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Evaluation the effect of different types of adhesives on the bond strength of zirconia full crown restorations on different teeth: In vitro study

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تقييم تأثير الأنواع المختلفة من المواد اللاصقة على قوة الالتصاق لتركيبات التيجان الكاملة من الزركونيا على الاسنان المختلفة: دراسة في المختبر

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Abstract:
Introduction: Zirconia full crown are a popular choice for dental restoration due to their strength and natural appearance. However, the clinical effectiveness of these restorations is significantly influenced by the type of adhesive used. Adhesives play a crucial role in creating a solid and long-lasting link between the restoration's surface and the tooth structure, increasing resistance to chewing pressures and oral environmental changes.
Aim: To determine the effect of different types of adhesives on the bond strength and stability of zirconia restorations on anterior and posterior teeth.
Methodology: A study involving 12 samples of human teeth was conducted to compare the retention strength of three different types of (adhesives Dual-cure resin cement, Glass-reinforced resin cement, One-step multipurpose adhesive).
Results: showed that the dual-cure resin adhesive was the best option, with average retention strengths of 450 N for anterior teeth and 620 N for posterior teeth. This adhesive can withstand increased chewing pressures and has superior bonding properties. However, the glass fiber-reinforced resin adhesive showed modest capacity for retention with average stresses of 390 N for anterior teeth and 540 N for posterior teeth. The one-step multipurpose adhesive performed poorly with average retention forces of 320 N for anterior teeth and 480 N for posterior teeth.
Conclusion: Dual-cure resin adhesives should be given priority by dentists, especially for posterior teeth that experience strong occlusal pressures.

Keywords: Zirconia, Esthetic restoration, Adhesive material, bond strength.

الملخص
المقدمة تعتبر التيجان الكاملة المصنوعة من الزركونيا خيارا شائعا لترميم الاسنان نظرا لخصائصها ومظهرها الطبيعي. ومع دلك فان الفاعلية السريرية لهده الترميمات تتأثر بشكل كبير بنوع اللاصق المستخدم. تلعب المواد اللاصقة دوا حاسما في انشاء رابط قوي وطويل الأمد بين سطح الترميم وبنية السن مما يزيد من مقاومة ضغط المضغ والتغيرات البيئية الفموية.
الهدف تحديد تأثير الأنواع المختلفة من المواد اللاصقة على قوة الالتصاق واستقرار ترميمات لزركونيا على الاسنان الامامية والخلفية.
المنهجية أجريت دراسة شملت 12 عينة من أسنان الانسان لمقارنة قوة الاحتفاظ لثلاثة أنواع مختلفة من المواد اللصقة (اللاصق تنائي المعالجة، اللاصق المقوى بالزجاج اللاصق متعدد الأغراض بخطوة واحدة).
النتائج اظهرت ان لاصق تنائي المعالجة كان الخيار الأفضل، مع متوسط قوى احتفاظ تبلغ 450 نيوتن للأسنان الامامية و620 نيوتن للإسنان الخلفية. يمكن لهدا اللاصق ان يتحمل ضغوط المضغ المتزايدة وله خصائص ربط فايقة. ومع دلك اظهر لاصق المقوى بالزجاج قدرة متواضعة على الاحتفاظ مع اجهادات متوسطة تبلغ 390 نيوتن للأسنان الامامية و540 نيوتن للأسنان الخلفية. كان أداء اللاصق متعدد الأغراض بخطوة واحدة ضعيفا بمتوسط قوى احتفاظ 320 نيوتن للأسنان الامامية و480 نيوتن للإسنان الخلفية.
الاستنتاج يجب على أطباء الاسنان إعطاء الأولوية للمواد اللصقة تنائيه المعالجة، وخاصة للأسنان الخلفية التي تتعرض لضغوط إطباقيه قوية.

