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Dr. Bhuwneshwer Pandey
Assistant Professor, Department of Dentistry, Nootan Medical College and Research Centre, Visnagar, Gujarat, India

Dr. Deepti Upadhyay
Assistant Professor, Department of Dentistry, G.C.R.G. Medical College and Hospital, Lucknow, Uttar Pradesh, India

Dr. Himanshu Joshi
Associate Professor, Department of Dentistry, Daswani Dental College and Research Centre, Kota, Rajasthan, India

Corresponding Author:
Dr. Himanshu Joshi
Associate Professor, Department of Dentistry, Daswani Dental College and Research Centre, Kota, Rajasthan, India

Comparison of shear bond strength of aesthetic materials: *In vitro* study with clinical application

Dr. Bhuwneshwer Pandey, Dr. Deepti Upadhyay and Dr. Himanshu Joshi

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Abstract
Background: Oral aesthetics is currently a widespread area of dentistry, and its advancement has gained significant importance. Dental ceramics are important in this regard because they not only have high colour stability and the capacity to resemble genuine teeth, but also because they are biocompatible, have good wear resistance, and are simple to maintain. A metal/ceramic pair's success is largely dependent on how well the ceramic adheres to the metal basis.
Objective: To compare the shear bond strengths of conventional glass ionomer, resin-modified glass ionomer, polyacid-modified composite, and composite resin along with the evaluation of the failure modes (adhesive, cohesive, and mixed).
Methods: In order to evaluate different restorative materials, the occlusal dentin of 28 removed human teeth was randomly divided into four groups of ten teeth each. Traditional glass ionomer cement (Group I), resin-modified glass ionomer cement (Group II), polyacid-modified composite resin (Group III), and hybrid composite resin (Group IV) are the four groups. Shear bond strength (SBS) tests were performed on the joined materials using an Instron Universal Testing Machine with a crosshead speed of 0.5 mm/min. A stereomicroscope with a 10x magnification was used to inspect the bond failure site.
Results: The mean SBS for Groups I through IV was, respectively, 4.378, 8.45, 10.74, and 15.42 MPa. The bond strength of resin-modified glass ionomer cement, polyacid-modified composite resin and hybrid composite resin were higher than the of Traditional glass ionomer cement. We observed an adhesive failure, a cohesive failure (within material and dentin) and mixed failure with these interfaces.
Conclusion: The composite restorative materials have shear bond strengths that are greater than those of composite resin but lower than those of conventional glass-ionomer and resin-modified glass-ionomer.

Keywords: Shear bond strength, dental prosthetics, dental interface, composite resin, Ionomer cement

Introduction

The human tooth is anatomically unique because it includes features that are both inside to the body and external to the body. A dental implant is frequently used to replace a missing tooth in order to improve appearance and make it easier to chew food. Hard tissue must be included into the implant surface for the replacement of the missing tooth to be effective. A supra-structure (an implant-supported prosthesis) can be supported by an endosteal dental implant, an artificial biomedical device that is surgically implanted and secured to the jaw bone to replace lost teeth [1]. Fixed or removable prostheses attached to the remaining teeth have historically been used by dental doctors to treat tooth loss; however, with this form of prosthesis, the remaining teeth are susceptible to harm from the different stresses given to the prosthesis [2]. As a result, dental implants are now widely used in contemporary clinical dentistry and are recommended as a first prosthetic alternative for restoration. Enhancing osseointegration depends heavily on the microtopography and chemical composition of the implant surface.

A dental implant system's three main parts are an implant, an abutment, and an artificial crown. Dental implant systems feature two biological interfaces: a hard tissue-implant interface and a soft tissue-abutment interface because implants are inserted into the jaw bone and abutments are situated in the soft tissue (gingiva) region between the jaw bone and the mouth [3]. To replace missing teeth, the implant surface should integrate bone, and to prevent inflammatory reactions around the implant system, the gingiva should be securely linked to the abutment surface [4, 5]. It is important to take into account the implant-abutment interface because of the way its biomechanical properties affect the physiology of the bone and gingiva

Dental ceramics are important in this regard since they are not only biocompatible, have strong wear resistance, and are simple to treat, but also provide good colour stability and the ability to approximate the look of genuine teeth [6]. Common feldspar ceramics may now be produced in a variety of colours and with good optical qualities thanks to low temperature sintering. The tendency to fracture, particularly in the presence of mechanical loads and flaws, is these materials' principal drawback. As a result, they ought to only be applied to metal supports that are coated. Ceramic will support the stresses placed on prosthesis effectively by maintaining adequate adhesion between the ceramic and the metal, considerably lowering the chance of fracture [7].

