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Original Article

Influence of different crosshead speeds on diametral tensile strength of a methacrylate based resin composite: An *in-vitro* study

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Abstract

Aim: The aim was to evaluate the influence of different crosshead speeds on diametral tensile strength (DTS) of a resin composite material (Tetric N-Ceram).

Materials and Methods: The DTS of Tetric N-Ceram was evaluated using four different crosshead speeds 0.5 mm/min (DTS 1), 1 mm/min (DTS 2), 5 mm/min (DTS 3), 10 mm/min (DTS 4). A total of 48 specimens were prepared and divided into four subgroups with 12 specimens in each group. Specimens were made using stainless steel split custom molds of dimensions 6 mm diameter and 3 mm height. The specimens were stored in distilled water at room temperature for 24 h. Universal testing machine was used and DTS values were calculated in MPa.

Results: Analysis of variance was used to compare the four groups. Higher mean DTS value was recorded in DTS 2 followed by DTS 4, DTS 1, and DTS 3, respectively. However, the difference in mean tensile strength between the groups was not statistically significant ($P > 0.05$).

Conclusion: The crosshead speed variation between 0.5 and 10 mm/min does not seem to influence the DTS of a resin composite.

EGCG at the studied concentrations were not effective in eliminating *S. mutans* from dentin caries-like lesions.

Keywords: Composite resins; crosshead speed; tensile strength

INTRODUCTION

Direct resin composite is the most widely use the restorative material in restorative clinical practice. The mechanical properties are constantly evolving make clinician to use this material as anterior and posterior restorative materials.[1] With the constant evolution of the resin composite materials, evaluation of the material properties such as compressive strength, diametral tensile strength (DTS), and flexural strength, serve as a bridge between fundamental material sciences and clinical applications.[2,3]

Diametral tensile strength testing was developed to investigate brittle materials with little or no plastic deformation. In this test, cylindrical specimen is subjected to a compressive load in the diametral plane, which is perpendicular to the longitudinal axis.[1] The evaluation of strength properties is done using a universal testing machine which commonly use crosshead speed as 0.5 mm/min. However, some of the studies use crosshead speeds as 0.1 mm/min,[4] 0.2 mm/min,[5] 0.25 mm/min,[3] 0.5 mm/min,[4,6-10] 0.75 mm/min,[11-13] 1 mm/min,[1,3,14,15] 5 mm/min,[16] and 10 mm/min.[17] There exist lacunae in the literature with respect to the application of different crosshead speed to the specimens while evaluating the DTS. Hence, the aim of the study was to evaluate the influence of different crosshead speeds on DTS of a resin composite material, Tetric N-Ceram (Ivoclar Vivadent).

Research hypothesis

There is difference between the DTS of Tetric N-Ceram (Ivoclar Vivadent) using different crosshead speeds.

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MATERIALS AND METHODS

The methacrylate based nano hybrid resin composite material Tetric N-Ceram — Ivoclar Vivadent (shade A2), was evaluated for DTS using 4 different crosshead speeds 0.5 mm/min, 1 mm/min, 5 mm/min, 10 mm/min.

Experimental groups

Forty prepared specimen were randomly divided by simple random sampling into four experimental groups with 12 samples in each group:

- Group I - DTS at crosshead speed of 0.5 mm/min
- Group II - DTS at crosshead speed of 1 mm/min
- Group III - DTS at crosshead speed of 5 mm/min
- Group IV - DTS at crosshead speed of 10 mm/min

Specimen preparation

Stainless steel custom split mold was used for the specimen preparation. 48 cylindrical specimens were fabricated from Tetric N-Ceram — Ivoclar Vivadent (Shade A2) (Lot-R47829), having dimensions as 6.0 ± 0.1 mm in diameter and 3.0 ± 0.1 mm in thickness according to specification no. 27 of ANSI/ADA.[6,8,18] The resin composite material was placed in custom stainless steel split mold of dimension 6 mm in diameter and 3 mm in thickness. Resin composite was incrementally built up in three layers of 2 mm thickness. Each increment was cured for 20 s using a light curing unit (Bluephase, Ivoclar Vivadent) with the tip of the light source held as close as possible without contacting the surface. The intensity of the curing light was monitored using radiometer after every 10 curing.[3]

The final increment in all the subgroups was cured by placing a mylar strip (Samit products, Delhi) covered with a glass plate (Blue Star Company, India) to get a smooth finish of the specimen.[1,3,6,8,9,17]

Specimens were ejected from the molds and the excess material was removed using 600 grit SiC paper.[1,6] The specimens were inspected for voids or incorrect dimensions and the ones with voids or other defects or incorrect dimensions were discarded. The dimensions of the specimen were checked using digital caliper (Aerospace, Panama Orthodontics, Inc., USA). Specimen were then stored in distilled water in light proof container at room temperature for 24 h.[1,3,9,10,16,17]

Diametral tensile strength testing

Diametral tensile strength was evaluated by mounting the specimen diametrically on a Universal Testing Machine (Hounsfield universal testing machine, s-series) with crosshead speeds of 0.5 mm/min, 1 mm/min, 5 mm/min, 10 mm/min. Results were recorded in kgf which were then converted to MPa.

