

The Impact of Different Bonding Protocols and Thermal Cycling on the Final Bond Strength of Zirconia Restorations, Literature Review

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Abstract Objective: to categorize and examine the existing methods and materials proposed to enhance the bonding of zirconia to dental substrates. **Materials and Methods:** A review of studies was conducted regarding the evaluation of zirconia bonding to dental substrates. On the basis of papers published between 2019 and 2023, the research was conducted in January 2024. Prisma, or the Preferred Reporting Items for Systematic Reviews and Meta-Analysis, was the basis for the methodologies used in this investigation. **Results:** After ageing, MDP cement in combination with tribochemical silica coating (TSC) or SA produced more durable results. Furthermore, when SA and TSC are treated with non-MDP cement and non-MDP primer, better bond endurance is seen. Compared to SA, TSC might improve bond durability; when mixed with SA or TSC, MDP cements might have comparable results. The zirconia-resin interface should priorities two important aspects when choosing bonding mechanisms: strong initial bond strength and long-term bond endurance. The effectiveness of treatment may be limited because mechanical tests, such as micro-tensile bond strength and shear bond strength, may not accurately reflect material behaviour under practical settings, even though they are frequently used to evaluate the bond quality between resin luting agents and zirconia substrates. Conventional cements can also be used to cement zirconia crowns if the right crown preparation strategy guarantees adequate retention without bonding. **Conclusion:** The pressures applied during chewing and the state of the tooth are two more elements that significantly affect the retention of restorations in addition to adhesion techniques. Adhesive methods are becoming increasingly important in order to guarantee the effectiveness of restorations, as minimally invasive techniques become more popular.

Keywords: resin bonding, dental bonding, bond strength, zirconia, cement, adhesion

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1. Introduction

The field of dental restorations has seen a significant change in the last few years. The increasing need for restorations that are both aesthetically pleasing and mechanically robust is what led to this change [1]. Traditional metal-ceramic prostheses have become less common due to allergic reactions, decreased biocompatibility, metallic appearance, and wear down of neighbouring teeth. Instead, metal-free alternatives, especially monolithic zirconia restorations, have gained prominence [2]. Restorations made of monolithic zirconia are highly acknowledged for their superior aesthetics, biocompatibility, and remarkable mechanical qualities. They are a potential alternative in contemporary dentistry because they provide a special blend of increased strength and cosmetic appeal [2].

When compared to adhesive methods that have higher bond strengths, better retention, and minimise the risk of micro-leakage and secondary decay, conventional cementation is known for its simplicity, affordability, and good retention. However, its drawbacks include lower bond strength and an increased chance of micro-leakage over time. Additionally, adhesive methods offer superior colour stability and translucency for improved aesthetics. However, nothing is free; adhesive cementation can be more costly and necessitates a more involved and technique-sensitive procedure. Nonetheless, obtaining a stable and long-lasting adhesive cementation is a persistent obstacle to realising the full potential of zirconia-based restorations [3,4,5,6,7,8] [9,10,11,12].

Despite the fact that a multitude of laboratory research have examined various adhesive procedures, the lack of considerable clinical evidence makes it difficult to translate these findings into trustworthy clinical guidelines [13]. Several techniques have been suggested as possible ways to improve bond strength, including tribochemical

silica coating, alumina sandblasting, and the use of primers and cements containing 10-methacryloyloxydecyl dihydrogenphosphate (10-MDP). Moreover, the multi-phase procedure known as the APC Concept, which is founded on in-depth study and methodical literature studies.

First, the zirconia surface is prepared for bonding using air-particle abrasion (APC-Step A) and tiny alumina particles. This procedure cleans and roughens the surface at the same time. Zirconia might be strengthened by tiny abrasive particles. To improve bonding to zirconia, a ceramic primer (APC-stage P) containing sticky phosphate monomers is used in the second stage. Maintaining compatibility requires sticking to suggested product lines. The third step (APC-Step C) is the use of dual- or self-cure composites for sufficient polymerization underneath zirconia restorations. The final appearance is affected by the cement shade selection [14]. For a variety of zirconia-based dental restorations, this method is essential to ensure their lifetime when properly bonded. Still, there are differences about how long bonds last after being subjected to water storage or artificial ageing [14,15].

