

# Surface Pre-Treatments and Bonding Materials for Indirect Zirconia Dental Restorations: A Systematic Review

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## ABSTRACT

A large variety of materials used for dental restorations especially for the fabrication of Fixed Dental Prostheses (FDP's) in contemporary clinical dental practice rely heavily on optimal bonding of prostheses and the tooth structure so as to achieve long term clinical success. Luting cements provide a linkage between the prepared tooth surfaces and a fixed prosthesis used for the rehabilitation of lost esthetics and function in a patient caused due to partial or complete loss of dentition. Nonetheless, due to variance in environment of chemical bonding between two dissimilar constituents viz., tooth and fixed denture prosthesis frameworks, the strength of the bond at the unification interface may be weak that there are no substantial values exists in the oral environment that determines durability and long term success of the restorations thus bonded. The recent advances in various restorative systems are due to the patient's consistent esthetic demand for long lasting esthetic and functional restorations. Due to high flexural strength and ease in fabrication of dental restorations using CAD-CAM technologies, non-glass-based polycrystalline ceramics like zirconia gained popularity, even though they are less translucent and more opaque. Achieving optimal bonding between tooth material and zirconia restoration is really a challenging task considering the non-crystalline nature of zirconia. This article reviews the various techniques, bonding materials and method of application on zirconia used for dental restoration with the main aim to recommend improved bonding and high success rate in terms of zirconia-based restoration for long term use..

**Keywords:** Zirconia, Silane Coupling, MDP

## INTRODUCTION

Pioneering and inventive techniques along with advancement in materials have revolutionized the practice of Fixed Denture Prosthodontics. Progressive Resin systems and introduction of enhanced adhesive cements have transformed and popularized the application of All-Ceramic and resin-retained fixed denture prostheses. Now a day, the clinicians have a multitude of choices to lute the fixed restorations using chemically dissimilar luting agents available in the contemporary clinical practice in Dentistry. Another option is to bond them to the minimally prepared tooth surface using adhesive resins.

Introduction of glass ionomer cement, composite resins and Zirconia has opened new horizon in the practice of esthetic dentistry. As the result, metal-ceramic restoration has its popularity diminished due to the consistent esthetic demands of the patient for long lasting metal free restorations. However, achieving a predictable bonding of indirect

Zirconia restorations on to the prepared tooth surface has been a pertinent question that perplexed clinicians and researchers right from the beginning of new millennium. Numerous research papers have failed to establish any single method or technique as a gold standard for bonding such restorations. The article reviews the contemporary materials and methods used to gain a predictable bond of Zirconia restorations with the prepared tooth surface.

## DISCUSSION

Each and every patient's appealing demand for the restoration of lost esthetics and function has led to the development of All-ceramic Fixed Denture Prostheses (FDP's) and different bonding systems [1]. In contemporary practice of restorative dentistry, Yttrium Stabilized Zirconia Poly Crystals (Y-TZP system) is the principal material used for esthetically and functionally superior FDP's [2]. Excellent mechanical properties and bio-compactability of this medical grade All-ceramic core material has led to its extensive use in various medical sub-specialties like Orthopedics [3].

Partially stabilized zirconia is a multi-phase material which is generated by the inclusion of a stabilizing oxide viz., Yttrium oxide to pure zirconia. This inclusion of Yttrium Oxide stabilizes it at room-temperature. This process which is called as "transformation toughening" has led to the development of outstanding properties like fracture toughness and superlative strength of Y-TZP which exceptionally popularized its use in dentistry [4].

Stress corrosion due to the presence of water in the oral environment initiates sub critical crack propagation in Y-TZP system which is attributable to the long lasting success of Zirconia restorations compared to the enhanced decomposition of the glass structure in conventional glass containing systems [5]. In one of the in-vitro studies, Y-TZP specimens revealed fracture toughness values which were virtually double the values confirmed by alumina based ceramics and nearly three times the fracture toughness values

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validated in studies carried out with lithium-disilicate based glass ceramics [6].

