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ORIGINAL RESEARCH

Composite Diametral Tensile Strength

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ABSTRACT

Aim: The aim of this study was to evaluate and compare the diametral tensile strength (DTS) of 4 types of composite materials including bulk fill type (tetric evo ceram) cured with two different curing intensities.

Materials and methods: Four types of light-activated composite materials of A3 shade were selected for this study: Tetric Evo Ceram-Ivoclar Vivadent; Ceram X.mono- Dentsply; Nano Ceram-Bright-DMP; Estelite Sigma Quick-Tokuyama. Twenty specimens of each composite material were prepared: ten specimens were cured with high intensity 1200 mW/cm^2 (n = 10) (high-intensity group) for 20 seconds and ten specimens were cured with low intensity 650 mW/cm^2 (n = 10) (low intensity group) for 20 seconds. Specimens were prepared following the ISO 4049 and ADA/ANSI 27 Specifications in which cylindrical specimens (n = 20 of each material) of 4 mm in depth and 6 mm in diameter were prepared and stored in distilled water for 24 hours at 37°C. The DTS test was performed using the universal testing machine (Testometric/UK) with a crosshead speed of 1.0 mm/minute. The specimens were placed with their long axes perpendicular to the surface of the applied compressive load until failure. Values of the DTS in MPa were calculated and statistically analyzed by one way analysis of variance (ANOVA) and Tukey tests at 95% level of significance.

Results: The mean of DTS in the high-intensity group ranged from 38.49 to 48.79 MPa, whereas the mean of DTS in the low-intensity group ranged from 24.58 to 38.15 MPa. The *p* values of statistical tests were all less than 0.05. One-way analysis of variance (ANOVA) tests for DTS values of all the four composite groups cured with high intensity at 1200 mW/cm^2 and for DTS values of all the four composite groups cured with low intensity at 650 mW/cm^2 revealed that there were statistically significant differences ($p \leq 0.05$).

Conclusion: Within the limitations of the study we can conclude that high-intensity curing significantly resulted in higher DTS values in all the composites being tested in this study due to a better degree of conversion and composite composition also significantly influences its DTS values.

Clinical significance: Diametral tensile strength (DTS) of any restorative material is an essential test that simulates the tensile behavior of the restorative material during function in the oral cavity which is an indicator for the general strength and durability of the restoration in oral service.

Keywords: Composite resin, Diametral tensile strength, Mechanical properties.

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INTRODUCTION

One of the most important discoveries in the history of operative dentistry was the improvement of light-activated composite resin for direct restorations, and this material has revolutionized this field in a way that today restorative dentistry cannot be imagined without dental composite.[1,2]

The demand for lifelike appearance makes the patients looking for tooth-colored restorations in anterior and posterior teeth similarly.[3] Skinner in 1959 wrote, "the esthetic quality of restoration may be as important to the mental health of the patient as the biological and technical qualities of the restoration are to his physical or mental health." And till today esthetic considerations are still the primary reason for demanding dental treatment.[3]

Requirements for filling materials include the physical properties and wear resistance should be close to that of the tooth structure, good optical properties, detectable on X-ray, easy to handle and to polish, have the ability to bound to tooth structure, should be tasteless and biocompatible, and many more of these requirements are recorded in the ISO (4049) standards.[4]

For a successful composite restoration, properties like diametral tensile strength, compressive strength, flexural strength, the linear coefficient of thermal expansion, water sorption, wear resistance, surface texture, radio-opacity, modulus of elasticity, solubility, must be optimal.[3] Such mechanical properties affect dental composite, whether to be used in the anterior or posterior region.[5]

Because of the improvement of this material, it gives us the advantages to be used for restoring posterior stress-bearing cavities, and as an alternative to amalgam.[6] The first attempt to put composite in posterior teeth was not successful because of inadequate mechanical properties, such as inadequate resistance to wear, fracture within the body of the restoration, and microleakage due to polymerization shrinkage, were the most common cause of failure in posteriors teeth, but some of those disadvantages have been greatly overcomed in the last few years. Improvements in the material properties along with the clinical performance encourage the practitioner to use composite resin in posterior teeth as an alternative to amalgam.[6]

Tensile strength is the force needed to break a material when the material is subjected to two sets of forces that are directed away from each other in the same straight line, diametral tensile strength testing was developed to investigate brittle material such as, composite, with little or no plastic deformation.[5]

The aim of this study was to evaluate and compare the DTS of four types of light activated composite materials (Tetric Evo Ceram-Ivoclar Vivadent as a bulkfill type; Ceram X.mono-Dentsply; Nano Ceram-Bright-DMP; Estelite Sigma Quick-Tokuyama) cured with two different light activation intensities.

