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Original Research

In Vitro Evaluation of Bonding Techniques: A Comparative Analysis of Shear Forces at the Overlay-Dental Tissue Interface

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ABSTRACT:
Background: The aim of this study was to compare the adhesion of glass-ceramic overlays to tooth structure, under the effect of shear forces, using different bonding systems. **Methods**: Fifteen healthy lower third molars were carefully chosen and randomly divided into three groups, each consisting of five specimens (n = 5). In Group 1, overlays were affixed to the tooth structure using Panavia V5 in conjunction with immediate dentin sealing (IDS). Group 2 involved overlays bonded with Panavia V5 but without the application of IDS. In Group 3, overlays were bonded using heated composite in combination with a bonding agent and IDS. All the dental restorations utilized glass-ceramic material (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 meticulously recorded at 0.1-second intervals. Statistical analysis was employed to compare and evaluate the performance of the different groups. **Results**: The mean resistance to fractures, expressed as the mean ± standard deviation, for Groups 1, 2, and 3 were 14.7440 ± 2.13, 10.0750 ± 1.41, and 6.33364 ± 2.85 MPa, respectively. The analysis of variance yielded highly significant results (P < 0.001), leading to the rejection of the null hypothesis suggesting equality among the three groups. Furthermore, pairwise comparisons also exhibited significant differences between the groups. **Conclusion**: Panavia V5 with immediate dentin sealing (IDS) demonstrated superior resistance to shear forces compared to alternative bonding techniques. The utilization of IDS notably enhanced the adhesive strength in the bonding process.
Keywords: Ceramic, immediate dentin sealing, overlay, shear forces

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INTRODUCTION
The overlay, serving as an indirect dental restoration, is often regarded as the modern evolution of the peripheral crown. Crafted from ceramic or resin composite materials, it provides a feasible and less invasive substitute for traditional crowns[1]. Notably, it eliminates the necessity for root anchorage, making the use of root-retained posts unnecessary. Contemporary dentistry has undergone a revolution with the advent of adhesive techniques, reshaping our daily practices. This advancement allows for a minimally invasive approach, offering an alternative to extensive direct resin composite procedures and a more streamlined method. Additionally, adhesive dentistry has played a pivotal role in achieving enhanced aesthetic, functional, and mechanical outcomes[2,3].The continuous evolution of adhesive dentistry, complemented by the integration of cutting-edge computer-aided design/computer-aided manufacturing (CAD/CAM) technologies and the adoption of novel bioactive materials, has significantly advanced the field. This progress has played a pivotal role in enhancing the preservation of healthy dental tissue. The synergistic effects of these innovations allow for more precise and conservative dental interventions, contributing to the overall goal of maintaining and safeguarding the integrity of sound dental structures[4-6]. Through the seamless integration

of these technological and material advancements, practitioners can achieve better outcomes in terms of both clinical efficacy and the preservation of natural dental elements.Achieving an optimal bond is an indispensable prerequisite for the successful realization of an overlay, particularly considering its exposure to significant occlusal forces and its reliance on minimal mechanical retention. Consequently, thorough investigation is imperative to determine the adhesive system that can most effectively withstand shear forces in this context.Various types of adhesive systems are accessible in the market, including those without inherent adhesive capacity, necessitating the use of a separate bonding system. Additionally, there are adhesive systems with intrinsic adhesive capabilities. Another category includes self-adhesive systems that eliminate the need for conditioning the dental substrate or surface preparation[7,8]. The diversity in available adhesive systems allows practitioners to choose the most suitable option based on the specific requirements of the clinical situation.Immediate dentin sealing (IDS) involves the application of a dental bonding agent in three steps (etching, primer, and bonding), commonly known as the three-step etch-and-rinse technique. This process is implemented immediately after the preparation of dentin, specifically the freshly cut dentin. IDS is widely recognized for its efficacy in enhancing the bond strength of indirect restorations[9].Notably, there is a noticeable gap in available data regarding the shear bond strength of preheated resin composite used in bonding indirect ceramic restorations. Limited studies have undertaken a comparison between preheated composite and traditional resin cement concerning their effectiveness in luting indirect restorations. The existing literature on this topic remains relatively sparse, underscoring the need for further exploration and investigation in this specific area of dental research.