Y-TZP has got a wide range of indications in contemporary clinical dental practice ranging from solitary crowns to full mouth rehabilitations with exceedingly predictable long term clinical success. Even though Y-TZP is considered to be as the superlative material for all-ceramic indirect dental restorations, the most pertinent query to be answered is how to retain these restorations on the prepared tooth surface either by cementing or bonding them on to the tooth surface [7]. But long term clinical studies have demonstrated encouraging results regarding the bonding of these restorations to the minimally prepared tooth surface [8].

Poly-crystalline nature of zirconia and the bio-compatibility of bonding agents to the tooth structure pose a significant challenge in the selection of bonding agents for zirconia based indirect dental restorations or prostheses. Conventional surface treatment and etching process employed for the resin bonded glass based indirect dental restorations could not be utilized for bonding fully sintered Y-TZP indirect restorations and hence silane coupling agents are least effective in achieving chemical bonding with zirconia restorations since these indirect restorations do not have a glass phase [9].

Even though alumina and zirconia based indirect dental restorations are considered to be cementable without many technique sensitive bonding steps due to its enhanced flexural strength; conventional cements even with self-adhesive resins could not be used in situations of inadequate mechanical retention to retain the restoration on to the prepared tooth surface such as in the case of resin-bonded FPD's, inlays/onlays, and laminates [10]. All the above mentioned restorations warrant pure resin to the prepared tooth surface bonding. Since Zirconia are non-silica based dental restoratives, silane applied directly on to the bonding surface of such restorations prior to the bonding procedures may not be ideal for achieving long term durable bonding with the prepared tooth surface. Throughout the bygone years, a multitude of techniques have been advocated by various authors to enhance the success rate with regards to the formation of predictable bond and longevity of such restorations in the harsh oral environment. [11].

Surface pre-treatments for Zirconia Indirect Dental Restorations

Various surface treatments of intaglio surface of indirect Zirconia Dental restorations are the following:-

**(a) Grit blasting** is a process by which the intaglio surface of Zirconia indirect restorations are surface treated with air particle abrasion using alumina particle under air pressure using a pen blaster which considerably increases the bonding area of the intaglio surface of the restorations. Alumina particles will also get embedded on to the bonding surface of such restorations which aids in the conventional salinization process. But long term laboratory studies have demonstrated that such bonds formed over the intaglio surface of non-silica based indirect restorations are hydrolytically unstable thus affecting the durability of bond. [12].

**(b) Tribo-chemical silica (TCS) bonding** is a process utilizing mechanical energy to create chemical and physico-chemical changes on the intaglio surface of non-silica based indirect dental restorations to enhance durable bond. Utilization of the principles of tribo-chemistry could create a layer coated with silica on to the bonding surface of the restorations so that subsequent process of silane application will help in achieving clinically durable bond. This process increases micro-mechanical retention as the result of augmented surface coarseness of the bonding surface [13]. A patented tribo-chemical Rocatec system either Rocatec Soft or Rocatec Plus system (3M ESPE, Seefeld, Germany) utilizes variable sized silica coated alumina particles under variable air pressures to coat the intaglio surface of non-silica based indirect dental restorations. Subsequently, silane coupling agents are applied on this tribo-chemically pre-treated surface of the restorations and a composite resin cement is used to achieve clinically durable bond with the prepared tooth surface [14].

**(c) Selective infiltration etching (SIE)** is another surface pre-treatment method of Zirconia restorations in which the intaglio surface of these restorations are layered with a reedy deposit of glass and subsequently heating it above the glass conversion temperature. As a result the surface grains of glass will slide and slip due to surface tension and capillary forces. This will in turn creates new retentive surfaces on the bonding surface of restorations. Once it cools down, it is dipped and cleaned in an acid bath to remove the impurities [15]. Further studies have also demonstrated that disintegration of the bond is considerably reduced by the subsequent application of silane [16].

**(d) Laser irradiation** utilizes Nd-YAG or Er-YAG lasers to augment the surface area of the interface of indirect restorations where resins are applied. Later on to this irradiated surface, silane is applied and a very robust bond is achieved between the Zirconia restoration and the minimally prepared tooth surface when resin cement is used at the interface [17].

**(e) Nano-structured Alumina Coating** is a thermochemical treatment process by which hydrolysis of aluminum nitride (AlN) is carried out in a diluted aqueous solution that facilitates the precipitation of aluminum hydroxides. Later executing thermal treatment creates high surface area on the substrate that promotes the micro-mechanical interlocking of resins that enhances bond strength between Zirconia and resins [18].