When compared to an undamaged tooth, a repaired tooth often transfers stress differently. Any force acting on the restoration will result in compression, tension, or shear at the tooth/restoration contact [8], which will result in complex stress distributions that include compressive, tensile, and shear stresses. The real nature of the adhesive strength of the materials at the interface is reflected by the shear bond strength because the process of mastication is one of indentation, which is fundamentally connected to shearing phenomena. These sticky materials' modes of failure—cohesive, adhesive, or mixed—reflect the calibre and effectiveness of their bonding. With increasing bond strengths, there are more cohesive failures within the dentinal substrates [9].

In order to compare and evaluate the shear bond strengths of conventional glass ionomers (Fuji IX GP), resin-modified glass ionomers (Fuji II LC), polyacid-modified composite resins (Compoglass - F), and composite resins (Z-250), as well as to assess and identify the modes of failure (adhesive, cohesive, and mixed) displayed by all of the materials after debonding.

Materials and Methods

Specimen preparation

The twenty-eight human permanent molars that were taken for periodontal reasons were free of cavities. They were then completely cleansed of calculus and soft tissue debris and kept in distilled water until they were needed. With the use of 1.5 cm 5 cm aluminium moulds, they were immersed in self-curing acrylic resin such that the occlusal surfaces were parallel to the surface of the acrylic resin block. A clean dentinal surface was exposed after the occlusal surfaces were flattened using a double-faced diamond disc. In order to mimic the creation of a smear layer, the polished dentin surfaces were then polished with 180, 320, and 600-grit wet silicon carbide paper. Following storage in distilled water for 24 hours at 37 °C, all the prepared specimens were then randomly separated into four groups of ten teeth each depending on the restorative materials examined.

Experimental approach

Group I: Fuji IX GP, Conventional Glass Ionomer Cement, and Control: The occlusal dentin was treated with 20% polyacrylic acid for 10 seconds, then rinsed with water for the same amount of time before being dried with cotton pellets. Conventional Glass Ionomer cement was prepared per the manufacturer's instructions, transported to the correct mould, and then condensed into the dentin surface using a titanium-coated tool and stainless steel condenser. A Mylar strip was used to apply positive condensation pressure for 4-5 minutes, or until the material had set.

Group II: Fuji II LC, Resin-modified Glass Ionomer Cement: Comparable to Group I, the occlusal dentin had comparable conditioning. In accordance with the manufacturer's instructions, the Resin Modified Glass Ionomer cement was applied to the stabilised tooth identical to Group I and allowed to cure for 20 seconds under visible light. For Groups I and II, the surface of the set cement was shielded by the application of two coats of varnish.

Group III: Compoglass, a polyacid-modified composite resin: The occlusal dentin was etched for 15 seconds with 37% ortho phosphoric acid, then washed for 10 seconds with water and dried with cotton pellets. Surface-applied Prime and Bond NT bonding compound was exposed to light for 10 seconds to cure. The stabilising device's Teflon mould was then used to place the installed teeth there using the use of a gun-tip positioned within the mould, the composite restorative material was dispensed, positive pressure was applied using Mylar matrix, and visible light curing was performed for 40 seconds.

Group IV: Hybrid Composite Resin, Z-250: The occlusal dentin was etched for 15 seconds with 37% orthophosphoric acid, then washed for 10 seconds with water and dried with cotton pellets. A hybrid composite resin (Z-250) was dispensed and condensed onto the dentin held in place by a Teflon mould, subjected to visible light curing for 20 s, and dried for 2–5 s with air blast and light cured for 10 s each. Two coats of Adper Single Bond were applied using a fully saturated disposable brush tip.

