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Original Research

Analyzing Shear Forces on the Overlay-Dental Tissue Interface: A Comparative In Vitro Study of Different Bonding Techniques

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ABSTRACT:
Background: The objective of this research was to assess the bonding strength of glass-ceramic overlays to tooth structure when subjected to shear forces, employing various bonding systems for comparison. **Methods**: Sixty healthy lower third molars were randomly divided into three groups (n = 10) for this experiment. Group 1 involved attaching overlays to tooth structure using Panavia V5 with immediate dentin sealing (IDS). In Group 2, overlays were bonded with Panavia V5 without IDS, while Group 3 utilized overlays bonded with heated composite in conjunction with a bonding agent and IDS. All restorations were crafted from glass-ceramic (Suprinity, Vita). Subsequently, the restored teeth were immersed in distilled water for 7 days at room temperature. Shear forces were then applied using a universal testing machine, and load and displacement were recorded at 0.1-second intervals. **Results**: The mean fracture resistance ± standard deviation for Groups 1, 2, and 3 were 16.7440 ± 2.13, 11.0750 ± 1.41, and 6.33364 ± 2.85 MPa, respectively. The analysis of variance revealed high significance ($P < 0.001$), leading to the rejection of the null hypothesis suggesting equality among the three groups. Furthermore, pairwise comparisons also yielded significant results. **Conclusion**: The utilization of Panavia V5 with immediate dentin sealing (IDS) demonstrated superior resistance to shear forces in comparison to alternative bonding techniques. The incorporation of IDS contributed to enhanced adhesion in this context.
Keywords: Ceramic, immediate dentin sealing, overlay, shear forces

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INTRODUCTION

The overlay in modern restorative dentistry is a noteworthy advancement, representing a departure from the traditional approach embodied by peripheral crowns. This dental restoration, crafted from either ceramic or resin composite materials, has gained prominence for its minimally invasive nature. Unlike conventional crowns, the overlay does not necessitate the utilization of root-retained posts, thereby avoiding the need for root anchorage. This departure from traditional methods aligns seamlessly with the principles of adhesive dentistry, a revolutionary concept that has transformed everyday dental practice.Adhesive dentistry, with its emphasis on minimal invasiveness, has reshaped the landscape of restorative procedures.[1] This approach has allowed for a more conservative treatment philosophy, preserving more natural tooth structure while achieving optimal esthetic, functional, and mechanical outcomes. The overlay, as a product of this paradigm shift, exemplifies the positive impact of adhesive techniques in contemporary dental restorations.In essence, the overlay serves as a testament to the evolution of dental materials and techniques, offering practitioners a viable and less invasive alternative to traditional crowns. Its adaptability, coupled with the principles of adhesive dentistry, underscores the ongoing pursuit of providing patients with restorative solutions that prioritize preservation, esthetics, and overall oral health.[2,3] The overlay stands as a tangible representation of how modern dentistry continues to advance, embracing innovative approaches for the benefit of both practitioners and patients alike.Advancements in adhesive dentistry, coupled with the integration of computer-aided design/computer-aided manufacturing (CAD/CAM) technologies and the utilization of novel bioactive materials, have ushered in a new era of dental preservation. These developments collectively aim to optimize the conservation of healthy dental tissue, marking a departure from more invasive traditional approaches.

In the context of overlays, the achievement of an optimal bond is imperative. Overlays are exposed to substantial occlusal forces, and they rely on minimal mechanical retention. Consequently, thorough investigations are essential to identify the adhesive systems that can effectively withstand shear forces and ensure the longevity and stability of the restoration.The market offers various types of adhesive systems, each with its unique characteristics.[4,5] Adhesive systems without inherent adhesive capacity necessitate the use of a separate bonding system. In contrast, adhesive systems with adhesive capacity come equipped with the necessary adhesion properties. Additionally, self-adhesive systems have emerged, eliminating the need for conditioning the dental substrate or surface preparation.The selection of the most appropriate adhesive system becomes a critical consideration in the success of overlay restorations. The constant evolution and diversification of adhesive technologies empower dental practitioners to make informed choices that align with the principles of minimally invasive dentistry, promoting the preservation of natural dental structure while ensuring the durability and functionality of restorations.[6,7,8] As a result, the ongoing integration of adhesive dentistry principles and cutting-edge technologies continues to shape a more conservative and patient-centric approach to dental restoration. Immediate dentin sealing (IDS) is a technique that involves the application of a dental bonding agent in three steps (etching, primer, and bonding) immediately after the preparation of dentin, typically on freshly cut dentin. This method is recognized for its ability to enhance the bond strength of indirect restorations, contributing to the overall success and longevity of dental prosthetics.Despite the established benefits of IDS, there is a notable gap in the existing data pertaining to the shear bond strength of preheated resin composite when used for bonding indirect ceramic restorations. Limited studies have explored the comparison between preheated composite and traditional resin cement in the context of luting indirect restorations, leaving a void in comprehensive understanding.primary objective of this study is to address this gap by evaluating and comparing the resistance to shear forces exhibited by overlays bonded with two adhesive systems lacking inherent adhesive capacity.[9-13] The adhesive systems under scrutiny are Panavia V5, with and without the application of IDS, and heated composite combined with a bonding agent, also applied with IDS.This research endeavor aims to contribute valuable insights into the performance and efficacy of different adhesive systems in bonding overlays, particularly in scenarios involving preheated resin composite. By assessing shear bond strength, the study seeks to provide relevant data that can inform and enhance clinical practices, ultimately guiding practitioners in making informed decisions regarding the selection of adhesive systems for bonding indirect ceramic restorations.

