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Comparative evaluation of compressive and diametral tensile strength: Nanoceramic versus conventional composite resins

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Abstract:
Advanced filler technologies in composite resins aim to improve mechanical performance and clinical durability. Therefore, it is of interest to compare the compressive strength and diametral tensile strength of nanoceramic and conventional composite resin materials. Two groups were evaluated: Group A, Neo Spectra ST nanoceramic composite and Group B, Filtek Z250 XT. Twenty specimens each for CS (6 × 3 mm) and DTS (6 × 12 mm) were tested using a universal testing machine. Thus, the nanoceramic composite showed higher CS and DTS than conventional composite resin, indicating superior mechanical performance.

Keywords: Nanoceramic composite, conventional composite resin, compressive strength, diametral tensile strength

Background:
The success and longevity of direct restorative procedures depend largely on the selection of restorative materials with adequate mechanical strength, durability, esthetics and resistance to functional stresses **[1]**. Resin-based composite resins have become an integral part of contemporary restorative dentistry because of their conservative approach, favorable esthetic properties, versatility and ability to bond to tooth structure **[2]**. The clinical performance of composite resins is influenced by their chemical composition, degree of polymerization, filler characteristics and interaction between the resin matrix and filler particles **[3]**. Among these factors, the type, size, shape, distribution and loading of inorganic fillers play a significant part in defining the mechanical and physical properties of the material **[4, 5]**. Continuous developments in composite resin technology have focused on improving filler systems and optimizing the interaction between the organic matrix and inorganic components **[6]**. Conventional composite resins have undergone substantial modifications in filler size and distribution, resulting in improved strength, wears resistance, polishability and esthetic performance **[7]**. More recently, nanotechnology has contributed to the development of nanoceramic composite resins, incorporating nanoscale filler particles and ceramic-based components **[8]**. These materials are designed to provide improved mechanical properties, surface characteristics, handling and esthetic stability while maintaining the advantages of resin-based restorative materials **[9]**. Restorative materials are subjected to complex and repetitive stresses during mastication. Therefore, adequate resistance to compressive and tensile forces is essential for maintaining restoration integrity and preventing fracture **[10]**. Compressive strength represents the ability of a material to withstand forces acting toward its center, whereas diametral tensile strength provides an indirect assessment of resistance to tensile stresses and fracture. Evaluation of these properties can provide valuable information regarding the ability of different composite resin formulations to withstand functional loading **[11, 12]**. Therefore it is of interest to evaluate the compressive and diametral tensile strength of a nanoceramic composite resin and a conventional composite resin.

Materials and Methods:

Study design:
In vitro experimental research was carried to compare the mechanical properties of a nanoceramic composite resin with those of a contemporary composite resin by evaluating compressive strength (CS) and diametral tensile strength (DTS).

Materials and grouping:
Two commercially available composite resins were evaluated. Group A consisted of a nanoceramic composite resin (Neo Spectra ST, Dentsply Sirona) and Group B consisted of a contemporary nanohybrid composite resin (Filtek Z250 XT, 3M ESPE). The materials were handled and polymerized according to the respective manufacturers' instructions.

Specimen preparation:
A total of 40 specimens were prepared, comprising 20 specimens for compressive strength (CS) testing and 20 specimens for

diametral tensile strength (DTS) testing. For each test, 10 specimens were prepared from each material, resulting in two groups of 10 specimens. Standardized stainless-steel molds were used for specimen fabrication. For CS testing, cylindrical specimens measuring 6 mm in diameter and 3 mm in height were prepared, whereas DTS specimens measured 6 mm in diameter and 12 mm in height. The composite resin was carefully packed into the respective molds and covered with a transparent matrix strip. The specimens were light-cured according to the manufacturer's recommended curing protocol. After polymerization, the specimens were removed from the molds and examined for visible defects. Specimens showing cracks, voids, or irregularities were excluded and replaced.

Evaluation of compressive strength:
Each specimen was positioned vertically between the platens of the universal testing machine (UNITEST 10). A compressive load was applied at a crosshead speed of 1 mm/minute until fracture occurred. The maximum load sustained by each specimen was recorded. CS was calculated using the formula:

$CS = F / \pi r^2$

Where F is the load at fracture (N), r is the radius of the specimen (mm) and $\pi = 3.1416$. The CS values were expressed in MPa.

Evaluation of diametral tensile strength:
Each cylindrical specimen was positioned horizontally between the platens of a universal testing machine (UNITEST 10). A compressive load was applied along the diameter at a crosshead speed of 1 mm/minute, producing tensile stresses perpendicular to the central vertical plane of the specimen. The load at fracture was recorded in Newtons (N). DTS was calculated using the formula: $DTS = 2P / \pi DT$; where P is the load at fracture (N), D is the specimen diameter (mm), T is the specimen thickness/length (mm) and $\pi = 3.1416$. The DTS values were expressed in megapascals (MPa).

Statistical analysis:
The measured CS and DTS data from the two groups were compiled and subjected to statistical analysis. Results were presented as mean ± standard deviation (SD). Statistical comparison between the groups was performed using an appropriate inferential test, with $P < 0.05$ considered indicative of statistical significance.