MATERIALS AND METHODS

Four types of light-activated composite materials of A3 shade were selected for this study: [Tetric Evo Ceram (bulkfill)]–Ivoclar Vivadent; Ceram X.mono–Dentsply; Nano Ceram-Bright-DMP; Estelite Sigma Quick-Tokuyama). Twenty specimens of each composite material were prepared: ten specimens were cured with high intensity 1200 mW/cm^2 (n = 10) (high-intensity group) for 20 seconds and ten specimens were cured with low intensity 650 mW/cm^2 (n = 10) (low-intensity group) for 20 seconds. Eighty resin composite specimens were prepared (n = 20 of each type of composite material) by incremental (two increments) insertion of composite into a circular nickel-chromium split mold with 6 mm in inner diameter and 4 mm in height and cured using Blue phase G2 (Ivoclar, Vivadent) light curing unit for 20 seconds for each 2 mm increment of composite thickness except for Tetric Evo Ceram bulkfill composite the curing was done for the whole thickness of the composite specimen for 20 seconds (Fig. 1A). Following the ISO 4049 and ADA/ANSI 27 specifications for standardized DTS testing in which cylindrical specimens of 6 mm in inner diameter and 4 mm in thickness have to be prepared (Fig. 1B). The specimens then stored in distilled water for 24 hours at 37°C before the mechanical testing. The DTS test was performed using the universal testing machine (Testometric/UK) with a crosshead speed of 1.0 mm/minute. The specimens were placed with their long axes perpendicular to the surface of the applied compressive load until failure (Fig. 1C).

The DTS was calculated using the equation: DTS = $2L/\pi Dh$, where L is the failure load, D the diameter, and h the height of the specimen.

Figs 1A to C: Devices and composite specimen used in this study. (A) Blue phase G2 light curing unit; (B) Cylindrical composite specimen of 6 mm in diameter and 4 mm in height; (C) The universal testing machine (Testometric/UK)

Mean DTS values were expressed in MPa and data were analyzed by t-test at the 0.05 level of significance.

RESULTS

Mean DTS values, standard deviations of the four composites with high and low intensity curing in MPa are presented in Table 1. Graph 1 represents the mean DTS values of the four composites being tested with high and low intensity curing in MPa.

One-way analysis of variance (ANOVA) tests for DTS values of all the four composite groups cured with high intensity at 1200 mW/cm^2 and for DTS values of all the four composite groups cured with low intensity at 650 mW/cm^2 revealed that, there were statistically significant differences ($p \leq 0.05$) as shown in Tables 2 and 3, respectively.

Further analysis of the data with t-test indicated that, there was a statistically significant difference in DTS values between all the 12 pairs of the four groups cured with high and low intensities ($p \leq 0.05$) except between pairs no. 5, 7, 9 and 11 that showed no significant differences between them as shown in Table 4.

DISCUSSION

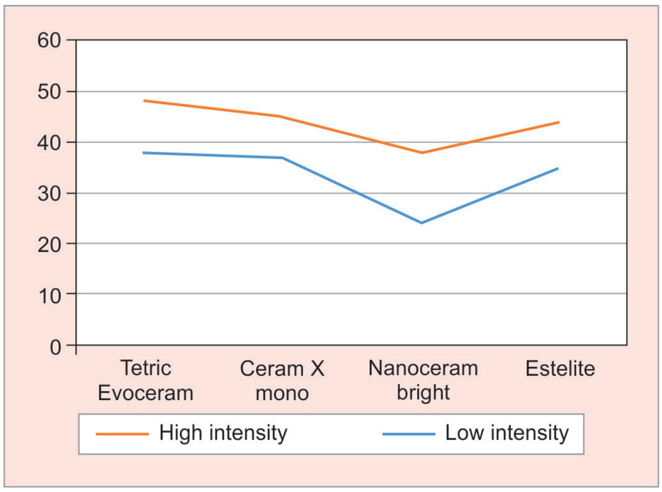
The main importance of diametral tensile strength testing came from it gives an indication about the resistance to fracture of restorative materials in clinical service, and minimizing the clinical problems associated with it.[5]