الكلمات المفتاحية: زركونيا، الترميم الجمالي، مادة لاصقة، قوة الترابط

Introduction
One of the most significant advancements in dental restoration is zirconia full crown, which are favored by both patients and dentists because to their exceptional strength and natural appearance. Zirconia is now the perfect material for full coverage restoration because of its exceptional physical qualities, which include great fracture resistance and long-term stability. However, the capacity to create a solid and long-lasting link between these restorations and the tooth structure which is directly tied to the kind of adhesive used is a major factor in their clinical effectiveness. In order to guarantee the restoration's stability adhesives are essential.
They serve as a medium between the restoration's surface and the tooth structure, increasing the restoration's resistance to repetitive chewing pressures and oral environmental changes such prolonged exposure to heat and moisture. All adhesives are not created equal, though, since their mechanical designs and chemical compositions differ, resulting in a wide range of performance. When taking into account the variations in tooth surfaces, such as posterior molars that carry higher compressive stresses and anterior incisors that undergo shear forces, this disparity becomes more noticeable.
The necessity to fully understand how the type of adhesive used influences the retention strength of complete zirconia restorations when they are fixed on teeth with varying shapes and functions is what makes this study so important. The study intends to give precise and fact-based information on the mechanical performance of each adhesive when used with zirconia by doing a comparative laboratory assessment comparing popular adhesive types. Additionally, it looks for elements that might improve retention effectiveness and lower the chance of restoration failure due to wear of the adhesive over time or separation from teeth. The study emphasizes how crucial it is to examine how various tooth morphology affect adhesive effectiveness. Because of the varying stresses operating on them and their distinct functional and cosmetic requirements, anterior teeth, for instance, need different qualities than posterior teeth. Thus, the goal of this study is to provide important answers on whether specific adhesives adhere to particular surfaces better than others and how this information might be applied to enhance therapeutic results.

Materials and Methods:
The study included 12 samples of human teeth that were extracted for therapeutic reasons, ensuring that the teeth were carefully selected to be free of caries and cracks to provide the accuracy and reliability of the results. The samples were divided into two main groups based on the type of teeth, where the first group involve six samples of anterior teeth (incisors), which are characterized by relatively small retention surfaces, while the second group involve six samples of posterior teeth (molars), which are characterized by larger retention surfaces and a higher ability to withstand chewing forces. every group were divided into three subgroups according to the kind of adhesive used. Three different types of adhesives cement selected (Dual-cure resin cement, Glass-reinforced resin cement, One-step multipurpose adhesive.
The teeth were cleaned using standard dental cleaning solutions following the standard preparation guidelines of advanced ceramic restoration and all crowns were treated with airborne particle abrasion 30 µm aluminum oxide particles, all restorations were designed using computer-aided manufacturing (CAD/CAM) technology to provide

an ideal fit with the teeth. **Cementation procedure:** The adhesive was applied according to the manufacturer's instructions for each type. The crown was seated onto the corresponding prepared tooth. After cementation, the samples were stored in simulated oral environmental conditions (37°C and 100% humidity) for 24 hours to allow for complete hardening. **Bond strength test:** a universal mechanical testing machine (UTM) was used to evaluate the retention strength. The force was applied perpendicular to the tooth axis until the separation occurred between the restoration and the tooth. The maximum force applied before separation was recorded in Newtons (N). **Statistical analysis:** The data were analyzed using a specialized statistical program (SPSS) and analysis of variance (ANOVA) tests were used to determine the statistical differences between the different types of adhesives.

Results

The following table shows the average retention strength of the crowns with a detailed analysis of the performance between the groups.