MATERIALS AND METHODS

A total of 60 healthy lower third molars were extracted due to various reasons, including insufficient space, eruption complications, or the presence of a cyst. Following extraction, the teeth were preserved in a physiological saline solution at room temperature for a maximum duration of 7 days. Subsequently, the extracted teeth were randomly assigned to three distinct groups, each comprising 20 teeth. This random allocation aimed to ensure an unbiased distribution of teeth across different experimental conditions or interventions. The grouping of extracted molars sets the stage for subsequent investigations or interventions, allowing researchers or practitioners to systematically analyze and compare outcomes based on the assigned groups.

The dental preparations followed a standardized procedure, involving the creation of 2.5 mm deep pits using a round diamond bur (green ring) with a head diameter of 2.5 mm.[13] The process initiated at the center of the buccal and lingual grooves, extending to the central groove mesially and distally, and concluding at the tips of the cuspids. The bur was inserted into the tooth structure until complete penetration of the bur's cylinder. Post-preparation, the depths of the pits were verified with a periodontal probe, and the groove bottoms were marked with a pencil. Subsequently, all grooves were interconnected using a diamond disc bur (green ring), specifically an occlusal reduction bur from Dumont Instrument. This continued until the pencil marks disappeared, achieving a round and anatomical reduction. The entire preparation process, performed by a single operator, resulted in nonretentive configurations with a "flat" profile. The overlays' retention relied solely on the adhesive system. Each tooth underwent drilling with new burs, and the entire procedure was carried out under water irrigation.

Prior to bonding the overlays, a three-step adhesive system was administered in accordance with the manufacturer's guidelines.[14] Subsequently, a glycerine layer was applied, and an additional 10 seconds of polymerization ensued. Following this, the enamel periphery underwent further preparation using a green ring chamfer diamond bur from Dumont Instruments. In this phase, no immediate dentin sealing (IDS) was performed on the remaining 10 teeth in Group 2. The treated teeth were then stored in a physiological saline solution for 3 days at room temperature.

For the shear test, the tooth roots were embedded in a resilient thermopolymerizable resin, with the tooth/overlay boundaries extending 2 mm beyond the resin support. Subsequently, they were placed in a container under a 2.5 bar pressure. Each tooth was oriented at 90° to the vertical plane within a device. Shear forces were then applied to the ceramic restorations at a point 1 mm from the tooth/overlay boundary. The forces, measured in Newton, were exerted until fracture occurred, which could manifest in different types:

- Type 1: Adhesive fracture, occurring between the bonding agent and the dentin, between the bonding agent and the resin cement, or between the resin cement and the ceramic.
- Type 2: Cohesive fracture, happening within the ceramic, within the resin cement, or within the dentin.
- Type 3: A combination of cohesive and adhesive fracture.
- Type 4: Fracture occurring within the support material.

RESULTS

The shear bond strength results for the various systems under examination are detailed in Table 2. Upon examination of the fractured surfaces, as outlined in Table 3, similar outcomes were observed across Groups 1, 2, and 3. The predominant fracture pattern noted was of the "adhesive type" (Type 1). Interestingly, the incorporation of Immediate Dentin Sealing (IDS) demonstrated a robust adhesion to the extent that it induced fracture within the supporting device used for sample stabilization (Type 4). Notably, only Group 2 exhibited a cohesive fracture within the dentin.