Table 1: Mean DTS values, standard deviations of the four composites with high and low intensity curing in MPa

Intensity	*Groups composite*	*DTS in MPa, (SD)*
High intensity 1200 mW/cm2	Tetric Evo Ceram Bulk fill	48.799, (1.8)
	Ceram X mono	45.777, (1.4)
	Nanoceram – Bright	38.494, (3.7)
	Estelite	44.805, (1.2)
Low intensity 650 mW/cm2	Tetric Evo Ceram Bulk fill	38.150, (2.1)
	Ceram X mono	37.764, (1.9)
	Nanoceram – Bright	24.582, (3.2)
	Estelite	35.935, (1.07)

Tetric EvoCeram achieved the highest DTS mean values among all the composite groups being tested in this study in both high and low-intensity groups while Nano Ceram-Bright composite achieved the lowest DTS mean values among all the composite groups being tested in this study in both high and low-intensity groups Table 1 and Graph 1.

The results obtained from the study were supported by the findings of Koplin and Takahashi who found that the values of the diametral tensile strength of Tetric Evo Ceram under high intensity to be 48 MPa.[7,8] Moraes[9] reported a mean value of 46 MPa for Tetric Evo Ceram under high-intensity curing. Probably the main reasons behind the high mean values of diametral tensile strength achieved by Tetric Evo Ceram bulk fill in this study might be attributed first to its resin composition as it contains Bis-GMA, Bis-EMA and UDMA Table 5. During the polymerization reaction, monomers are being converted into a long chain cross-linked polymer matrix. The organic matrix phase of Tetric Evo Ceram composite makes about 21% of the total mass. Tetric Evo Ceram composite is the result of a harmonious optimized monomer matrix and fillers combination. The second reason might be attributed to its magic mixture of different types of filler (two different mean particle



Graph 1: Mean DTS values of the four composites with high and low intensity curing in MPa

Table 2: One-way analysis of variance (ANOVA) for DTS of all the four composite groups cured with high intensity 1200 mW/cm^2

Source	*SS*	*df*	*MS*	*F*	*p*
Between-treatments	581.2351	3	193.745	41.40083	< 0.00001
Within-treatments	168.4706	36	4.6797	–	–
Total	749.7057	39	–	–	–

Table 3: One-way ANOVA for DTS of all the four composite groups cured with low intensity 650 mW/cm^2

Source	*SS*	*df*	*MS*	*F*	*p*
Between-treatments	1268.3934	3	422.7978	52.69384	< 0.00001
Within-treatments	288.852	36	8.0237	–	–
Total	1557.2454	39	–	–	–

Table 4: t-test of the DTS values between different pairs of the four groups cured with high and low light intensities

Intensity	*Pair no.*	*Pair of groups*	*t*	*Critical value* 2.101
High intensity 1200 mW/cm^2	1	G1 X G2	4.0203	Sig.
	2	G1 X G3	8.5585	Sig.
	3	G1 X G4	5.5453	Sig.
	4	G2 X G3	6.3833	Sig.
	5	G2 X G4	1.5555	Not sig.
	6	G3 X G4	-5.6666	Sig.
Low intensity 650 mW/cm^2	7	G1 X G2	0.4455	Not sig.
	8	G1 X G3	10.9051	Sig.
	9	G1 X G4	1.0797	Not sig.
	10	G2 X G3	10.8789	Sig.
	11	G2 X G4	0.7868	Not sig.
	12	G3 X G4	-7.9164	Sig.