Diametral tensile strength was computed using the formula.[1,6,8,10,15,18]

$$\text{DTS} = 2P/\pi dt$$

where P = Load, d = Diameter (~6 mm) and t = thickness (~3 mm)

Diametral tensile strength was calculated and expressed in MPa.

Statistical analysis

The statistical analysis technique used was the analysis of variance (ANOVA). In order to find out among which pair of groups there exist a significant difference, multiple comparisons were carried out using Bonferroni method. Therefore, a one-way ANOVA with a Bonferroni adjustment was used to consider each group as a separate entity and to allow for direct comparisons. The Bonferroni adjustment is a mathematical correction that can be used to reduce falsely significant results. Statistical procedures were performed using the Statistical Package for Social Sciences (SPSS 13.0) for Windows

RESULTS

The mean and standard deviation values (MPa) obtained with DTS for four groups evaluated are listed in Table 1. The one-way ANOVA [Table 2] showed no significant difference among the groups ($P > 0.05$) indicating that there was no influence of crosshead speed variation on the DTS. However, higher mean tensile strength was recorded in DTS 2 (40.04 ± 4.84 Mpa) followed by DTS 4 (41.17 ± 7.21 Mpa), DTS 1 (40.83 ± 4.79 Mpa), and DTS 3 (39.62 ± 6.37 Mpa) [Figure 1 and Graph 1].

DISCUSSION

Standardization of test conditions are difficult to attain with clinical trials, therefore *in vitro* tests play an important role in carrying out preliminary studies and providing scientific data.

Table 1: Mean DTS (MPa)

DTS	Mean	SD (±)	SE of mean	95% CI for mean		Minimum	Maximum
				Lower bound	Upper bound		
DTS 1	40.83	4.79	1.38	37.78	43.87	31.23	49.56
DTS 2	42.04	4.84	1.40	38.96	45.11	28.17	46.38
DTS 3	39.62	6.37	1.84	35.57	43.67	25.92	48.74
DTS 4	41.17	7.21	2.08	36.59	45.75	25.33	49.16

SD: Standard deviation, SE: Standard error, CI: Confidence interval, DTS: Diametral tensile strength

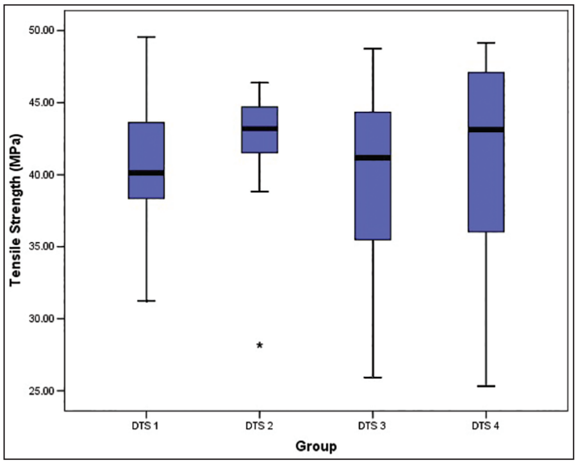


Figure 1: Box plots of diametral tensile strength according to crosshead speeds. Lines on the boxes signify the mean and standard deviation

Table 2: ANOVA

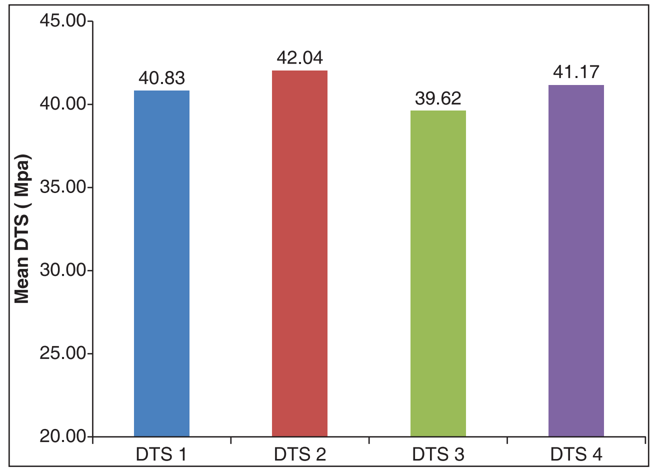
Source of variation	Df	SS	Mean SS	*F*	*P*
Between groups	3	35.925	11.975	0.345	0.793(NS)
Within groups	44	1528.984	34.750	—	—
Total	47	1564.909	—	—	—

SS: Sum of squares, Df: Degree of freedom, ANOVA: Analysis of variance, NS: Non significant

The *in vitro* studies are cost effective and less time-consuming and permits an enormous level of simplification of the system under study. Even though laboratory fracture strength tests do not reproduce intra-oral loading conditions, they offer a controlled environment for preparing and testing the specimens thus allowing for comparable evaluation of the variables under investigation. Hence, an *in vitro* experimental approach was considered suitable for this study.[19]