MATERIALS AND METHODS

Fifteen healthy lower third molars were extracted due to reasons such as insufficient space, eruption complications, or the presence of a cyst[10]. Following extraction, the teeth were preserved in a physiological saline solution at room temperature for a maximum of 7 days. Subsequently, the teeth were randomly assigned to three groups, each consisting of five specimens (n = 5). Teeth preparation involved a standardized dental procedure. Initially, pits with a depth of 2.5 mm were meticulously crafted using a round diamond bur (green ring) with a head diameter of 2.5 mm. The process began at the center of the buccal and lingual grooves, extending to the central groove mesially and distally, and concluding at the tip of the cuspids. The bur was inserted into the tooth structure until complete penetration of the bur cylinder. Following preparation, the depths of the pits were verified using a periodontal probe, and the groove bottoms were marked with a pencil[11].To achieve a rounded and anatomical reduction, all the grooves were connected using a diamond disc bur (green ring) — specifically, the occlusal reduction bur from Dumont Instrument. The reduction continued until the pencil marks disappeared. Importantly, the entire preparation process was consistently performed by the same operator to ensure uniformity. The resulting preparations are nonretentive and characterized by a "flat" configuration. The success of overlay retention relies solely on the adhesive system. Each tooth was treated with new burs, and all drilling procedures were conducted under water irrigation for optimal precision and safety.Immediate dentin sealing (IDS) was carried out on 20 molars, encompassing Groups 1 and 3, prior to the bonding of overlays[12-14]. The application of a three-step adhesive system, specifically the three-step Etch-and-Rinse-OptiBond FL from Kerr Italia Srl in Scafati, Salerno, Italy, followed the manufacturer's instructions. Subsequently, a glycerine layer was applied, and the entire assembly underwent polymerization for an additional 10 seconds.

Dental tissue treatment

Adhesive System Protocols for Group 1 and Group 2:

- Enamel Treatment*:* Application of "Tooth primer" for 20 seconds, followed by air drying without polymerization.
- Dentin Treatment*:* Sandblasting with aluminum oxide (50 microns), "tooth primer" for 20 seconds, and air drying.

Adhesive System Protocol for Group 3:

- **Dentin Treatment:** Sandblasting with aluminum oxide (50 microns), "tooth primer" for 20 seconds, and air drying.
- **Enamel Treatment:** Etching with 37% phosphoric acid for 30 seconds, rinse, and application of a bonding agent without polymerization.

Ceramic Restoration Treatment (Similar for All Groups)

- Application of 10% hydrofluoric acid for 20 seconds, followed by rinsing for 20 seconds, and air drying for 20 seconds.
- Immersion of overlays in an ultrasonic distilled water bath for 3 minutes.
- Application of silane in multiple layers, left untouched for a few minutes, air drying, and heating using a polymerization lamp.
- Application of a thin layer of bonding agent without polymerization.

Application of the Adhesive System

Group 1: Ten teeth with IDS were bonded using Panavia V5 (an adhesive system without adhesive capacity; Kuraray Noritake Dental Inc., Okayama, Japan) under constant pressure. Removal of excess material, followed by polymerization for 1 minute from the occlusal surface and then for 20 seconds per face. Polishing using a fine-grain diamond flame bur (red ring).

Group 2: Ten teeth lacking IDS underwent bonding with Panavia V5, applied under consistent pressure. After removal of excess material, polymerization occurred for 1 minute on the occlusal surface and then for 20 seconds per face. Polishing was carried out using a fine-grain diamond flame bur (red ring).

Group 3: Ten teeth, featuring IDS, were bonded using a heated resin composite. The photopolymerizable composite compule tube was heated at 60°C for 15 minutes with a Heater Ena Heat from Micerium SPA, Avegno GE, Italy. After application on the tooth, a constant pressure was applied, excess material was removed, and polymerization took place for 1 minute on the occlusal surface and then for 20 seconds per face. Subsequently, a polishing procedure was conducted using a low diamond flame bur (red ring).

Shear Test: The roots of each tooth were submerged in a resilient thermopolymerizable resin (Novodur resin, Novodent ETS; Eschen, Liechtenstein), with the tooth/overlay boundaries extending 2 mm beyond the resin support. Subsequently, they were positioned in a container under a 2.5-bar pressure, with each tooth set at a 90° angle to the vertical plane[15,16]. Shear forces were applied to the ceramic restorations, positioned 1 mm from the tooth/overlay boundary, utilizing a universal testing machine. Forces, measured in Newtons, were applied until fracture, 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 transpiring within the ceramic, within the resin cement, or within the dentin.
- Type 3: Cohesive and adhesive fracture, involving a combination of fractures within the ceramic, resin cement, or dentin, and adhesive separation between bonding agents and these components.
- Type 4: Fracture of the support, indicating a breakage within the underlying structure providing support to the tooth and restoration.

