Original Article

Evaluation of fracture resistance of maxillary premolars of different geometrical cavities restored with different composite resins incorporated with chitosan nanoparticles

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Abstract

Background: Composites with 0.2% chitosan nanoparticles (CSN) are used recently; however, this combination needs to be studied in different cavity designs.

Aims: The aim of the study was to compare the fracture resistance of maxillary premolars with different cavity geometries restored with different types of composite resins incorporated with 0.2% CSN.

Methods: About 130 extracted human single-rooted maxillary premolars were embedded in acrylic molds 2 mm below cementoenamel junction, divided into five groups for cavity preparations of standardized dimensions. Group 1: (control) intact teeth ($n = 10$), Group 2: Class I cavities ($n = 40$), Group 3: Class II mesio-occlusal (MO) ($n = 40$), Group 4: Class II mesio-occluso-distal (MOD) ($n = 40$). Groups 2, 3, and 4 were subdivided into four subgroups for composite restoration; A: Neo spectra ST-Universal (NST); B: Tetric N-Ceram Bulk-fill (TNC); C: NST + CSN; and D: TNC + CSN and tested for fracture resistance using universal testing machine.

Statistical Analysis: One-way analysis of variance and *post hoc* Tukey's tests were used for data analysis ($P \leq 0.05$).

Results: In all groups, the highest fracture resistance was found in MOD cavities, followed by MO and least in Class I cavities. Subgroup D (TNC with CSN) showed the highest fracture resistance in all groups ($P \leq 0.05$).

Conclusion: Tetric N-Ceramic bulk fill with 0.25% CSN showed high fracture resistance in cavities with different geometries.

Keywords: Bulk-fill composite; chitosan nanoparticles; fracture resistance; universal composite

INTRODUCTION

Composite resins are the most widely used restorative materials in dentistry mainly for esthetic reasons. Over the years, improvements in composite materials and techniques including bonding systems were seen with longevity and direct filling capabilities in posterior restorations.[1]

Universal resin composites were developed for easy adaption to cavity walls, margins, and surfaces in both direct and indirect restorations.[2] Neo spectra ST (NST) (Dentsply, Konstans, Germany) is a nanoceramic-based universal composite resin that has been developed based on superior composite technology known as Sphere technology (SphereTEC) consisting of granulated spherical fillers of different sizes

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along with optimized resin matrix. Their morphology, particle size distribution, and surface microstructure deliver the benefits of easy handling, nonsticky in nature with adequate adaptation, easy condensation, that is available in both high and low viscosities. Shade selection is simple with five universal shades that match all teeth with excellent esthetics and can be used for both direct and indirect restorations.[3,4]

Bulk-fill composites were designed for placement of resin composite in a bulk, thus reducing the technique sensitivity and chair side time,[5] Tetric N-Ceram (TNC) Bulk fill (Ivoclar Vivadent, Schann, Liechtenstein) is a nanohybrid bulk-fill composite. It contains glycol dimethacrylate monomer resin matrix – 21%, fillers made up of barium, ytterbium fluoride, and trioxides – 61%, 17% of polymer filler, and 1 wt. % of initiators, stabilizers, and pigments. It exhibits less polymerization shrinkage with higher polymerization depth and allows for placement in a single increment of about 4 mm. Hence suitable for posterior direct restorations which pose technical challenges during placement.[6,7]

Posterior composite restorations pose difficulty due to technique sensitivity, accessibility, isolation, and the cavities of different geometries in posterior areas such as Class I, Class II, and mesio-occluso-distal (MOD) cavities are subjected to several types of stresses and masticatory load.[8]

Extensive studies were done for improving the esthetics and properties of composite resins. Antibacterial composite resins were synthesized by employing antibacterial agents such as methacryloxylethyl cetyl dimethyl ammonium chloride (DMAE-CB) and cetylpyridinium chloride.[9]

Studies suggest that chitosan nanoparticles (CSN) incorporated in composite resins or dental adhesives exhibited improved antibacterial property, without affecting the bond strength.[3,10] However, the combination of composites with CSN might affect the strength of the tooth, since the addition of any other substance or material to existing material might affect its properties such as the compressive/tensile strength and bond strength, since different types of composites such as Bulk Fill and universal composites that are recommended for restoration in posterior region; hence, it is essential to evaluate the effect of addition of CSN to these composites. Till now, no studies were reported regarding the fracture resistance of maxillary premolar teeth with different types of cavity designs restored with different composites incorporated with CSN; hence, this study was undertaken.