Table 5: Comparison of materials properties provided by manufacturers

Materials	*Filler composition*	*Matrix composition*	*Shade and Batch*
Tetric Evo Ceram Bulk Fill Ivoclar-Vivadent (Schaan, Liechtenstein	• Ba-glass, YbF3, mixoxide, PPF • 76%	• Nano-Hybird Bis-GMA, Urethane dimethacrylate, Ethoxylated Bis-EMA, UDMA	• A3 • R56348
Ceram X mono (Dentsply)	• 76%.	• Nano- Fill • Methacrylate modified polysiloxane • Dimethacrylate resin	• A3 • 1405000969
Nano Ceram–Bright (DMP LTD)	• Barium glass, mixed oxide. • 80%.	• Nano–Hybrid, Bis-GMA, TEGDMA	• A3 • 630340
Estelite sigma quick	• Silica-zirconia filler • 82% filler weight	• Nano fill, Bis-GMA and Triethylene glycol dimethacrylate	• A3 • E839

sizes, an "Isofiller" with barium aluminum silicate glass, ytterbium fluoride and spherical mixed oxide) to achieve the preferred composite physical and mechanical properties. Tetric Evo Ceram light activated composite has a standard filler content of approximately 61% by volume and 17% "Isofillers" (Scientific Documentation Tetric Evo Ceram® Bulk Fill).[10] The third reason might be attributed to its unique photoinitiator Ivocerin®–a dibenzoyl germanium derivative[11,12] which plays an important role in its optimum polymerization due to the optimal compatibility with Blue Phase G2 light curing unit as Ivocerin photoinitiator wavelength peak absorption values is with Blue Phase G2 light curing unit which was specifically designed to cure Ivoclar Vivadent composite products . It allows optimal curing of posterior composite restorations in larger single increment thickness of up to 4 mm, without affecting the optical properties of the such as translucency or hue. The combined initiator system (camphorquinone) plus Ivocerin® results in a material featuring an absorption optimum in the blue light range from around 370 to 460 nm.[13]

The DTS of the high-intensity group was significantly higher than that of the low-intensity group (Graph 1). These findings were consistent with findings of other research like Rueggeberg[14] who concluded that the higher the light intensity, the higher the degree of conversion, which results in improvement in the general properties of the dental composite, but might lead to increase in polymerization shrinkage.[15,16]

The findings of the current study is also in agreement with the findings of many other previous studies in that, the average DTS values for many conventional dental composites are fallen within our range 34–45 MPa (Table 1) when cured with full light intensity and also we agreed with their justification for results obtained from their studies in that, "The diametral tensile strength test may reveal different values for apparently similar materials. However, this variation has been explained by the difference between the polymeric matrix, the size of fillers and bond between fillers and matrix.[17] The matrix of most resins is composed of bisphenol-A glycidylmethacrylate (Bis-GMA), which is an aromatic ester of a dimethacrylate, synthesized from an epoxy resin and methyl methacrylate; thus, it is rigid yet presents high viscosity. The viscosity of the polymeric matrix is reduced by the addition of other low molecular weight polymers such as urethane dimethacrylate (UEDMA) or triethyleneglycol dimethacrylate (TEGDMA), as in the composite Filtek Z-250, to improve the incorporation of fillers and increase the degree of conversion of composite resins. Therefore, it has been reported that replacing BisGMA by TEGDMA increases the diametral tensile strength yet reduces the flexural strength, whereas replacing either Bis-GMA or TEGDMA by UEDMA increases the diametral strength and flexural strength,[17] which was confirmed by the results in that study". In the current study, we also found that, replacing either Bis-GMA or TEGDMA by UDMA or incorporation of UDMA resin monomer in composite resin matrix composition) (Table 5) significantly increases the diametral tensile strength of many conventional composites, as in Tetric Evo Ceram composite, which was confirmed by the results obtained in the current study and also explained why Nano Ceram-Bright composite exhibited the least DTS mean values among all the composite being tested in this study and supports and might be one of the main causes behind the high DTS mean values of Tetric Evo Ceram composite as it was mentioned before (Table 5).[18-20]

CONCLUSION

Within the limits of this study, we can conclude:

- High light intensity significantly resulted in higher DTS values in all the composites being tested than the low light intensity.
- The composite composition also significantly influences its DTS values.

CLINICAL SIGNIFICANCE

Diametral tensile strength (DTS) of any restorative material is an essential test that simulates the tensile behavior of the restorative material during function in the oral cavity which is an indicator for the general strength and durability of the restoration in oral service.

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