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Evaluation Of Push Out Bond Strength Of Different Concentrations Of Chitosan Nano Particles And Fiber Glass Particles Incorporated Composite Resin And 8th Generation Bonding Agent For Class 2 Restoration In Premolar Teeth: An In Vitro Study

Dr. Deepmala Jogani[1], Dr. Manu Bansal[2], Dr. Parul Verma[3], Dr. Gargee Karmveer[4], Dr. Himalay Rathod[5], Dr. Rebecca Shylla[6]

[1]Post Graduate, Department of Conservative Dentistry and Endodontics, Jaipur Dental College (Mvgu), Jaipur, Rajasthan

[2]Professor & Head of Department, Department f Conservative Dentistry and Endodontics, Jaipur Dental College (Mvgu), Jaipur, Rajasthan

[3]Associate Professor, Department Oof Conservative Dentistry and Endodontics, Jaipur Dental College (Mvgu), Jaipur, Rajasthan

[4]Senior Lecturer, Department of Conservative Dentistry and Endodontics, Jaipur Dental College (Mvgu), Jaipur, Rajasthan

[5]Phd Scholar Department of Periodontology, Narsinhbhai Patel Dental College, Sakalchand Patel University, Visnagar, Gujarat

[6]Post Graduate Department of Conservative Dentistry and Endodontics, Jaipur Dental College (Mvgu), Jaipur, Rajasthan

Abstract

Aim and Objectives: *The aim of this study is to evaluate the push-out bonding strength of class II cavities a vitro study of Premolars restored with different concentrations of chitosan nanoparticles (CSN) and fiber glass particles incorporated in universal composite resin and eighth-generation dentin bonding agent (DBA).*

Methodology: *Eighty human extracted Premolar teeth recently extracted for periodontal reasons were collected, cleaned with Ultrasonic Scalers (woodpecker piezo scaler UDS-J, China), and stored in distilled water and mounted in acrylic mold up to 2 mm below cementoenamel junction and mesio-occlusal Class II cavities with standard dimension. CSN 2% and 0.25% powder were added to the DBA and composite resin by VORTEX method. The specimens were arbitrary allotted into 4 groups for restorations as follows Group 1: (Control group) (no CSN) Group 2: (2% fiber glass particles + Composite) Group 3A: (2% CSN + Composite) Group 3B: (2%CSN + DBA) Group 3C: (2%CSN+ DBA+ Composite) Group 4A: (0.25%CSN + Composite) Group 4B: (0.25%CSN + Composite + DBA) Group 4 (0.25%CSN+ DBA + Composite)*

Result and Conclusion: *Subgroup 4A (0.25% CSN + composite) has shown an increase in bond strength among all experimental groups with no significant difference between group 1 (control group). CONCLUSION: CSN 0.25% incorporated in composite or DBA exhibits no harmful effect on the bond strength of class II restorations. Hence, it can be used to improve the antibacterial action and longevity of composite resin.*

Keywords: *Chitosan Nanoparticles, Dentin Bonding Agents, Composite Resin, Hydroxy Ethyl Meth Acrylate, Cemento Enamel Junction, Universal Testing Machine*

INTRODUCTION

Resin-based dental composites have undergone substantial development over the past 50 years. Initially, advancements focused on reducing filler size, enhancing polish ability and wear resistance. The current research focus is on optimizing the polymer matrix to mitigate shrinkage and stress, with an added goal of achieving self-adhesion. Emerging trends point towards innovative materials capable of self-repair and dynamic response. [1]

Chitin, a widespread biopolymer, is commonly derived from marine waste and boasts a linear structure and substantial molecular weight. Chitosan, its FDA-approved counterpart, is sourced from diverse origins, including plants and animals. Crustaceans, insects, fungi, and specific plants like mushrooms are all potential sources of chitin.[2]

Chitosan (CS), a biopolymer endowed with cationic properties, has emerged as a highly promising material in the realm of dental research. Its unique characteristics and potential to augment the properties of dental composites have sparked considerable interest among researchers and clinicians alike. However, the limited solubility of chitosan in biological environments poses a significant challenge, hindering its widespread adoption in dental applications.[3]