METHODS

Approval from the ethical committee of the institute was obtained for this study (Ref no-IEC/2020-2021/S-17) and conducted accordingly.

Hundred and thirty freshly extracted human maxillary premolar teeth for orthodontic purpose were collected and cleaned using ultrasonic scalers (Woodpecker Piezo scaler USD-J, China) to remove soft-tissue debris and stains, followed by storage in distilled water until further use. The specimens were encased in acrylic resin blocks 2 mm below the cementoenamel junction (CEJ) and were divided into four groups:

- Group 1: (control) Intact teeth ($n = 10$)
- Group 2: Class I cavity ($n = 40$)
- Group 3: Class II mesio-occlusal cavity (MO) ($n = 40$)
- Group 4: Class II MOD cavity ($n = 40$).

Further four subgroups were done in the Groups 2–4 for composite restorations as:

- Subgroup A: NST Universal composite
- Subgroup B: TNC Bulk-fill composite
- Subgroup C: NST Universal composite + 0.2% CSN (NST + CSN) (1:1 ratio)
- Subgroup D: TNC Bulk-fill composite + 0.2% CSN (TNC + CSN) (1:1 ratio).

About 0.05 g CSN powder particles (SRL Pvt Ltd, Hyderabad, India) were dispersed in 23 ml of distilled water with 0.05 ml of acetic acid (Sigma laboratories, Mumbai, India) and mixed properly for obtaining 0.25% CSN solution. One milliliter of 0.06gms of tripolyphosphate solution (Sigma laboratories, Mumbai, India) was then added, and the mixture was allowed to stand for 24 h.[11,12] Freshly prepared 0.1 ml CSN solution was further added to 0.01 g of Neo spectra and TNC bulk-fill composites in 1:1 ratio separately in a glass beaker and mixed with a glass stirrer in the dark room and left for 24 h.

In Group 2, Class I cavities of standard dimensions of mesiodistal length of 4 mm, buccopalatal width of 3 mm, and pulpal depth 3 mm were prepared with a cylindrical diamond bur (Mani, Hyderabad, India) under high-speed air water-cooled handpiece (Drillerz-EM, Hyderabad, India).[13]

In Group 3, (Class II MO cavities) and Group 4 (Class II MOD cavities) were prepared with a 2 mm pulpal depth using straight bur (Mani, Hyderabad, India), and 2 mm cavity buccolingual width was prepared using inverted bur. Gingival floor was prepared 1 mm below the CEJ using a no -010 straight fissured diamond bur under a high-speed air water-cooled handpiece.[3]

In all the groups, G-Premio Bond (GC Dental Products Corp, Kasugai, Japan) adhesive was applied and left undisturbed for 10 s, then air-dried and light-cured for 20 s using LED curing unit (Woodpecker, Muenster, Germany), followed by placement of Palodent V3 sectional matrix system (Dentsply Sirona, USA) in Groups 3 and 4 for obtaining the tight contact.

In Subgroups A and C, NST composite resin with and without CSN was placed into the prepared cavities using the incremental technique of 1 mm thickness and light-cured for 20 s. Whereas, in Subgroups B and D, TNC Bulk-Fill composite with and without CSN were placed into the cavities in 4 mm thickness and light cured for 20 s. In all the groups, finishing and polishing were done with a composite polishing kit (Shofu Dental India Private Limited, India), and specimens were left aside for 24 h.

For the evaluation of fracture resistance, the specimens of each group were loaded vertically under a universal testing machine (Instron JOEL 3352, USA). Fracture resistance was tested using a steel ball of 4 mm diameter with a cross-head speed of 1 mm/min until the specimen fractures and load was recorded in Newtons [Figure 1].

Statistical analysis

The data were subjected to statistical analysis using R Programming software version R 3.2.1 (R core, New Zealand) by one-way analysis of variance (ANOVA) and *post hoc* Tukey's tests at a level of significance with $P \leq 0.05$.

RESULTS

Analysis by one-way ANOVA showed highest fracture resistance in Subgroup 4D, followed by 4C, 4B, 4A, 3D, 3B, 3C, 3A, 2D, 2B, and least in 2A. Among the groups, fracture resistance was found to be highest in Group 4, followed by Group 3, control group, Group 2, and least in Group 1. In all the groups, Subgroup D showed the highest fracture resistance, followed by Subgroups C and B and least in Subgroup A [Table l].