Measuring shear bond strength

The restorative ingredients were bonded together using a Teflon mould. Using a ball burnisher, the cured restorative materials were forced out of the Teflon mould. The shear bond strength of all forty specimens was then tested in a Universal Testing Machine (UTM) [Figure 3] at a crosshead speed of 0.5 mm/min. The shear bond strength was calculated as the ratio of the maximum load recorded at failure in Newtons to the surface area of the bonded cylinders in square mm. The specimens from all groups were examined under a stereomicroscope at a magnification of 10 to determine the exact location of the bond failure, which was classified as Adhesive failure (exclusively occurring at the restoration-dentin interface), Mixed failure (combining any of the cohesive modes), Cohesive failure-dentin, or Cohesive failure within Material.

Results

Mean shear strengths comparison

Comparison of mean shear bond strengths of all groups was done by one-way ANOVA test and comparison of means in between groups was done by Student's ‘t’ test (Figure 1). In the control group where Fuji IX GP was used shear bond strengths ranged from 1.97 to 6.44 MPa with mean shear bond strength of 4.738±1.23 MPa. For Group II (Fuji II LC) shear bong strength ranged from 6.27 to 10.7 MPa with a mean shear bond strength of 8.45±1.03 MPa, which was significantly higher than Group I and less than Group IV ($p<0.05$). Their difference in the mean shear bond strengths of Group II and III was not statistically significant. For Group III (Compoglass F / Prime and Bond NT) the shear bond strengths ranged from 8.17 to 13.89 MPa with a mean of 10.74±1.67 MPa, which was found to be significantly higher than the control (Group 1) ($p<0.05$) and less than group IV.

For Group IV (Z– 250/Adper single Bond) the shear bond strengths of were ranged from 12.75 to 19.61 MPa with a mean of 15.42±1.13 MPa, which was the highest of all groups and showed a statistically significant difference from Groups I, II and III (p<0.01).

With the exception of Groups II and III, which were statistically insignificant where P>0.05, all the groups showed statistically significant differences from one another after the findings were analysed using the 't-test at a 5% (0.0.5) level of significance.

The failure mode of all the specimens under a stereomicroscope

We saw cohesive fractures inside the restorative material of all the specimens in patients receiving Fuji IX GP (group I). Both adhesive and mixed failure were seen in Groups II and III specimens. Group II of the mixed failure displayed material failure, but Group III failed cohesively inside dentin. In Group IV, mixed failure predominated and was primarily cohesive within dentin.