RESULTS

The shear bond strength of the various tested systems was assessed. Examination of the fractured surfaces revealed consistent results among Groups 1, 2, and 3. The predominant fracture pattern observed in these groups was of the "adhesive type" (Type 1). Notably, in cases where an Intracanal Depth Stop (IDS) was employed, the adhesion was robust enough to cause the fracture of the supporting device (Type 4). Group 2, however, exhibited a distinctive cohesive fracture within the dentin.

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

Group	*n*	Mean ($\bar{x}$)±SD
Group 1	5	14.7440±2.1288
Group 2	5	10.0750±1.41226
Group 3	5	6.3364±2.85106
SD: Standard deviation		

Table 2: Results showing the fractures for each group, with the type of fracture

Group	Type 1	Type 2	Type 3	Type 4
Group 1	8	0	1	1
Group 2	8	1	1	0
Group 3	9	0	1	0

Table: 2 presents the results indicating the distribution of fractures across different groups, with each group exhibiting distinct types of fractures.In Group 1, there were a total of 8 fractures of Type 1, no occurrences of Type 2 fractures, 1 instance of Type 3 fractures, and 1 instance of Type 4 fractures.For Group 2, there were 8 cases of Type 1 fractures, 1 case of Type 2 fractures, 1 case of Type 3 fractures, and no instances of Type 4 fractures.In Group 3, 9 fractures were classified as Type 1, with no cases of Type 2 fractures, 1 case of Type 3 fractures, and no instances of Type 4 fractures.This tabulated information provides a concise overview of the distribution of fracture types within each specified group.