Multiple comparisons by *post hoc* Tukey test showed significant difference between all groups except between Group 1 (control) and Subgroup 3D, between Subgroup 2A and 2B, between 3A and 3B, 3C, Group 3B with Group 3C and 4A with Group 4B [Table 2].

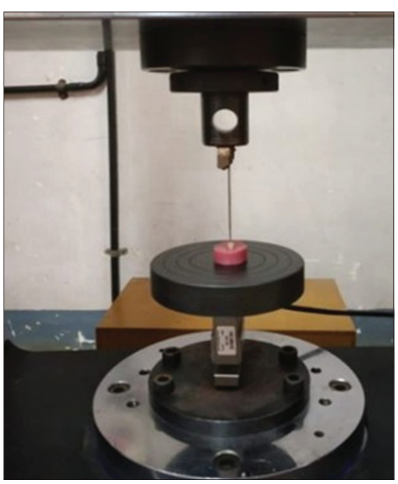

Figure 1: Determination of fracture resistance of the specimen loaded under universal testing machine

DISCUSSION

Fracture of restoration in a tooth can be explained as an incomplete or complete break in the material itself or along with the tooth structure that often results from excessive occlusal forces. The cavity preparation significantly increases the weakness of the remaining tooth structure. Restored teeth have some cuspal deflection due to excess forces acting on them which results in fracture/crack of the material or the tooth structure.[14]

One of the advantages of direct composite restorations is the preservance of the remaining tooth structure.[15] However, the drawbacks of composite restorations are the limited life span, secondary caries, and polymerization shrinkage. During the curing phase, composite resins undergo contraction of material, and its flow decreases as the hardness increases which depends on the type of composite resin used and the cavity geometry, hence resulting in increased stress distribution which leads to bond failure.[16] To overcome these drawbacks, some newer materials such as CSN were added with composites to improve its properties such as antimicrobial activity and pushout bond strength.[3,17]

In the present study, the highest fracture resistance was found with Tetric N Ceram Bulk Fill compared to NST universal composite resin. Agarwal *et al*. stated that the viscosity of the bulk-fill composite material influences the amount of marginal interface and its quality of adaptation to the inner walls.[12] The present study is in line with the above study and with Kale *et al*.[14] and Bilgi *et al*.,[15] with the highest fracture resistance of TNC bulk-fill composite resin.

Table 1: One-way ANOVA analysis of fracture resistance of all the groups

Group	Mean	SD
Group 1 (positive control)	550.8	20.4621
Group 2 (Class I)		
Subgroup A	214.6	30.4269
Subgroup B	241.2	5.2631
Subgroup C	344.8	7.7589
Subgroup D	396.0	12.9422
Group 3 (Class II MO)		
Subgroup A	463.8	12.0706
Subgroup B	474.8	5.8052
Subgroup C	474.0	12.9421
Subgroup D	571.4	10.0648
Group 4 (Class II MOD)		
Subgroup A	656.6	15.0930
Subgroup B	664.2	10.0349
Subgroup C	720.0	35.5317
Subgroup D	892.4	28.6409
P	<0.00001 (S)	

MO: Mesio-occlusal, MOD: MO distal, S: Significant difference

Table 2: Multiple comparison of fracture resistance among all groups by *post hoc* Tukey test

