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Original Article

Shear punch strength evaluation of nanocomposite and compomer, post-conditioning in dietary solvents – An in-vitro study

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ABSTRACT

Background: Perpetual research in esthetic dentistry has stupendously contributed in improving the mechanical and esthetic properties of restorative materials. Recently introduced nanocomposite claim to possess higher optimized esthetic and mechanical properties superior to other esthetic restorative materials in clinical use. It has been highlighted in many studies that intraoral degradation of composites is a consequence of both mechanical factors and chemical degradation. Thus, this *in-vitro* study was conducted to determine the strength of commonly used esthetic restorative materials after conditioning them in dietary solvents, thereby, simulating the intraoral environment.

Aim: Evaluation of shear punch strength of nanocomposite and compomer, post-conditioning in dietary solvents.

Materials and methods: Two test groups mentioned above, each containing sixty preconditioned samples, divided into four subgroups of fifteen samples each and conditioned in different dietary solvents, were subjected to shear punch test in custom designed shear punch apparatus in Universal Testing Machine.

Results: Among the dietary solvents, citric acid caused maximum decrease in the strength while conditioning in heptane showed increase in strength of the test restorative materials.

Conclusion: Nanocomposite revealed to have higher strength, thereby indicating its better application universally.

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1. Introduction

The exponential rise in new restorative materials and techniques allow for minimally invasive treatment and consequently leads to better esthetics and function.¹ Compomers are known to provide the combined benefits of composites (the “comp” in their name) and glass ionomer (“omer”).² Since few decades, dental composites have become popular choice for esthetic restorations due to their ability to match tooth color, withstand oral fluids, and bond to acid-etched enamel surfaces.³ Nanocomposite comprising of organically modified ceramic (Ormocer) nanoparticles and fillers of size 0.01–0.04 mm has been developed. These nano-ceramic particles are inorganic–organic hybrid particles in which both nano-ceramic particles and nano-fillers have methacrylate groups available for polymerization. Nanocomposite offer numerous advantages such as reduced polymerization shrinkage, better gloss retention and wear resistance comparable to that of microfill and microhybrid composite resins.⁴ It is expected that this novel nanocomposite system would be useful for all posterior and anterior restorative applications.⁵ The performance of all restorations is dependent on the biodynamic environment of the oral cavity.⁶ Thus to simulate the oral conditions and determine its effect on the performance of resin restorative materials, dietary solvents as recommended by FDA as food simulating liquids were used in this study. Shear punch test was considered as a standardized procedure to evaluate the strength of test materials.⁷ The aim of study was to determine the strength of nanocomposite and compomer after conditioning them in dietary solvents, which would help us understand the effects of these dietary solvents on the restorative materials in hostile oral environment.

2. Materials & methods

Shear punch specimens were made by placing the restorative material into the brass washers (with inner diameter of 5 mm

Fig. 1 – Preparation of samples.

Fig. 2 – Preconditioning in distilled water.

and outer diameter of 14 mm and 1-mm thick), supported by glass slide in the mounting jig [Fig. 1]. Mylar strip was attached to each glass slide with the respective color coded adhesive tape [Blue – Ceram-X and Red-Compomer]. A second glass slide was placed on the top of the washers in the slot in the jig followed by tightening of the screw embedded in the vertical arms of the jig to apply gentle and uniform pressure on the upper slide to extrude the excess material.³ Nanocomposite resin specimens were cured using Max polymerization unit according to manufacturers' curing times. The glass ionomer cement was allowed to set for five minutes with the glass slides in place. Sixty specimens of each material were made and stored in distilled water (separately) in airtight glass vials, at 37 °C for one week [Fig. 2]. The specimens, together with their washers, were then randomly divided into four groups of fifteen each and conditioned in subgroups as follows:

At the end of conditioning period of another one week in the different dietary solvents, [Fig. 3] the specimens were washed, blotted dry and subjected to shear punch strength testing using custom designed shear punch apparatus in Universal Testing Machine, [Fig. 4] at a cross head speed of 2.0 mm/min and the maximum load to make punch through the specimen was recorded.⁸

The peak load values obtained in Newton's (N) formed the basis for computing of shear strength (MPa) in accord to the following formula:

Dietary solvents (at 37 °C)	Nanocomposite (Ceram-X)	Compomer (Dyract)
Control–distilled water	A1	B1
0.02 M Citric acid	A2	B2
50% Ethanol–water solution	A3	B3
Heptane	A4	B4

Fig. 3 – Conditioning in dietary solvents.