Results:
The nanoceramic composite resin (Group A) demonstrated significantly higher compressive strength and diametral tensile strength than the conventional composite resin (Group B). The mean compressive strength was 95.80 ± 2.50 MPa for Group A compared with 47.71 ± 2.80 MPa for Group B. Similarly, the mean diametral tensile strength was 41.21 ± 1.80 MPa in Group A and 28.11 ± 1.60 MPa in Group B (**Table 1**). Thus, the nanoceramic composite exhibited superior mechanical performance in both compressive and diametral tensile strength tests.

Table 1: Compressive and Diametral Tensile Strength of Nanoceramic and Conventional Composite Resins

Mechanical Property (MPa)	Group A: Nanoceramic Composite (n=10)	Group B: Conventional Composite (n=10)	*t* value	*P* value
Compressive strength	95.80 ± 2.50	47.71 ± 2.80	40.20	<0.001*
Diametral tensile strength	41.21 ± 1.80	28.11 ± 1.60	17.08	<0.001*

**Statistically significant at P < 0.05.*

Discussion:
The mechanical performance of restorative composites plays a critical role in their ability to withstand the stresses encountered during clinical service **[13]**. Among the various mechanical properties, compressive strength and diametral tensile strength are particularly important because restorative materials are subjected to complex combinations of compressive and tensile stresses during mastication. Adequate compressive strength helps the material resist deformation and fracture under occlusal loading, whereas diametral tensile strength provides an indirect assessment of resistance to tensile stresses and crack propagation. Evaluation of both properties therefore provides useful information regarding the ability of a composite resin to withstand functional stresses **[14]**. The present *in vitro* study compared the compressive strength and diametral tensile strength of a nanoceramic composite resin with a conventional composite resin. The results of the present study demonstrated higher CS and DTS values for the nanoceramic composite, indicating superior mechanical performance under the conditions of the study. The differences observed may be related to variations in resin-matrix composition, filler characteristics, filler loading, particle morphology and the interaction between the filler and polymer matrix. The superior mechanical performance of the nanoceramic composite may be attributed to its highly optimized filler system and dense filler network. NeoSpectra™ ST contains an organically modified ceramic component within its resin matrix and a high filler content of approximately 78–80% by weight. Its filler system comprises spherical prepolymerized Sphere TEC filler particles, along with barium glass and ytterbium fluoride **[15, 16]**. The spherical and smooth morphology of these particles provides a relatively low active surface area, permitting greater filler incorporation into the resin matrix and contributing to a denser filler network with reduced interstitial spaces. Their uniform integration within the resin matrix may further promote the formation of a robust resin–filler interface, facilitating efficient stress transfer and minimizing localized stress concentrations. Collectively, these characteristics may enhance the structural integrity of the composite and contribute to improved resistance to mechanical stresses and wear **[17]**. Bahig *et al.* reported favorable long-term

clinical performance and wear behavior of nanoceramic resin composites, supporting the potential contribution of optimized filler characteristics and resin–filler interactions to the mechanical durability of these materials. Furthermore, the reduced intrinsic friction between the spherical filler particles and resin matrix under shear stress may contribute to improved resistance to crack initiation and propagation. These characteristics could partly explain the higher compressive and diametral tensile strength observed in the nanoceramic composite group **[18]**. In comparison, the conventional composite resin contains a Bis-GMA-, Bis-EMA-, PEGDMA and TEGDMA-based resin matrix with approximately 82% filler loading by weight. Although its higher filler loading might be expected to contribute to mechanical strength, filler loading alone does not determine the overall mechanical behavior of a composite resin. Filler particle size, morphology, distribution, surface treatment, matrix composition and the quality of the filler–matrix interface also influence the ability of a composite to withstand applied stresses. Thus, the slightly higher filler loading of the conventional composite did not translate into higher CS or DTS in the present study. The higher DTS observed for the nanoceramic composite may similarly be associated with its filler architecture and resin-matrix characteristics. DTS is particularly influenced by internal defects, stress concentration and the quality of bonding between the filler phase and resin matrix. A more homogeneous filler distribution and effective filler–matrix interaction may facilitate stress transfer and delay crack initiation and propagation. The proposed explanations should therefore be interpreted cautiously, given that the study did not include microscopic evaluation of filler–matrix interactions or fracture-surface characteristics. Overall, the findings suggest that the nanoceramic composite demonstrated better resistance to both compressive and tensile loading than the evaluated conventional composite resin. Evaluation of CS and DTS together is particularly relevant because these properties provide complementary information about the mechanical behavior of restorative materials and their potential ability to withstand the complex stresses encountered during clinical service **[19-21]**. Further studies incorporating flexural strength, fracture toughness, wear resistance, surface hardness; thermocycling and long-term aging are recommended to provide a more comprehensive assessment of clinical performance.

Conclusion:

The nanoceramic composite resin showed higher compressive strength and diametral tensile strength than the conventional composite resin. The findings indicate that the nanoceramic composite may offer improved resistance to functional stresses and favorable mechanical performance for direct restorative applications. Further studies involving long-term aging and additional mechanical properties are recommended to confirm these findings and determine their clinical relevance.

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