Groups	Comparison groups	Difference	P
Group 1	Subgroup 2A	336.2	<0.00001 (S)
	Subgroup 2B	309.6	<0.00001 (S)
	Subgroup 2C	206.0	<0.00001 (S)
	Subgroup 2D	154.8	<0.00001 (S)
	Subgroup 3A	87.0	<0.00001 (S)
	Subgroup 3B	76.0	<0.00001 (S)
	Subgroup 3C	76.8	<0.00001 (S)
	Subgroup 3D	20.6	0.8901 (NS)
	Subgroup 4A	105.8	<0.00001 (S)
	Subgroup 4B	113.4	<0.00001 (S)
	Subgroup 4C	169.2	<0.00001 (S)
	Subgroup 4D	341.6	<0.00001 (S)
Subgroup 2A	Subgroup 2B	26.6	0.5674 (NS)
	Subgroup 2C	130.2	<0.00001 (S)
	Subgroup 2D	181.4	<0.00001 (S)
	Subgroup 3A	249.2	<0.00001 (S)
	Subgroup 3B	260.2	<0.00001 (S)
	Subgroup 3C	259.4	<0.00001 (S)
	Subgroup 3D	356.8	<0.00001 (S)
	Subgroup 4A	505.4	<0.00001 (S)
	Subgroup 4B	449.6	<0.00001 (S)
	Subgroup 4C	505.4	<0.00001 (S)
	Subgroup 4D	677.8	<0.00001 (S)
Subgroup 2B	Subgroup 2C	103.6	<0.00001 (S)
	Subgroup 2D	154.8	<0.00001 (S)
	Subgroup 3A	222.6	<0.00001 (S)
	Subgroup 3B	233.6	<0.00001 (S)
	Subgroup 3C	232.8	<0.00001 (S)
	Subgroup 3D	330.2	<0.00001 (S)
	Subgroup 4A	415.4	<0.00001 (S)
	Subgroup 4B	423.0	<0.00001 (S)
	Subgroup 4C	478.8	<0.00001 (S)
	Subgroup 4D	651.2	<0.00001 (S)
Subgroup 2C	Subgroup 2D	51.2	0.0021 (S)
	Subgroup 3A	119.0	<0.00001 (S)
	Subgroup 3B	130.0	<0.00001 (S)
	Subgroup 3C	129.2	<0.00001 (S)
	Subgroup 3D	226.6	<0.00001 (S)
	Subgroup 4A	311.8	<0.00001 (S)
	Subgroup 4B	319.4	<0.00001 (S)
	Subgroup 4C	375.2	<0.00001 (S)
	Subgroup 4D	547.6	<0.00001 (S)
Subgroup 2D	Subgroup 3A	67.8	<0.00001 (S)
	Subgroup 3B	78.8	<0.00001 (S)
	Subgroup 3C	78.0	<0.00001 (S)
	Subgroup 3D	175.4	<0.00001 (S)
	Subgroup 4A	260.6	<0.00001 (S)
	Subgroup 4B	268.2	<0.00001 (S)
	Subgroup 4C	324.0	<0.00001 (S)
	Subgroup 4D	496.4	<0.00001 (S)
Subgroup 3A	Subgroup 3B	11.0	0.9998 (NS)
	Subgroup 3C	10.2	0.9999 (NS)
	Subgroup 3D	107.6	<0.00001 (S)
	Subgroup 4A	192.8	<0.00001 (S)
	Subgroup 4B	200.4	<0.00001 (S)
	Subgroup 4C	256.2	<0.00001 (S)
	Subgroup 4D	4286	<0.00001 (S)
Subgroup 3B	Subgroup 3C	0.8	<0.00001 (S)
	Subgroup 3D	96.6	<0.00001 (S)
	Subgroup 4A	181.8	<0.00001 (S)
	Subgroup 4B	189.4	<0.00001 (S)
	Subgroup 4C	245.2	<0.00001 (S)
	Subgroup 4D	417.6	<0.00001 (S)
Subgroup 3C	Subgroup 3D	97.4	<0.00001 (S)
	Subgroup 4A	182.6	<0.00001 (S)
	Subgroup 4B	190.2	<0.00001 (S)
	Subgroup 4C	246.0	<0.00001 (S)
	Subgroup 4D	418.4	<0.00001 (S)
Subgroup 3D	Subgroup 4A	85.2	<0.00001 (S)
	Subgroup 4B	92.8	<0.00001 (S)
	Subgroup 4C	148.6	<0.00001 (S)
	Subgroup 4D	321.0	<0.00001 (S)
Subgroup 4A	Subgroup 4B	7.6	0.9999 (NS)
	Subgroup 4C	63.4	<0.00001 (S)
	Subgroup 4D	677.8	<0.00001 (S)
Subgroup 4B	Subgroup 4C	55.8	<0.00001 (S)
	Subgroup 4D	228.2	<0.00001 (S)
Subgroup 4C	Subgroup 4D	172.4	<0.00001 (S)

Contd...

Table 2: Contd...