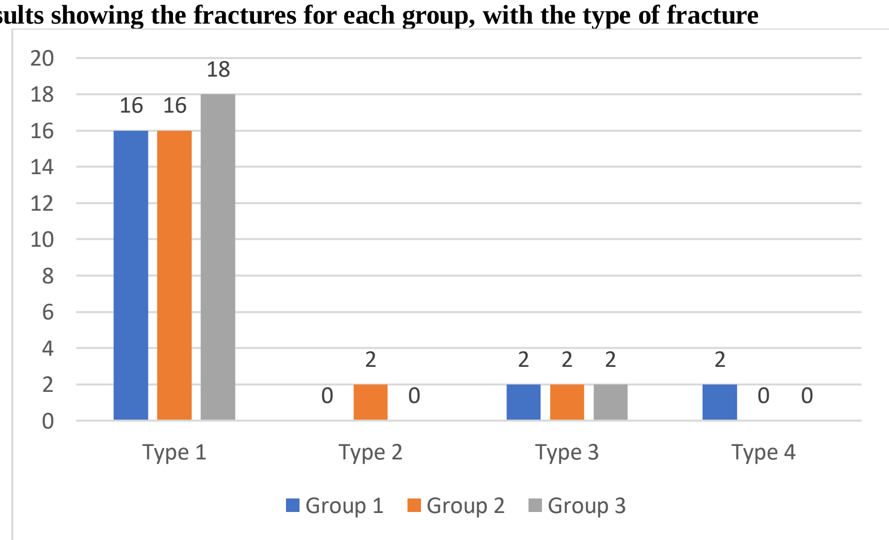
These findings shed light on the effectiveness of the different bonding systems tested and provide insights into the fracture patterns, highlighting the impact of factors such as the use of IDS on the overall bond strength.[15] The prevalence of adhesive fractures suggests a strong interface between the bonded materials, while specific fracture types offer clues about the nature and strength of the bonds formed within the dental structures. Such detailed analysis contributes to a comprehensive understanding of the performance of these systems in practical applications, guiding practitioners and researchers in optimizing bonding protocols for dental restorations.

Table 1: Shear forces results. With the mean ($\bar{x}$) and the standard deviation for each group

	n	**Mean ($\bar{x}$)±SD**
Group 1	20	16.7440±2.1288
Group 2	20	11.0750±1.41226
Group 3	20	6.3364±2.85106

A Kolmogorov–Smirnov test was conducted, affirming that the data adhered to a normal distribution. Subsequently, the data underwent a statistical analysis of variance (ANOVA) with a significance level set at 5%. The ANOVA yielded highly significant results ($P < 0.001$), leading to the rejection of the null hypothesis asserting the equality of the three mean shear bond strengths. Following this, paired comparisons between the adhesive systems were executed using a Bonferroni test, and these comparisons also generated significant results.[16]The Kolmogorov–Smirnov test serves as an important initial step in assessing the normality of the data distribution. The subsequent ANOVA analysis, coupled with Bonferroni post-hoc testing, allows for a robust examination of the statistical significance of differences between the adhesive systems. These statistical methods contribute to the credibility and reliability of the study's findings, offering valuable insights into the comparative shear bond strengths of the tested systems and supporting informed conclusions regarding their performance in dental applications.

Figure 1: Results showing the fractures for each group, with the type of fracture



The presented figure elucidates the incidence of fractures across different groups, delineated by distinct fracture types. In Group 1, the predominant fractures are of Type 1, totaling 16 cases, while Type 3 fractures are observed in two instances, and Type 4 fractures account for two cases as well. Notably, Group 1 does not manifest any Type 2 fractures.[17] Moving to Group 2, Type 1 fractures are again predominant with 16 occurrences, accompanied by two instances of both Type 2 and Type 3 fractures. Group 2, however, demonstrates no cases of Type 4 fractures. Lastly, Group 3 displays a preeminence of Type 1 fractures with 18 cases, and similar to Group 1, two instances of Type 3 fractures are noted. Unlike the other groups, Group 3 lacks any occurrences of Type 2 or Type 4 fractures. This detailed breakdown underscores the nuanced distribution of fractures within each group, shedding light on potential patterns or variations that may inform further clinical analysis and guide targeted interventions.

DISCUSSION

Overlays, characterized by full cusp coverage, serve as indirect restorations and prove especially beneficial for the rehabilitation of extensively damaged teeth, offering a viable alternative to traditional crowns. In our study, we opted for a glass-ceramic overlay (Suprinity, Vita). This material comprises a glass matrix with alkaline ternary oxides and a minimum of 30% volume of crystalline fillers like leucite, along with lithium monosilicate and zirconia.[18,19]The selection of both material and adhesive system plays a crucial role in achieving satisfactory functional and aesthetic outcomes, as well as ensuring a robust marginal seal. Given that overlays lack mechanical retention, establishing optimal bonding through a meticulous bonding protocol becomes paramount. This protocol initiates with the treatment of the intaglio surface of the glass-ceramic restoration using hydrofluoric acid for 20 seconds. This step influences the surface/interface topography, thereby influencing the ceramic's bonding strength. Subsequently, a silane is applied to the intaglio surface of the prosthesis. Numerous studies indicate that heating the silane at 100°C enhances its effectiveness by eliminating water, alcohol, and other by-products from the silanized surface.