To overcome this limitation, researchers have been actively exploring various methods to improve the solubility and functionality of chitosan. Deacetylation and chemical modification are two such approaches that have shown promise in enhancing the properties of chitosan. By tailoring the chemical structure of chitosan, researchers can create derivatives with improved solubility and functionality, thereby expanding its potential applications in dentistry.[4,5]

The bonding performance between composite resin and tooth structure is a critical factor that determines the longevity and success of dental restorations. A strong and durable bond is essential to withstand the stresses and strains imposed by mastication, thermal changes, and other environmental factors. Recent advancements in nanomaterials, particularly chitosan nanoparticles, have demonstrated significant potential in improving the mechanical properties and biocompatibility of dental composites. [6,7]

Chitosan nanoparticles have been shown to possess antimicrobial activity, enhanced mechanical strength, and improved handling properties, making them an attractive additive for dental composites. The incorporation of chitosan nanoparticles into composite resins has been found to improve their mechanical properties, such as flexural strength and modulus, as well as their antibacterial activity.[8]

This study aims to investigate the push-out bond strength of composite resins incorporating chitosan nanoparticles and eighth-generation bonding agents. By evaluating the bonding performance of these novel materials, this research seeks to provide valuable insights into their potential clinical applications and contribute to the existing body of knowledge on dental composite resins and bonding agents.[9,10]

The findings of this study will have significant implications for the development of novel dental materials with improved properties and bonding performance. By understanding the effects of chitosan nanoparticles on the mechanical properties and bonding performance of composite resins, clinicians and researchers can design more effective and durable dental restorations that meet the demands of clinical practice.[11]

Ultimately, this research has the potential to inform the development of next-generation dental composites that combine enhanced mechanical properties, improved biocompatibility, and excellent bonding performance. By harnessing the unique properties of chitosan nanoparticles, researchers can create innovative dental materials that improve patient outcomes. [12,13]

MATERIALS AND METHODS

This in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics, Jaipur Dental College and Hospital, Jaipur collaboration with Seminal applied science laboratory and Sharda University, Delhi, India. A total number of 56 samples were prepared. Materials used in the study are Composite Resin (FUSION), Chitosan Powder, Fiberglass Particles ,Huge Bond Universal (Vincismile), Etchant gel (Fusion), Ultrasonic unit (Woodpecker), Universal Testing Machine.

Preparation of experimental materials

Preparation of Chitosan Nanoparticles Ionic Gelation Method: Dissolve 0.5-1.0 g of Chitosan in 100ml of1-2% (V/V) acetic acid solutions. Dissolve 0.5-1.0 g of Sodium Tripolyphosphate (TPP) in 100 ml of distilled water. Mix Chitosan & TPP and stir it continuously (magnetic stirrer and heating at about 55-degree Celsisus overnight.The mixture will form nanoparticles through ionic gelation method.

Incorporating Chitosan Nanoparticles & Fiber Glass Particles Into Composite Resin Using Vortex Method: 56 noncarious, Extracted Human Premolars teeth were selected for the study. After extraction, teeth were washed with water to remove blood and scaled with scaler to remove attached periodontal tissue, plaque and calculus were stored in glycerin solution. Preoperative radiographs were used to ensure that the collected teeth did not have root caries or restorations.

Grouping of Samples: N=56 Group 1: Control Group (No CSN) Group 2: (2% fiber reinforced glass particles + Composite) Group 3A: (2% CSN + Composite) Group 3B: (2% CSN + DBA) Group 3C: (2% CSN+ DBA + Composite) Group 4A: (0.25% CSN+ Composite) Group 4B: (0.25% CSN + Composite + DBA) Group 4C: (0.25% CSN+ DBA)

Specimen Preparation: Preparation of DO CLASS 2 Cavities on the tooth specimen was done using a standard dimension of 2mm pulpal depth using straight bur (Mani, Hydrebad, India), 2mm of Buccolingual Width using Inverted Bur, and the gingival floor on the distal side was prepared 1mm below the CEJ with new straight fissured diamond bur (Mani) in high speed airoter cooled Handpiece. (Apple Dentmart). (Fig.1)

Figure 1: Preparation of DO CLASS 2 Cavities

In the specimens of group 1 (control group), DBA was applied & left undisturbed for 10 sec, then air dried and light cured for 20s followed by the placement of Universal Matrix Tofflemire and stabilized for tight Contact. Placement of composite Restorative material into the cavity by incremental technique of 1mm thickness and light cured for 20 sec.