The goal of this study of the literature is to examine the complex topic of zirconia ceramic bonding. We aim to find relationships between the types of cement, primers, surface treatments, and thermal cycling parameters and the durability of connections created with zirconia ceramics by classifying investigations according to these factors. Whether distinct bonding procedures and heat cycling have a substantial effect on the bond strength between zirconia ceramics and resin-based luting cements is the main question we hope to answer. Our objective is to offer a more comprehensive comprehension and a more uniform method for accomplishing successful adhesive cementation for dental restorations made of zirconia through this integrated study. By doing this, we hope to close the knowledge gap between clinical research and real-world implementation.

2. Materials and Methods

To review the literature, the National Library of Medicine database was consulted using PubMed. The research was carried out on 11 January 2024, and the studies published from 1 January 2019 to 31 December 2023 were selected. The ScienceDirect by Elsevier Library database was also analyzed with a limitation on publication year (2019–2023). This time frame was chosen to gain insight into the current state of knowledge on the discussed subject, particularly with respect to the new materials recently introduced to the market. Studies concerning the assessment of the different bonding protocols were reviewed and the following terms and their combinations were used for the search: "Zirconia," "Adhesion," "Adhesive cementation," "Bonding," "Dentin," and "Enamel." The research encompasses laboratory studies, and systematic reviews.

3. Result

By reading the abstract, studies that are not considered relevant, those that do not meet the aging requirements, or

do not meet the inclusion criteria are discarded, the total number of systemic reviews which met the inclusion criteria was 7. 4 of them are prohibited to access without membership. Also, some studies have been eliminated because they are not relevant (e.g., adhesion of zirconia brackets or posts).

It is clear that different methods exist for creating a strong connection between resin cements and zirconia. But it's important to recognise that bond deterioration and related effects are frequently expected in oral settings (masticatory forces, salivary influence, heat variables, and tiredness, for example). Because of this, when choosing bonding mechanisms for vital clinical scenarios, two important considerations should be given top priority: strong initial binding strength and long-term bond endurance at the zirconia-resin interface. The effectiveness of treatment may be limited because mechanical tests, such as micro-tensile bond strength and shear bond strength, may not accurately reflect material behavior under practical settings, even though they are frequently used to evaluate the bond quality between resin luting agents and zirconia substrates. Before therapeutically prescribing a technique or novel material, it is proposed to supplement mechanical tests with chemical analysis of bonding materials to increase the credibility of study outcomes [9,10]. However, zirconia adhesion to resin cement is still an unknown difficulty. Notably, if proper crown preparation design guarantees adequate retention without bonding, zirconia crowns can also be cemented using traditional cements.

4. Discussion

For zirconia adhesion, a contaminant-free surface must be achieved. This usually entails ultrasonic cleaning and silicon carbide tool polishing. It is also common practice to employ various cleaning solutions, including as distilled water, alcohol, acetone, ethanol, and isopropanol, for one to ten minutes at a time. However, the specific impact of these solutions on adhesion is still mostly unknown [16,17,18,19,20] [21,22,23,24] [25,26,27] [28,29,30].

Sandblasting can modify the zirconia surface but requires a chemical conditioner for long-term stability [31,32,33,34]. Alumina sandblasting and tribochemical silica coating are widely applied, yet the influence of particle size on bond strength necessitates further investigation.

Because zirconia is resistant to traditional acid etching, researchers are looking into other approaches, such as treating it like glass ceramic by depositing a glassy layer thick with silicon oxides [35]. Hydrofluoric acid is then used to etch this layer, and silane is added as a coupling agent after that. Marginal mismatch may result from the thickness of the glass ceramic layer put to the inner surface of zirconia restorations. Furthermore, some writers draw attention to worries about the vitreous layer's brittleness, which can start surface flaws and spread fissures.

It seems that adequate adhesion can be achieved by applying a glass ceramic coating and then etching with HF [31,36,37]. With a clinically acceptable marginal misfit of about 10 μm , spray application techniques outperform

powder/liquid systems [38,39,40,41]. Certain writers report a decrease in bond strength after artificial ageing techniques, which they ascribe to insufficient binding between zirconia and the glass ceramic layer. Van der Waals contacts and weak micromechanical interlocking, which are prone to hydrolysis, are the foundations of this bonding [42].