Strength is a conditional material property which is used for comparison purposes.[6] Compressive and DTS testing are important *in vitro* analyses that have typically been considered good indicators for simulating the forces that the restorative materials are subjected to under mastication.[3,16,17] Tensile strength is lower than compressive strength and is considered more relevant. As it is not possible to measure the tensile strength of brittle materials directly, DTS was adopted by British Standards Institution.[16] Diametral tensile testing is a common method for measuring the tensile strength of brittle materials because it avoids some of the difficulties inherent in direct and flexural tensile testing.[20]

Comparison of results from different DTS studies is difficult at best because of a number of variables that might influence the results obtained. There are significant differences in the storage, preparation of samples, and number of samples per group. Due to these variables and the large distribution of results, confident conclusions cannot be drawn when materials and techniques are compared. Crosshead speed has also been speculated to add to the variation of test results.



Graph 1: Diametral tensile strength values (in Mpa)

To our knowledge, this is the first investigation on influence of different crosshead speeds on DTS of resin composites.

The parameter of crosshead speed has not yet been standardized. Most of the studies employ speeds of 0.5 mm/min,[4,6-10] 0.75 mm/min[11-13] and 1 mm/min.[1,3,14,15] Nevertheless different crosshead speeds such as 0.1 mm/min,[4] 0.2 mm/min,[5] 0.25 mm/min,[3] 5 mm/min,[16] and 10 mm/min[17] have been employed by other authors. Hence in current study, DTS was evaluated using 0.5 mm/min, 1 mm/min, 5 mm/min and 10 mm/min crosshead speed in accordance to plethoric literature.

The resin-based composite used in the current study was Tetric N-Ceram which is a type of methacrylate-based nano hybrid composite. The use of nano hybrid composite have been the focus of much recent research as a potential alternative to conventional composites owing to their advantage of having better strength, radiopacity, surface gloss and lower polymerization shrinkage.

For the present study, the specimens prepared were made according to ANSI/ADA specification no. 27 with dimensions, 6 ± 0.1 mm in diameter and 3 ± 0.1 mm in thickness.[6,8] The light curing unit used was Bluephase, Ivoclar Vivadent, and the intensity of light was measured after every 10 curing using a radiometer.[3,19] Radiometer was used to check for any loss of intensity of the curing bulb which can occur over time.[21]

The statistical analysis for this study was done using one-way ANOVA.

A comparative analysis of four different experimental groups showed higher mean tensile strength in DTS 2 (40.04 ± 4.84 Mpa) followed by DTS 4 (41.17 ± 7.21 Mpa), DTS 1 (40.83 ± 4.79 Mpa), and DTS 3 (39.62 ± 6.37 Mpa), respectively. However, the difference in mean tensile strength between the groups was not statistically significant (P > 0.05). Therefore, the present data in the study concluded that, variations in crosshead speed are not significantly influencing the DTS of resin-based composites.

The results of this study are consistent with studies by Reis *et al.* and Yamaguchi *et al.*, where they evaluated the influence of different crosshead speeds of 0.1 mm/min, 0.5 mm/min, 1.0 mm/min, 2.0 mm/min, 4.0 mm/min and 0.5 mm/min, 1.0 mm/min, 5.0 mm/min, 10.0 mm/min, respectively on resin-dentin microtensile bond strength.[22,23]

When investigating orthodontic bond strength with different crosshead speeds (0.1 mm/min, 0.5 mm/min, 1.0 mm/min, 5.0 mm/min) Klocke and Kahl-Nieke found no significant difference between different groups with different crosshead speeds.[24]

The results of this study were in contrast with studies by Hara *et al.* and Tamura *et al.* where they evaluated the influence of different crosshead speeds of 0.5 mm/min, 0.75 mm/min, 1.0 mm/min, 5.0 mm/min and 0.1 mm/min, 0.5 mm/min, 1.0 mm/min, 5.0 mm/min, respectively on bond strength. The authors observed that higher the crosshead speeds higher the bond strength values. The observed differences in these studies could be attributed to the deviation of the applied force away from the adhesive interface to other components of the specimen, such as a composite or dentine substrate when higher applied forces were used, allowing higher bond strength values to be obtained.[19,25] Furthermore, in contrast with the current study these studies evaluated the bond strength where the methodology for the experiment is different than the evaluation of DTS for resin composites. Hence, the results from these studies cannot be used for the DTS evaluation.

Most of the previous studies on evaluation of DTS used different crosshead speeds. If the results of this study could be extrapolated and validated in further research, then studies of different crosshead speed can be directly compared for secondary research like systematic review and meta-analysis. Hence for future reference, the current study can guide the researchers in this aspect.

CONCLUSION

According to the results of present study, the research hypothesis was rejected as the use of crosshead speed at 0.5 mm/1 mm/5 mm and 10 mm/min does not seem to influence the DTS of a resin composite.

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