In Group 2 specimens were restored with 2% Fiber Reinforced Glass Particles, incorporated in experimental Composite Resin and DBA.

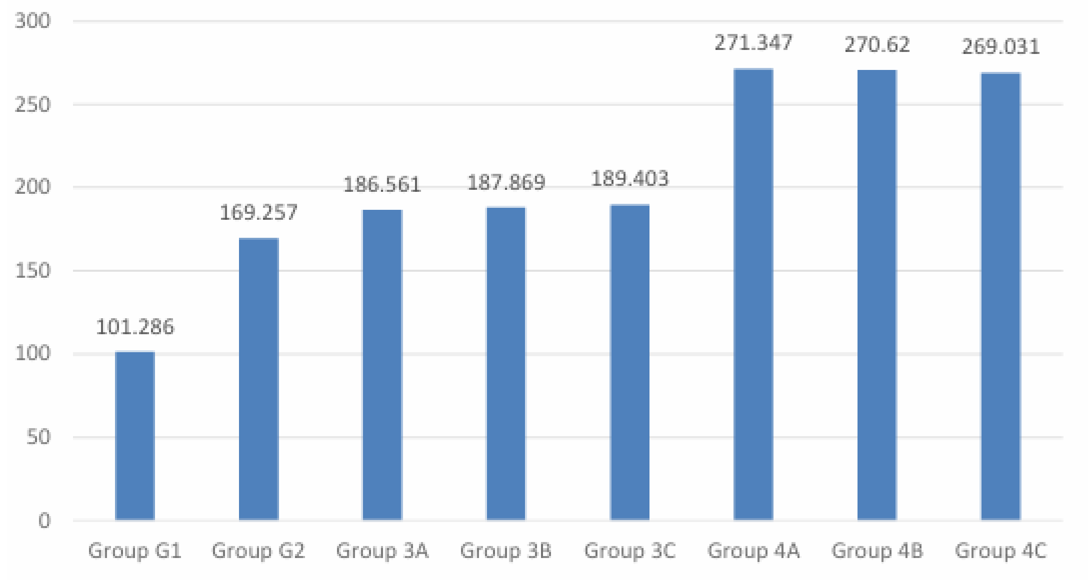
In Group 3 and 4 specimens were restored with 2% and 0.25% CSN incorporated in experimental Composite Resin and DBA. In all groups Finishing & Polishing were done with Composite polishing kit (Shofu) and specimens were then stored in humid conditions for 24 hrs.

Evaluation of Push Out Bond Strength: To prepare the samples for UTM, a reference point was marked on all the specimens for the placement of a testing needle at the canter of the tooth at the interference between the prepared cavity and the restorations for the pointed bur to be inserted. The specimens were then placed under a UTM (Instron) for push out bond strength. A needle consisting of a round cross-sectional area of 0.5mm gauge, length of 1mm, and radius curvature of 0.6mm was inserted in each specimen at speed of 1mm until the restoration gets dislodged from the cavity, and data were recorded. (Fig. 2)

Figure 2: Evaluation of Push Out Bond Strength

Statistical Analysis: The data for the present study was entered in the Microsoft Excel 2007 and analyzed using the SPSS statistical software 23.0 Version. The descriptive statistics included mean, standard deviation. The inter group comparison was done using One Way ANOVA to find the difference between groups. The level of the significance for the present study was fixed at 5%. The Shapiro–Wilk test was used to investigate the distribution of the data and Levene's test to explore the homogeneity of the variables.(graph 2)