Because of their diverse compositions and secret proprietary formulae, resin cements fall under a complicated classification. Furthermore, inadequate information from manufacturers frequently results in the specific composition or percentage of each component being unknown. As a result, the cement was classified as self-adhesive, cement with 10-MDP, and Bis-GMA (non-self-adhesive or non-containing 10-MDP) cement. There is disagreement on which cement is better than the others, with the exception of Bis-GMA, which showed lower adhesion values than the other two groups.

Studies cannot accurately reproduce clinical variables, such as saliva contamination or parafunctional behaviours, which can adversely affect adhesion, because this comprehensive review was based on in vitro research [13]. Consequently, in order to develop trustworthy methods, further investigation and clinical trials are required. The ageing process has an impact on the bond strength as well, with thermocycling alone having less of an impact than thermostorage in combination. Due to smaller adhesion areas and a decreased chance of discovering cementing flaws, micro bond strength tests typically produce higher adhesive values. This guarantees a minimum number of pre-test bond failures, which may have an impact on study results depending on the bonded area [43].

In reference to the referenced systematic review, Thammajarak [44] collected papers exclusively through the year 2016. Bond strength values from several test types (micro and macro) are compared in the meta-analysis. In spite of this, the present review agrees with their conclusions to some extent.

As a surface pretreatment for zirconia, plasma treatment has been established with the goal of enhancing surface energy and improving substrate chemical surfaces while maintaining structural integrity. Nevertheless, upon artificial ageing, the application of oxygen or argon plasma failed to provide adhesion values that were sufficient [45,46,47]. Furthermore, the use of a laser did not produce acceptable adhesion values or strengthen the bond more than sandblasting [17,21,24,33] due to the appearance of microcracks on the surface of the zirconia, leading to a phase transformation and weakening the mechanical properties [33]. Hence, laser treatment is presently not regarded as a viable mechanical pretreatment method [17,24].

Contamination during clinical phases can hinder adhesion [48]. While various cleaning methods are available, such as rinsing with H₂O, H₂O₂, ethanol, or acetone, the utilization of orthophosphoric acid, ethyl cellulose-based paints, ultrasonic cleaning, or plasma treatment proves ineffective in removing contaminants [49,50,51,52,53]. Sandblasting with Al₂O₃ powder emerges as the most efficient method for removing contaminants, although repeated applications on the material can compromise the structure of zirconia.

Cleansing with NaOCl solutions or using the cleaning paste Ivoclean (Ivoclar Vivodent, Schaan, Liechtenstein) (composed of sodium hydroxide, ZrO₂, water, polyethylene glycol, and pigments) appears to be a viable alternative considering costs and practicality, as well as the potential preservation of the zirconia structure [50,52,54].

The chemical affinity between the solution's constituents and the pollutants found in saliva determines the effectiveness of Ivoclean, which contains an aqueous solution containing zirconium particles [49]. Just 20 seconds of water spray rinsing seemed to be enough to restore binding strength to levels comparable to the control group, where contamination did not occur, in cases of saliva contamination after treatment with a 10-MDP primer [49].

A few recent research have evaluated the feasibility of adherence of translucent zirconia, introducing new issues for adhesive protocols. Results show that extremely translucent zirconia bonding exhibits behaviour similar to conventional 3Y-TZP [55,56]. Few clinical investigations have been conducted on Resin Bonded Fixed Dental Prosthesis (RBFDP), and the findings regarding the durability of the restorations have been inconsistent [7,57,58,59].

The retention of restorations is greatly impacted by factors other than adhesion protocols, such as chewing pressures and tooth preparation [60,61]. The importance of adhesive protocols for the effectiveness of restorations increases with the increasing use of less invasive techniques [62,63].

5. Conclusion

It is valuable to underscore specialists' viewpoints, which highlights that various factor apart from adhesion protocols, including tooth preparation and the forces exerted during chewing, play a substantial role in the retention of restorations. With the rise of minimally invasive techniques, there's a growing emphasis on adhesive protocols to ensure the success of restorations.

Author Contribution

Turki A Alzahrani and Dr. Abdulmajeed O Alotaibi both designed the study, wrote the protocol, planned the study, carried out data collection, and manuscript writing, drafting and review.

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Declaration of competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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