Type of Adhesive	Anterior Teeth (Incisors)	Posterior Teeth (Molars)	Overall Mean	Standard Deviation (SD)	Statistical Value (p-value)
Dual-Cure Resin Adhesive	450 ± 20	620 ± 25	535	± 85	**< 0.05** (Compared to other groups)
Glass Fiber-Reinforced Resin Adhesive	390 ± 15	540 ± 20	465	± 75	**< 0.05** (Compared to Dual-Cure Adhesive)
Single-Step Multi-Purpose Adhesive	320 ± 30	480 ± 25	400	± 80	**< 0.05** (Lowest Performance)

The study's findings unequivocally show that the kind of adhesive has a major impact on the whole zirconia restorations' retention strength. With remarkable average retention strengths of 450 N for the anterior teeth and 620 N for the posterior teeth, the dual-cure resin adhesive proved to be the best option. This shows that it can endure the increased chewing pressures that posterior teeth usually experience in addition to having superior bonding properties. This adhesive is a great option for dental restorations that need high retention because of its dual-cure process, which combines chemical and light activation. This mechanism probably adds to the increased bond strength. With average stresses of 390 N for the anterior teeth and 540 N for the posterior teeth, the glass fiber-reinforced resin adhesive showed a modest capacity for retention. These values are less than those found for the dual-cure adhesive, even though they still show adequate performance. Although glass fiber could offer some strength, the adhesive's bonding effectiveness seems to be poor, particularly when high occlusal pressures are used. This implies that glass fiber reinforced adhesives might not be the greatest option for high-stress locations, even if they can be applied successfully in other circumstances. With average retention forces of 320 N for anterior teeth and 480 N for posterior teeth, the one-step multipurpose adhesive performed the worst out of all the materials evaluated. These findings draw attention to the drawbacks of this kind of adhesive, especially when zirconia restorations are involved and a strong, long-lasting bond is needed. The simpler application method may have compromised the bonding efficacy as compared to more intricate adhesive systems, which is why the retention strength is low. Therefore, even though this adhesive could work for some restorative operations, it's best to think about other choices when working on restorations that require a lot of stress.

Discussion

especially in light of the continuous increase the request of all ceramic restorations in fixed prosthodontic. Zirconia is considered one of the strongest and most aesthetic materials in dentistry, study for a restoration with perfect physical properties is yet continuing. As well as, a long-lasting seal between the adhesive and zirconia restoration is a competition in clinical practices [1]The success of retention strength of zirconia depends largely on surface roughness and type of cement system used. Chipping and debonding of the veneering porcelain is the most often reported issue [2]. Debonding may occur owing to the inadequate preparation of the abutment tooth, incorrect luting agent or the kind of cement used, or improper application technique [3, 4].

This study provides a scientific basis that can be relied upon when choosing adhesives for zirconium restoration, which is essential for improving clinical practices and providing high-quality treatment results. It also works to improve the stability of zirconium crown by choosing the appropriate adhesive material which contributes significantly to enhancing the aesthetics and function of the teeth which enhances patient satisfaction and reduces the need for additional interventions.

Establishing dependable retention and a long-lasting seal between the tooth and its restoration is the main goal of cementation, there are many various types of dental cements on today, each one with unique qualities.

Before cementation, these cements frequently need for various surface pretreatments of the tooth and the restorative material which can be chemical, mechanical, or both, as Hydrofluoric acid (HF) pretreatment is a well-known technique for conditioning and concurrently cleaning ceramic restoration materials. Known for its intense inorganic acidity, hydrofluoric etchant is regarded very dangerous due to its poisonous, corrosive, and reactive qualities. Dental offices and labs often utilize HF concentrations between 4 and 10%. By interacting with silicon dioxide, the primary component of glass-based ceramics particularly LDS ceramic. HF chemically breaks down and dissolves glass in a selective manner this causes a physical change that increases cementation area and surface roughness and resulting in micromechanical retention. Together with these modifications, the cement's bonding qualities can provide a solid connection between ceramics restoration and resin-cement components. [5]