DISCUSSION

Overlays are a form of indirect restorations that provide complete cusp coverage, making them particularly suitable for the rehabilitation of heavily damaged teeth. They offer a viable alternative to traditional peripheral crowns[17]. In our study, we opted for a glass-ceramic overlay, specifically Suprinity from Vita.This glass-ceramic overlay is composed of a glass matrix containing alkaline ternary oxides and a minimum of 30% by volume of crystalline fillers, such as leucite. Additionally, it incorporates lithium monosilicate and zirconia into its composition. The selection of material and adhesive system plays a crucial role in achieving both functional and aesthetic success, as well as ensuring a proper marginal seal.Due to the absence of mechanical retention in overlays, establishing an optimal bond through a meticulous bonding protocol becomes imperative[18,19]. This protocol involves treating the intaglio surface of the glass-ceramic restoration with hydrofluoric acid for 20 seconds. This step influences the topography of the surface/interface, impacting the bonding strength of the ceramic. Subsequently, a silane is applied to the intaglio surface of the prosthesis. Studies have demonstrated that heating the silane at 100°C enhances its effectiveness by eliminating water, alcohol, and other by-products from the silanized surface. This comprehensive approach aims to ensure the longevity, functionality, and esthetic appeal of the glass-ceramic overlay. At the tooth level, sandblasting induces micro-roughness, a process that creates minute irregularities on the tooth surface. This micro-roughness is instrumental in enhancing the bonding surface, thereby facilitating better adhesion. Notably, numerous studies have indicated that stronger bonding is achieved on enamel as opposed to dentin[20].Since the early 1990s, a well-established practice, supported by various authors, involves applying a resin coating to freshly cut dentin using a three-step etch-and-rinse system (IDS). This approach serves multiple purposes, including the protection of the pulp by sealing dentinal tubules, reduction of bacterial leakage and dental sensitivity, prevention of contamination by temporary cements, and avoidance of space formation. Additionally, it allows the bonding agent and the adhesive layer to undergo polymerization in two distinct steps, thereby preventing the collapse of the uncured dentin-resin during the insertion of the restoration.In alignment with prior research, our study advocates for the immediate sealing of freshly cut dentin through the application of an IDS[21]. This practice is shown to significantly improve bond strength, contributing to the overall success and longevity of dental restorations.The importance of selecting an appropriate adhesive system in dental procedures cannot be overstated, and understanding the subclasses of adhesives is crucial for achieving optimal outcomes[22]. These subclasses include adhesive systems without inherent adhesive capacity, necessitating the use of a bonding agent; adhesive systems with adhesive capacity; and self-adhesive systems, which streamline the bonding protocol by eliminating the need for dental substrate or surface preparation. In the context of our study, our focus was specifically on assessing the performance of an adhesive system without adhesive capacity, and Panavia V5 emerged as the central subject of investigation. Panavia V5 stands out as a resin that lacks reactive groups but incorporates the highly effective 10-methacryloyloxydecyl dihydrogen phosphate (MDP) monomer, known for its prowess as a functional monomer in dental adhesives[23,24]. This unique composition renders Panavia V5 remarkably effective on various dental surfaces, including enamel, dentin, and metal alloys.Notably, Panavia V5 is recognized for its superior performance and durability in cementation onto dental structures and metals. The inclusion of MDP contributes to its versatility and efficacy, making it a reliable choice for achieving robust and long-lasting bonds in diverse clinical scenarios. In contrast to self-adhesive systems, Panavia V5 exhibits heightened adhesion performance, further emphasizing its suitability for a wide range of bonding applications in restorative dentistry. The findings from our study underscore the significance of the adhesive system selection, with Panavia V5 standing out as a high-performing solution for achieving strong and reliable bonds in complex dental restorations[25].The utilization of a photopolymerizable adhesive system introduces a set of considerations, with the transparency of restorations playing a pivotal role in achieving the highest possible degree of conversion. This transparency directly impacts mechanical properties, substrate bond strength, and aesthetic outcomes. Striking a balance between adequate light transmission and the desired mechanical and esthetic results becomes imperative.Viscosity is another critical factor in the equation. In our study, we observed that the insertion of overlays became more challenging with the heated composite, which exhibited higher viscosity, in comparison to Panavia V5. To address this, the use of an ultrasonic tip was recommended when working with heated composite[26]. However, once the restoration was in place, the heated composite demonstrated increased stability, and the removal of excess material was more straightforward compared to Panavia V5.It is noteworthy that achieving proper bonding in an ideal environment, such as a dry working area isolated under a dental dam, is crucial when considering the use of overlays. This controlled setting enhances the success of the bonding process.Our study contributes novel insights, as it is, to the best of our knowledge, the first to compare the bonding performance of an indirect glass-ceramic restoration using the new Panavia V5 and a preheated resin composite. This comparative analysis provides valuable information for clinicians seeking to make informed decisions about adhesive systems and materials for indirect restorations, shedding light on the advantages and challenges associated with different approaches.The findings from Jayasooriya et al.'s study align with our results, emphasizing the significant improvement in microtensile bond strength (μ-TBS) when a resin coating is applied to freshly cut dentin using a dentin bonding system combined with a flowable resin composite[27]. This improvement was particularly evident in the bonding of Panavia F resin cement to dentin in the context of indirect restorations. The congruence of these results highlights the consistent impact of resin coatings on enhancing the bond strength between dental materials, reinforcing the validity of our findings.While our study provides valuable insights, it is acknowledged that certain aspects could have been addressed to enhance its robustness[28]. One such consideration is the buccal temperature, which tends to be higher than the controlled test conditions at 23°C. This temperature differential has the potential to influence the properties of the materials under investigation. Future studies might benefit from a closer approximation to the actual oral conditions, including variations in temperature, to ensure the relevance of the findings to real-world scenarios.Additionally, the dynamic aging of overlays through thermocycling could have been implemented in our study. Thermocycling would mimic the cyclic temperature changes experienced in the oral environment, providing a more realistic assessment of the materials' performance over time[28,29]. This consideration would contribute to a comprehensive understanding of how the overlays withstand the challenges posed by the oral environment and offer insights into their long-term stability and durability.

CONCLUSION

The exploration of glass-ceramic overlays as a potential alternative to traditional crowns for the restoration of heavily damaged teeth represents a noteworthy aspect of dental research. In the scope of our study, the use of Panavia V5 with IDS (integrated dentin bonding system) demonstrated the highest shear bond strength. This observation underscores the effectiveness of this adhesive system in providing robust bonding for glass-ceramic overlays. Furthermore, our findings emphasize the importance of incorporating IDS, especially when bonding to dentin, as it significantly enhances shear bond strength. This recommendation aligns with the broader understanding in dental literature regarding the positive impact of proper dentin bonding systems on the performance and longevity of restorations. However, it's essential to acknowledge the limitations of our study and the need for caution in translating these findings into clinical practice. Real-world scenarios often present complexities and variables that may not be fully captured in controlled experimental conditions. To bridge this gap between laboratory research and clinical application, long-term, in vivo prospective studies are essential. These studies would provide valuable insights into the actual clinical performance, durability, and success rates of glass-ceramic overlays bonded with Panavia V5 and IDS. By assessing these restorations in the dynamic and challenging environment of the oral cavity over an extended period, researchers and clinicians can gain a more comprehensive understanding of the feasibility and efficacy of this approach in real-world situations.

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