RESULT: The push-out bond strength demonstrated marked variation among the experimental groups. The highest mean bond strength was observed in Group 4A (0.25% CSN + Composite) with 271.35 ± 9.07 MPa, followed closely by Group 4B (270.62 ± 8.41 MPa) and Group 4C (269.03 ± 11.23 MPa), indicating that lower CSN concentration (0.25%) in combination with composite and/or bonding agent substantially improved adhesion. In contrast, Group 1 (control, no CSN) recorded the lowest mean bond strength at 101.29 ± 4.54 MPa, highlighting the enhancement offered by nanofiller incorporation. Intermediate values were seen in Group 2 (169.26 ± 5.98 MPa), Group 3A (186.56 ± 10.09 MPa), Group 3B (187.87 ± 5.75 MPa), and Group 3C (189.40 ± 8.06 MPa), reflecting the effect of using 2% CSN in various combinations. The skewness and kurtosis values across groups suggested an approximately normal distribution, with slight variations, making the dataset suitable for further parametric analyses. These results suggest that both concentration and combination of CSN with other materials significantly influence bond strength outcomes. (Graph 1, Table 1)



Graph 1: Mean Push Out Strength of Different Materials

Table 1: Intergroup Comparison of push-out bond strength

POST HOC COMPARISON

Comparison	Mean Difference	SE	P-value	Significant
Group 1 vs 2	67.97	3.07	0.000	Yes
Group 1 vs 3A	85.27	3.07	0.000	Yes
Group 1 vs 3B	86.58	3.07	0.000	Yes
Group 1 vs 3C	88.12	3.07	0.000	Yes
Group 1 vs 4A	170.06	3.07	0.000	Yes
Group 1 vs 4B	169.33	3.07	0.000	Yes
Group 1 vs 4C	167.75	3.07	0.000	Yes
Group 2 vs 3A	17.30	3.07	0.000	Yes
Group 2 vs 3B	18.61	3.07	0.000	Yes
Group 2 vs 3C	20.15	3.07	0.000	Yes
Group 2 vs 4A	102.09	3.07	0.000	Yes
Group 2 vs 4B	101.36	3.07	0.000	Yes
Group 2 vs 4C	99.78	3.07	0.000	Yes
Group 3A vs 3B	1.31	3.07	0.993	No
Group 3A vs 3C	2.85	3.07	0.875	No
Group 3A vs 4A	84.79	3.07	0.000	Yes
Group 3A vs 4B	84.06	3.07	0.000	Yes
Group 3A vs 4C	82.48	3.07	0.000	Yes
Group 3B vs 3C	1.54	3.07	0.983	No
Group 3B vs 4A	83.48	3.07	0.000	Yes
Group 3B vs 4B	82.75	3.07	0.000	Yes
Group 3B vs 4C	81.17	3.07	0.000	Yes
Group 3C vs 4A	81.94	3.07	0.000	Yes
Group 3C vs 4B	81.21	3.07	0.000	Yes
Group 3C vs 4C	79.63	3.07	0.000	Yes
Group 4A vs 4B	-0.73	3.07	1.000	No
Group 4A vs 4C	-2.31	3.07	0.952	No
Group 4B vs 4C	-1.58	3.07	0.983	No

Group 1: (Control group) (no CSN) Group 2: (2% fiber reinforced glass particles + composite) Group 3A: (2% CSN + Composite) Group 3B: (2%CSN + DBA) Group 3C: (2%CSN+ DBA+ Composite) Group 4A: (0.25%CSN + Composite) Group 4B: (0.25%CSN + Composite + DBA) Group 4C: (0.25%CSN+ DBA+Composite)

DISCUSSION: Chitosan, a natural polysaccharide, has emerged as a highly promising biomaterial in the field of dentistry. Its unique properties, including biocompatibility, bio adhesion, and non-toxicity, make it an attractive candidate for various dental applications. Chitosan nanoparticles have been explored as a biomodification material to enhance bond strength and durability in dental restorations. By modifying the smear layer, chitosan nanoparticles can improve the bonding performance between tooth structure and restorative materials.[14]