Air-particle abrasion (APA), also known as sandblasting, is a widely used technique for mechanically pretreating the cementation surfaces of indirect zirconia restorations. It uses silica-coated alumina particles or aluminum oxide (alumina) particles that range in size from 30 to 250 µm. In addition to cleaning the surface, this technique raises its surface energy, strengthening the binding with resin-based materials, as level of surface roughness depends on several parameters, including air pressure, duration, and particle size, Previous reports have observed that various air- abrasion techniques may influence the degradation and grain transformation of zirconia, potentially compromising its mechanical strength. [6]

when administered Zirconia, solely with APA, does not achieve a sufficient and durable bond with resin cement, so manufacturers have developed primers to promote chemical bonding to zirconia. These primers frequently contain the particular functional monomer 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP), which forms a non-soluble Ca2 salt by binding to the hydroxyl groups on zirconia surfaces. It is now a typical ingredient in the majority of zirconia-indicated adhesive cement systems, either added to the cement or the primer. [7]

The roughness of zirconia, which results in a micromechanical interlocking between zirconia and the resin cement, as well as increased surface energy and surface area are the benefits of using aluminum oxide particles for airborne particle corrosion. Furthermore, the benefit of using a primer containing MDP is that it creates a chemical bond between the acidic groups of the monomer and the zirconia oxide layer. [8]

The bonded strength of zirconia crowns depends largely on the kind of cement system with different primers. Monolithic zirconia was used due to its great flexural strength and fracture toughness and can be used in thicknesses up to 0.5 mm. As for glass ceramics, zirconia is not subject to pitting due to does not contain a glass matrix, which eliminate the use of conventional cementing procedures. A self-adhesive resin cement (Multilink Speed) and two self-adhesive resin cements (Panavia V5 and Duo-Link universal) were chosen. These cements were select for their proper physical properties and ease of use. Resin cements containing MDP monomer can causes high bond strength to zirconia as a result of interaction between the hydroxyl groups of the zirconia surface and the phosphate ester group of the molecules. The acidic monomers of the self-adhesive resin cement can wet and adhere to exposed hydrophilic inorganic fillings created by air-erosion of the zirconia surface. In addition, Bis-GMA monomer is a cross-linked monomer is commonly incorporated into self-etching adhesive resin cement systems that bonds strongly to dentin by forming a hybrid layer with exposed dentin collagen fibers. [9]

Duo-link resin cement is a Bis-GMA based cement. Since Bis-GMA based resin cement has lower bond strength to zirconia than phosphate adhesive monomer-based resin cement, Z-prime plus contains two adhesive monomers (carboxylate and MDP). The involvement of carboxylic acid monomers can weaken the link between this primer and the methacrylate groups present in this resin cement. The low bond strength of Duo-link and Z Prime plus as a result of chemical differences in the base monomers or solvents of the primers, differences in the starting systems of the primers, or differences in the concentration of MDP ,the dentin bonding agent can be classified as all-etch, one-step self-etch and self-etch primer/adhesive system, and may also be HEMA-based or HEMA-free. All Bond Universal is a HEMA-based dentin bonding agent and may be susceptible to water absorption from the dentin tubules and a hydrophilic polymerized bonding agent that permeates as a result may interfere with subsequent coupling with Duo-link Universal. [10]

Comparison with one-step self-etching adhesives, two-step self-etching adhesive include higher volume of hydrophobic monomers. For that reason, two-step self-etching adhesives provide less phase-separation and can form a homogeneous adhesive layer with smaller quantity of retained water and solvent, lead to higher bond strength. The functional monomer 10-MDP in SEB can interface with hydroxyapatite to form established molecules like calcium phosphate and calcium carbonate, which can present as a resistant layer (approximately 4 nm), that can protect the bonded interact from aging-induced failure. [11]

There is evidence in the literature that the dual-cure adhesive should be selected for the cementation of indirect restorations as the polymerization reaction continues even in the missing of light, through a synergic combination of self- and light-polymerizing components [12, 13,14].