At the tooth level, sandblasting creates micro-roughness, enhancing the bonding surface and facilitating improved adhesion. Notably, numerous studies have demonstrated that stronger bonding occurs on enamel compared to dentin.Since the early 90s, various authors have firmly established that applying a resin coating on freshly cut dentin, utilizing a three-step etch-and-rinse system (IDS), offers several advantages. This practice protects the pulp by sealing dentinal tubules, reduces bacterial leakage and dental sensitivity, prevents contamination by temporary cements, mitigates space formation, enables polymerization of the bonding agent and adhesive layer in two steps, and prevents the collapse of uncured dentin-resin during the insertion of the restoration.[20] Consistent with prior research, our study aligns with the recommendation to promptly seal freshly cut dentin (IDS) to significantly enhance bond strength.The selection of an appropriate adhesive system is a crucial factor in dental applications. Adhesive systems fall into three subclasses: those without inherent adhesive capacity requiring a bonding agent, those with adhesive capacity, and self-adhesive systems that necessitate no dental substrate or surface preparation, simplifying the bonding protocol.

In our study, we specifically tested an adhesive system without adhesive capacity, namely Panavia V5. This resin lacks reactive groups but incorporates the 10-methacryloyloxydecyl dihydrogen phosphate (MDP) monomer, recognized as one of the most effective functional monomers for dental adhesives. Demonstrating remarkable efficacy on enamel, dentin, and metal alloys, Panavia V5 is regarded as a high-performing and resilient material for cementation to dental structures and metals.[21] In comparison to self-adhesive systems, Panavia V5 exhibits superior adhesion performance.

In addition to the subclasses of adhesive systems, there are three types of polymerization modes: pure photopolymerization (as seen in heated composite), where the processing time is under the clinician's control, chemical polymerization (involving the mixing of two components to initiate a reaction), and dual polymerization (combining chemical and photopolymerization, as seen in Panavia V5). In chemical and dual polymerization, working and setting times are no longer dependent on the clinician, potentially making the insertion of the restoration and the removal of excess material more hallenging.While the use of a photopolymerizable adhesive system requires restorations to allow sufficient light transmission for maximal conversion, this directly impacts mechanical properties, substrate bond strength, and aesthetic outcomes.Material viscosity is also a crucial consideration. Our study observed that the insertion of overlays was more challenging with the more viscous heated composite than with Panavia V5.[22,23] Therefore, using an ultrasonic tip is recommended when working with heated composite. However, once placed, the restoration proved more stable, and excess removal was easier with the heated composite compared to Panavia V5.Whenever proper bonding in an adequate environment (a dry working area isolated under a dental dam) can be achieved, the use of overlays is recommended. To the best of our knowledge, our study is the first to compare the bonding of an indirect glass-ceramic restoration with the new Panavia V5 and a preheated resin composite. Our findings indicate that the adhesive system with IDS (Group 1) exhibited higher shear bond strength than the same system without IDS (Group 2). This aligns with the conclusions drawn by Okuda et al., who assessed the impact of a resin coating on micro-tensile bond strengths (μ-TBS) of indirect restorations to dentin using resin cement.[24] The authors recommended the application of a "resin coating" (Clearfil protect bond combined with a flowable resin composite) on freshly cut dentin to prevent pulp irritation and significantly enhance the μ-TBS of indirect restorations to dentin.

Similarly, Islam et al. reached the conclusion that a resin coating with hybrid bond significantly improved the bonding of dentin resin cement to dentin in composite crown restorations.In another study, Jayasooriya et al. demonstrated that applying a resin coating on freshly cut dentin, using a dentin bonding system combined with a flowable resin composite, significantly improved the μ-TBS of resin cement Panavia F to dentin in indirect restorations.[25] This finding is consistent with our study results.While our study contributes valuable insights, it could be enhanced by considering certain aspects. The buccal temperature, typically higher than our testing conditions (23°C), may influence material properties. Additionally, overlays could benefit from dynamic aging through thermocycling to better simulate real oral environmental conditions.

CONCLUSION

Glass-ceramic overlays emerge as a promising alternative to traditional crowns, particularly for the restoration of extensively damaged teeth. Based on the parameters within our study, Panavia V5 with IDS demonstrated the highest shear bond strength. Furthermore, when bonding to dentin, we advocate for the application of IDS, as it significantly enhances shear bond strength. It is essential to note, however, that our study's findings should be cautiously interpreted, and the translation to clinical applications requires further validation. Long-term, in vivo prospective studies are imperative to substantiate and confirm the robustness of our findings in real-world clinical scenarios.

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