-vitro study did not exactly simulate the oral conditions. In the oral cavity, the additive effects of saliva, temperature, curing time and polymerisation shrinkage may present more detrimental effect. Therefore, the results obtained from this in-vitro study may vary from the clinical outcome.

CONCLUSION(S)

Nanohybrid composite showed higher flexural strength in all beverages i.e., tea, carbonated beverage and distilled water. The flexural strength of nanohybrid and nanofilled composite resins was significantly higher when immersed in distilled water followed by aerated drink and tea. It means when composite was stored at room temperature showed better strength followed by low temperature and high temperature. The future in-vitro studies evaluating effect of temperature on nanocomposites should simulate oral conditions precisely to determine the flexural strength of composites after effect of hot and cold beverages. Other prospective studies must include role of curing and, role of other hot and cold beverages.

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