Shear strength (MPa)

$$= \frac{\text{Force (N)}}{\pi \times \text{punch diameter (mm)} \times \text{thickness of specimen (mm)}}$$

where value of $\pi = 3.14$. Punch diameter = 2 mm. Thickness of specimen = 1 mm.

The data obtained was subjected to descriptive statistical analysis.

3. Results

All the statistical operations were done through SPSS for windows (Version 15 evaluation Version, 2006), SPSS Inc., New York. The mean shear punch strength value was subjected to following statistical analysis: One-way ANOVA, Paired sample t test.

Descriptive values for mean shear punch strength of test restorative materials after conditioning in various dietary solvents depicted that the strength of nanocomposite [NC] (82.95 ± 6.93 MPa) was found to be highest in heptane and lowest for compomer (71.96 ± 12.16 MPa) in citric acid. Nanocomposite showed higher strength values after

Fig. 4 – Shear punch apparatus for testing in.

Table 1 – Descriptive values for mean shear punch strength of test restoratives post-conditioning in dietary solvents.

Dietary solvents	Test restorative	
	Nanocomposite mean $\pm$ S.D.	Compomer mean $\pm$ S.D.
Distilled water	78.87 ± 7.22	76.42 ± 11.38
0.02 M Citric acid	76.94 ± 11.12	71.96 ± 12.16
50% Ethanol–water solution	81.80 ± 11.93	73.52 ± 6.88
Heptane	82.95 ± 6.93	77.42 ± 10.62

conditioning in other dietary solvents as compared to compomer [Table 1]. One-way ANOVA revealed non-significant difference ($p > 0.05$) in the mean shear punch strength values of nanocomposite and compomer in relation to different dietary solvents [Table 2]. Paired t test revealed non-significant difference among two-test restorative material after conditioning in dietary solvents [Table 3].

4. Discussion

Nanotechnology, also known as molecular nanotechnology or molecular engineering, is the production of functional materials and structures in the range of 0.1–100 nm—the nano-scale—by various physical or chemical methods. When a particle shrinks to a fraction of the wavelength of visible light (0.4–0.8 μm), it would not scatter that particular light, resulting in the human eye's inability to detect the particles. In oral environment there is intricate process of disintegration and dissolution caused by food chewing and bacterial activity. No *in-vitro* test is capable of reproducing this complex process. This study undertaken was to highlight and compare the effect of various dietary solvents on the shear punch strength of compomer and recently introduced nanocomposite. Shear punch specimens of each material were made by placing the restorative material into brass washers from the single mix and was not layered and thin enough to be fully activated by a single application of the light activator, that is, the diameter of the specimen should be less than that of the exit window of the irradiation unit.⁹ The specimens were aged for one week prior to conditioning to allow for post-cure of composite and compomer.¹⁰ The specimens together with their washer, were then randomly divided into four groups of fifteen each and conditioned for one week in air tight glass vials (all having equal amount of liquid i.e. 10 ml) containing dietary solvents, recommended by the FDA guidelines as food simulating liquids.^{11,12} Distilled water was used as control to simulate the wet oral environment provided by saliva and water.¹¹ As per FDA guidelines it could be predicted that restorative materials exposed to light beverages, candy, fruits, mouth rinses, alcohol and to oils such as salad dressing, butter and fat in the oral environment will be softened in the same manner as those exposed to water, ethanol, citric acid and heptane respectively *in-vitro* conditions.¹³ As in this study, since the restorative materials were not exposed to mechanical forces, any observed changes would be from the chemical dissolution.¹⁴

Table 2 – One-way ANOVA among two test restoratives.

Test restorative	Source of variation	Sum of squares	Df	Mean square	F value	p value
Nanocomposite	Between groups	337.997	3	112.659	1.230	0.307 (<i>p</i> > 0.05)
	Within groups	5129.787	56	91.603		
Compomer	Between groups	288.41	3	96.138	0.846	0.475 (<i>p</i> > 0.05)
	Within groups	6367.46	56	113.705		
Df – degree of freedom, F – fisher’s value.						