The versatility of chitosan extends beyond its use in restorative dentistry. Its biodegradability, biocompatibility, and bio-adhesive properties make it suitable for applications such as direct pulp capping, treatment of dentinal tubule infections, and tissue regeneration in pulp wounds. Additionally, chitosan's chelating capacity for metal ions validates its use in various industries, further highlighting its potential in dentistry.[15]

Composite restorations have become a staple in modern dentistry due to their aesthetic appeal, ability to conserve tooth structure, and high strength. These restorations are widely used for both direct and indirect restorations, offering a long-term success rate and economic benefits. However, composite restorations are not without limitations. Secondary caries, polymerization stresses, shrinkage during light curing, postoperative sensitivity, and lack of antibacterial activity are some of the drawbacks that researchers continue to address.[16]

To overcome these limitations, researchers are developing new advancements in composite resin technology. The goal is to create restorative materials that not only provide excellent aesthetic and mechanical properties but also minimize drawbacks and enhance longevity. By improving the properties of composite resins, clinicians can provide patients with more durable and effective restorations.[17,18]

The technical advantages and evolution of composite resins have made them a popular choice for restoring posterior teeth, including class II cavities. These restorations are subjected to heavy occlusal stresses, and composite resins have proven to be effective in withstanding these forces. Clinicians recognize the importance of conserving tooth structure with minimal preparation, strengthening the tooth, and reducing fracture risk.[19,20]

As the field of dentistry continues to evolve, researchers are focusing on developing innovative composite resins that address existing limitations and provide optimal outcomes. By harnessing the potential of biomaterials like chitosan and advancing composite resin technology, clinicians can provide patients with more effective and durable restorations that enhance oral health and quality of life.[21]

Research by Solomon et al. demonstrated that incorporating beta quartz inserts into light-cured composite restorations significantly improved their performance. This finding has sparked ongoing investigations into optimizing composite restorations. Studies have focused on minimizing microleakage and dentin demineralization, aiming to enhance the durability and effectiveness of these restorations.[22]

The incorporation of chitosan nanoparticles (CSN) into restorative materials has garnered significant attention in dentistry due to its potential to enhance the properties and performance of these materials. Research has explored the benefits of adding CSN to various materials, including resin-modified cement and glass-ionomer cement. This study focused on improving composite restorations by adding CSN to dental bonding agents (DBA) and composite resin for Class II cavities.[23]

The adhesive system plays a vital role in the success of composite restorations. The success of the bond between the tooth and restorative material relies heavily on the adhesive system's effectiveness. A strong and durable bond is essential to withstand the stresses and strains imposed by mastication, thermal changes, and other environmental factors. Studies have demonstrated that CSN incorporation into DBA and composite resins can enhance bond strength and antibacterial properties, potentially leading to more durable and effective restorations.[24,25]

Research by Kudva et al. and de Carvalho Nunes et al. supports the benefits of CSN incorporation in enhancing bond strength and mechanical properties. The addition of CSN to DBA and composite resins has shown promise in improving the durability and effectiveness of restorations. The antibacterial activity of CSN is particularly significant, as it can help prevent secondary caries and ensure the longevity of restorations.[26]

Neo Spectra ST, a nano-ceramic based universal composite resin, offers several benefits, including easy handling, non-sticky properties, and adequate adaptation. This material is designed for both direct and indirect restorations, providing a versatile solution for various clinical applications. The use of universal composite resins like Neo Spectra ST can simplify restorative procedures and improve outcomes.[27,28]

The incorporation of CSN into composite resins or dental adhesives has been shown to exhibit improved antibacterial properties without compromising bond strength. This is a significant advantage, as antibacterial activity is crucial in preventing secondary caries and ensuring the longevity of restorations. The use of CSN in restorative materials holds promise for improving their properties and performance, potentially leading to more durable and effective restorations.[29,30]

CONCLUSION: The findings of this study align with existing research, demonstrating that the addition of 0.25% CSN to composite resin enhances bond strength in Class II cavities. The use of CSN in restorative materials has the potential to improve their properties and performance, leading to more durable and effective restorations. Further research is needed to fully explore the benefits and applications of CSN in restorative dentistry.

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