S: Significant difference, NS: No significant difference

França *et al*., in a study, evaluated fracture strength, microtensile bond strength, and microhardness of low- and high-viscosity bulk-fill composite restorations and stated that high-viscosity TNC bulk-fill composite resin exhibited higher KHN values at the increment of 4 mm than at 2 mm. The high-viscosity composites contain higher amount of fillers and are indicated in cavities prone to greater fracture or wear.[16]

The bonding effectiveness of composite restorative materials is affected by different techniques of composite placement. Considering this fact, the study findings are in accordance with Al-Harbi *et al*. stated that bulk-fill composite restorations provided better cervical interfacial quality than incremental fill restorations of Class II cavities along with increased microtensile bond strength.[17] In the present study, the highest fracture resistance in Tetric N-Ceram Bulk Fill can be attributed to its composition to the fact that the substitution of BisGMA and TEGDMA by UDMA that lowered solubility and water sorption, hence increased the mechanical properties due to the increased degree of conversion. The inorganic filler particle size that ranges between 0.1 μm and 30 μm with a mean particle size of 5 μm and low elastic modulus which acts as a shrinkage stress reliever. It also contains a new light initiator known as Ivocerin, which can absorb blue light wavelengths ranging from 370 to 460 nm. This is more reactive toward light compared to camphorquinone, thus allowing for quick polymerization with deeper curing depth. This resin composite has a compressive strength of 224 MPa.[18] On the other hand, Neo Spectra ST consists of organically modified ceramic organic matrix consisting of methacrylate-modified polysiloxane, dimethacrylate resins, ethyl-4 (dimethylamino) benzoate, and bis (4-methyl-phenyl) iodonium hexafluorophosphate. Fillers of about 78%–80% by weight that are spherical in shape, nonagglomerated, prepolymerized barium glass, and ytterbium fluoride SphereTEC fillers of particle size 50 ≈ 15 μm. Vickers microhardness (VHN) value of this resin is 62.69 VHN.[6] According to Farahanny *et al*., bulk-fill composite resins exhibit the highest fracture resistance in Class I cavities of endodontically treated teeth.[19]

The different cavity geometries of Class I, Class II MO, and MOD cavities are also the factors that influence fracture resistance, since the C-factor in different cavity preparations are different from each other, the highest C-factor in Class I cavities influences the fracture resistance than in Class II and Class II MOD cavities.[20] de la Macorra and Gomez-Fernandez measured the configuration factor value for Class I and Il cavities and simulated cervical erosions in molar tooth and showed that configuration (C-factor) was highest with Class I cavities followed by Class II MO and least in MOD cavities.[21] Hence, in accordance with the above studies, the highest fracture resistance was found in MOD cavities, followed by MO and least in Class I cavities with the highest C factor. The present study results are in accordance with Atiyah and Baban reported that MOD cavities restored with SDR (smart dentine replacement) bulk-fill material showed higher fracture resistance compared to packable composite resin.[22] This could be attributed to unique filler composition, highly cross-linked resin matrix, and resiliency of bulk-fill composites which helps to withstand higher stress before fracture.

Mohamed *et al*. assessed microtensile bond strength of CSN incorporated in composite resin with self-etch adhesive of aged restorations. Dentin was pretreated with 0.2% and 2.5% CSN and results showed the addition of CSN had shown to increase the bond strength even after 6 months aging.[23] In the present study, the addition of CSN has shown to improve the fracture resistance for both the composites. Botelho *et al*., in a study, evaluated microtensile bond strength of CSN incorporated self-etch adhesive system before and after artificial aging and stated that CSN promoted bond strength over time when incorporated with adhesive systems due to the formation of calcium phosphate layer on dentin.[24] Halkai *et al*. evaluated the pushout bond strength of CSN incorporated in self-etch dentin bonding agents and composites in Class II cavities in maxillary molars and reported that lower bond strength was found in CSN incorporated adhesives compared to CSN incorporated composites, this might be due to difference in materials used and aging periods.[3]

The clinical significance of the present study is to evaluate the effect of the addition of CSN to different composite resins restored in cavities of different geometries, thus providing information regarding the suitability of material for clinical success. Therefore, within the limitations of the present study, the highest fracture resistance was found with CSN-incorporated Tetric-N-Ceram Bulk-Fill composite resin. However, the limitations of the present study are it is an *in vitro* study, type of composite materials, and the bonding agent used might alter the results; therefore, further studies and clinical long-term research studies are needed.

CONCLUSION

TNC Bulk-Fill composite resin incorporated with 0.25% CSN showed the highest fracture resistance in cavities with different geometries.

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Conflicts of interest

There are no conflicts of interest.

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