For resin composites, the greatest overall effect was obtained from preconditioning with 50% ethanol solution with solubility parameter values of about 3 or $3.7 \times 10^{-4} \text{ J}^{1/2} \text{ m}^{-3/2}$. This implies that any oral or food ingredient component having a solubility parameter approximating this range will produce surface damage in the dental materials. These findings support the work of Wu et al and Mc Kinney and Wu.¹⁴

A strength test needs to measure the cohesion within the specimen and its resistance to deformation in order to allow compression between materials and to examine the effects of manipulative variables. The test should also be applicable to a range of materials and ease of specimen preparation and should not be technique sensitive. The shear punch test encompasses all these features.¹⁵ The only mandatory requirement for shear punch specimens is that the two main faces of the disc should be flat and parallel, thereby allowing uniform stress distribution around the punch circumference.¹¹ Independent 't' test among the pair of restorative materials revealed that shear punch strength of restorative materials after conditioning in heptane was found to be higher than in ethanol, citric acid and control i.e. distilled water. These results were coinciding with the results obtained by Yap.¹²

The possible explanations given for this significant increase in hardness as: heptane reduces oxygen inhibition during post curing and eliminates leaching out of silica and combined metal in fillers, which may occur after conditioning in aqueous solutions.^{12,14}

The strength of the two restorative materials in 50% ethanol–water solution was higher than that of control and citric acid. The values obtained in this study especially with regards to ethanol solution were in agreement with the previous studies, where ethanol solution resulted in higher values than citric acid, distilled water and heptane.¹⁰ Because of the deficiency on the study conducted on this parameter, results were compared with another study by Yap and others, in which flexural test were conducted using the same conditioning medium and time.¹² These results were contrary to the study conducted by Kao,¹³ Ferracane and Marker¹⁶ and Yap.¹¹

In a study conducted by Kao, it was concluded that maximum softening effect was produced by 75% ethanol–water solution as its solubility parameter ($\delta = 3.15 \times 10^{-4} \text{ J}^{1/2} \text{ m}^{-3/2}$)

approximates to that of Bis-GMA.¹³ In all of the above mentioned studies 75% ethanol solution was used which could produce maximum softening of the Bis-GMA based resin composite materials. Thus, the difference in ethanol concentration and the difference in materials, the testing methods and time might have caused disparity in results of this study as compared to the other studies mentioned.¹⁰

There was considerable decrease in strength after conditioning in citric acid. The values obtained in this study were in accordance with the study done by Yap & Low¹² and Yap.^{10,17}

Citric acid simulated the weak acids produced in the oral cavity by plaque metabolism and by intake of citrus juices. This acidic environment in the oral cavity cause dissolution of the inorganic fillers from resin restoratives and cause hydrolysis of the ester groups present in the resin matrix, thereby reducing the viability and strength of the material with span of time.^{13,18}

The shear punch strength values computed after conditioning in distilled water were lower than that of materials after conditioning in heptane and ethanol solution respectively but higher than that post conditioning in citric acid. The rank order of these values was in same order as that of the previously conducted study.¹⁰ The reason cited for such observation would be the absorption of small percentage of water by resin matrix of composite, which cause deterioration in the properties of resin restoratives.¹⁹ Independent 't' test revealed no significant difference between the strength values for nanocomposite and compomer after conditioning in various solvents. These observations were different to the study by Yap, which revealed significant difference between nanocomposite and compomer.¹⁰

In the entire dietary solvents, nanocomposite gave the best performance followed by compomer. These results were in cognizance to the study by Mitra, Wu, Holmes⁵ and Yap.¹⁰ Mitra developed a restorative material, which would be able to retain high polish and surface texture in anterior region as well to possess sufficient mechanical properties suitable for high stress bearing restorations by increasing the filler loading of nanocomposites. Studies have reported a positive correlation between the mechanical properties and volume fraction of the fillers by Yap and others.¹⁵ This novel composite with

Table 3 – Intergroup comparison of two test materials after conditioning in dietary solvents.

Restorative material	Dietary solvents			
	Distilled water	0.02 M Citric acid	50% Ethanol–water solution	Heptane
Nanocomposite/Compomer	0.489 ($p > 0.05$)	0.252 ($p > 0.05$)	0.028 ($p > 0.05$)	0.120 ($p > 0.05$)
<0.001 = highly significant <0.01 = moderately significant <0.05 = slightly significant >0.05 = non-significant.				

higher filler volume like Ceram-X showed to have higher strength than compomer, with lower filler volume.

5. Conclusion

Mechanical testing and persistent evaluation of restorative materials under various simulated conditions is essential for their efficient clinical use. Nanocomposite showed better performance than compomer in all simulated oral conditions thereby indicating its universal application.

Conflicts of interest

All authors have none to declare.

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