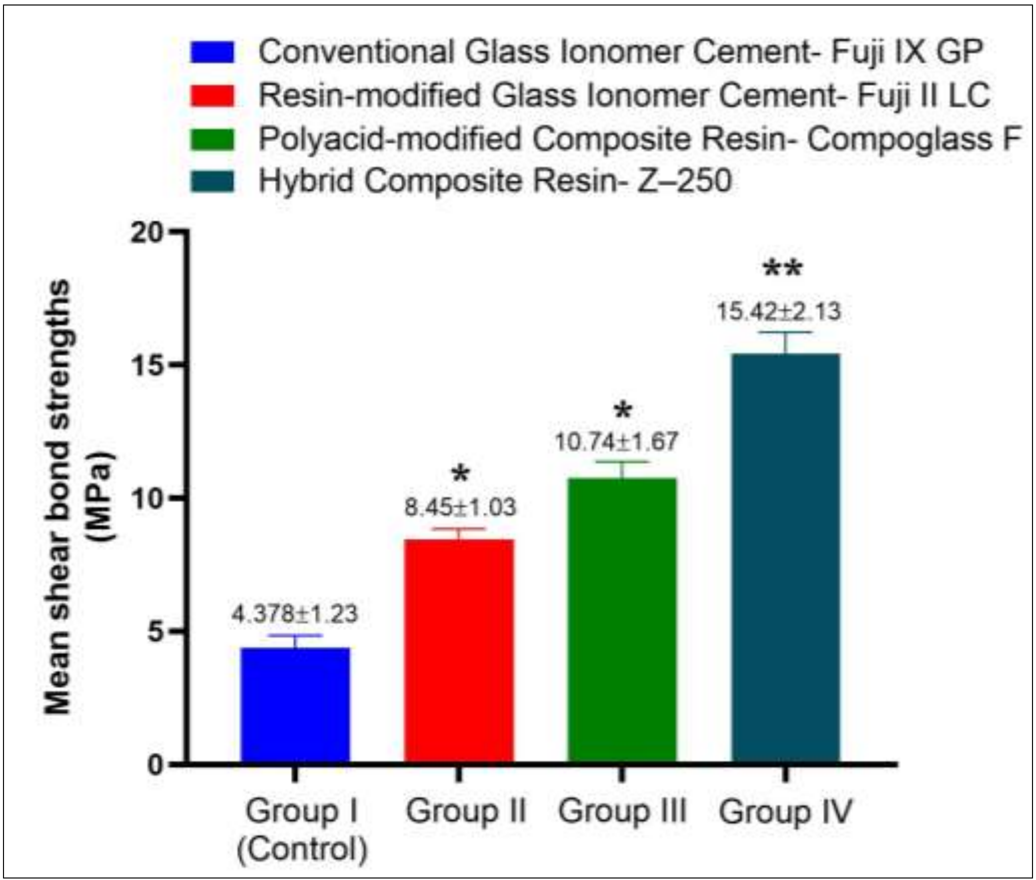

Fig 1: Shear bond strength (MPa) comparison in within different interfaces. Data is presented as Mean± Standard deviation. Statistical analysis was performed by One-Way ANOVA followed by Dunnett's post-hoc test. *p<0.05 and *p<0.01 vs control group

Discussion

Bond strength values are a general way of measuring how well restorative materials adhere to dentin. The shear bond strength test, which emphasises the strength at the bonded contact, is the least technique-sensitive of the several tests.

Conventional glass ionomer cement (Fuji II GP) achieved shear bond strengths of 4.378 MPa. The present study's findings for typical glass ionomer specimens were cohesive, suggesting that the measured values were not the actual strength of the bonded interface but rather the material's strength [10]. Increased bond strength values may result from efforts to make the material stronger.

Fuji II LC obtained a mean shear bond strength of 8.45 MPa. The major mode of failure seen was mixed (cohesive inside the material), indicating that the values obtained were really caused by the material's intrinsic weakness rather than the strength of the bonded interface [11]. The etching of dentin, which produced demineralized dentin with a collagen network that is penetrated by the bonding agent, hybrid layer formation, and higher bond strength values for Compomer (10.74 MPa) compared to Resin-modified Glass Ionomers, may be responsible [12]. When better bonding systems are used with compomer materials, the mean shear bond strengths obtained may be increased; hence, advancements in either the material or the bonding systems may increase bond strengths [13].

The composite's bond strength was higher than the tested composite's [14]. Despite the widespread use of self-etching generation bonding systems, fifth-generation bonding systems were used in the current study to bond hybrid composite resin because they were more dependable than self-etching adhesives for bonding resin composites. After debonding, stereomicroscopy of the bonded contact revealed cohesive and adhesive failures in the dentine, demonstrating that the value obtained is of the adhesive bond produced at the interface. Dentin has failed cohesively as a result of ripping out due to the greater strength brought on by both acid etching and the hybrid composite. Therefore, restoration needs to be robust enough to resist the pressures of mastication operating on the tooth and the restoration simultaneously.

The current investigation identified three different failure modes: cohesive failure (between material and dentin), mixed failure, and adhesive failure. Clinically speaking, if restoration fails, the cohesive breakdown inside the material would be preferable since it preserves the tooth structure for future preparation or secondary caries removal as the circumstance dictates. A cohesive breakdown in the dentin damages the sound tooth structure, causing both the sound tooth structure and the restorative material to be lost. In the current study, Group I's (Fuji IX GP) cohesive failure within material might be seen favourably in comparison to Group IV's (Hybrid composite resin), which is the least preferable in clinical settings.

The shear bond strengths of the composite restorative materials are higher than those of composite resin but lower than those of regular glass ionomer and resin-modified glass ionomer. It is extremely possible that a restorative material will not be properly kept in the oral environment if it displays a lower bond strength under ideal laboratory test settings, therefore additional retention has to be taken into consideration when applying it clinically.

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