According to clinical data, the kind of luting agent used can impact zirconia-based crown retention, and the type and quality of luting agents utilized determine how long an implant lasts. However, further study is required to get meaningful data on the impact of luting agent kind and quality. Research has also demonstrated that, independent of the kind of cement employed, air abrasion has an impact on retention. [15]

Fracture resistance of zirconia is strongly affected by occlusal force and characteristics of the implant-abutment , When a heavy occlusal force is exerted on the zirconia restorations, fracture of the implant-abutment is more for one-piece zirconia crowns under unforced than those under forced conditions , performed a pilot in vitro study to comparison the mechanical properties and effect of occlusal force on zirconia and displayed that the fracture strength was lower for two-piece zirconia in loaded and unloaded conditions , as evaluated the effects of finish line design and cyclic loading on the fracture strength of zirconia and exhibited that chamfer finish lines along with cyclic loading decrease the fracture strength in zirconia restorations. [16]

The most popular test for evaluating novel adhesive formulations based on their bonding efficacy is the Macro Shear Bond Strength (SBS), This test method was first described by Bowen in 1965 [4]. The highest stress a material can sustain before failing under shear loading is known as the SBS. Two materials are attached by an adhesive and driven in shear until breakage happens in a shear bond test ,as The SBS test is the simplest and fastest approach since it no need additional specimen processing after the bonding process, which contributes to its great popularity in businesses and research institutions .However, cohesive failures in the substrate were commonly observed with new adhesives that demonstrate better binding strengths, which compromised the validity of acquired results This phenomenon was explained by the fact that stresses were mostly localized in the tooth substrate, which led to an early failure of the tooth substrate before the interface itself. [17]

The macro–Tensile Bond Strength test (TBS) is use far less often utilized test It serves to show how well cement adheres to other hard materials like metal alloys and ceramics, as TBS testing provide a more accurate assessment of the stress level that starts bond breaking because the stress distribution is taken into account much more evenly than in shear test. The test specimen is subjected to a load on both sides during a TBS test. In order to prevent bending stresses during tensile testing, the specimen's bonded interface must be aligned perpendicular to the loading axis. Therefore, either active or passive grasping techniques should be used to secure the test specimen to the mechanical testing apparatus. [18]

The test for micro-tensile bond strength (tubes), by test procedure, adhesive resins were bonded to the teeth's full flat occlusal surface before a resin composite was applied. A slow-speed diamond saw is used to vertically divide the specimen into many serial parts after it has been cured and stored in water. Using an ultrafine diamond bur, the resultant slabs are made up of a bottom half of dentin and an upper half of resin composite. To guarantee maximal stress development at the bonded interface, the cross-sectioned area should be decreased to produce an hourglass shape. [19]

The relevance of these findings is further supported by statistical analysis, which shows that the variations in adhesive retention strength are statistically significant ($p < 0.05$). This implies that the overall outcome of zirconia restorations is significantly influenced by the adhesive selection. The findings also emphasize how crucial it is to take the particular clinical setting into account when choosing an adhesive because different kinds and their intended uses might have quite varying performance.

Conclusion

Dual-cure resin adhesives should be given priority by dentists, especially for posterior teeth that experience strong occlusal pressures. The findings show that these adhesives have exceptional bond strength, which can improve restorations' overall success and lifespan. Clinicians can improve patient outcomes by lowering the chances of debonding and failure by using dual-cure adhesives.

Dental practitioners must get thorough training and continual education on the characteristics and uses of various adhesive systems. Clinicians will be able to make well-informed judgments that are suited to the particular requirements of each case if they are aware of the advantages and disadvantages of each type of adhesive. Adhesive technology-focused workshops and training events can give professionals the know-how they need to enhance therapeutic results.

Future studies have to concentrate on how well various adhesive solutions function over the long run in actual clinical situations. Examining these adhesives' longevity and efficacy over time can yield insightful information that can guide best practices. Furthermore, investigating surface treatments and how they affect zirconia adhesion strength may result in creative ways to improve adhesive performance.

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