**(f) Internal Coating Technique** is a surface treatment by which intaglio surface of indirect zirconia restorations are coated with silica-based ceramics and applying silane subsequently before bonding the restorations. This process augments predictable bonding and durable success of bonded indirect Zirconia restorations on to the prepared tooth surface [19].

**(g) Chemical Vapor deposition (CVD)** utilizes gaseous treatment over the bonding surface of indirect Zirconia restorations using chloro-silanes and sulphur hexafluoride which allows the deposition of Silicone-oxide film which enables the process of silanization and subsequent application of resins to achieve better bonding of restorations with prepared tooth surface. The bond strength thus attained is higher than tribo-chemical functionalization as per the study conducted by Piascik Jr et al [20]

#### Current Trends and Future Developments of Coupling Agents

An amalgamation of micro-mechanical retention and chemical treatment is mandatory for long term durable bond of resins with zirconia as brought has been brought out in various in-vitro studies and systematic reviews [21]. Coupling agents are incorporated in primers and bonding agents for enhancing chemical adhesion between restorations and composites. Application of silane for the enhancement of adhesion between adhesive resins and indirect dental restorations are in use for more than five decades since their first introduction in dentistry [22]. However the long term durability of the adhesion enhancement using silane coupling agent is questionable due to bond degradation over a period of time in both in-vivo and in-vitro environment [23].

#### Self-Adhesive Resin Cements for Zirconia

Various studies have proven that zirconia restorations could benefit from self-adhesive resin bonding. Self-adhesive resin bonding are ideal in conditions when zirconia restorations needed to be bonded are thin; when there is a lack of adequate retentive tooth surface to hold the restorations; and in situations where onlays, inlays and laminate veneers needed to be bonded [24].

Self-adhesive resin cements are gaining popularity now-a-days due to its ease of use and better handling properties. Various studies have shown that long lasting durable unification between the restoration and the prepared tooth surface could be achieved when adhesive resins are used at the interface as compared to conventional cements like Zinc Phosphate [25]. Another recent review also concluded that self-adhesive resin cement is superior to attain long lasting bond between indirect Zirconia restorations and the minimally prepared tooth surface [26].

PANAVIA™ SA CEMENT, PANAVIA™ SA CEMENT PLUS, PANAVIA™ V5 CEMENT so on and so forth are the most commonly used self-adhesive resin cements in the contemporary clinical practice [27]. These cements have excellent handling properties and long term predictable bond could be achieved by utilizing bonding agents employing “Rapid Bond Technology” like CLEARFIL™ Universal Bond Quick (Kuraray Noritake Dental). In current clinical dental practice, the most effective and popularly used method for the unification of dissimilar materials is by the utilization of organo-phosphorus based universal primers and silane coupling agent. Universal primers are principally employed for bonding different dissimilar materials used for the rehabilitation of patients with worn out and lost dentition.

Apart from the promotion and enhancement of adhesion, silane coupling agents also enhances the qualities of dental materials by the phenomenon of adhesion. Studies have also demonstrated that silane agents would get converted as a constituent of the primary dental material used for rehabilitating the loss dentition [28].

#### MDP salts and Primers

In the contemporary prosthodontic practice, apart from silane coupling agents, other adhesion promoters are also utilized for augmenting the bond between the resins and the indirect dental restorations. Phosphate esters like 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) and 4-methacryloxy ethyl trimellitate anhydride (4-META) as well as 11 methacryloyloxy-1, 1-undecane dicarboxylic acid (MAC-10) are incorporated in adhesives, self-adhesive resin cements, metal primers and alloy primers as adhesion promoters [29]. Hydroxyl groups of fully sintered zirconia shows an affinity towards phosphate esters and could create durable bond. These adhesion promoters also augment the hydrolytic permanence of bonding even better than silane [30].

Physical means of improving adhesion by Air particle abrasion (APA) using 50 μ alumina thus increasing the surface area of intaglio surface of indirect fully sintered zirconia restorations has not been found adequate to enhance the long term adhesion. It is also prudent that conventional silane coupling agent could not bond with metal-oxide ceramics and hence the use of ceramic primers which contains special adhesive monomers like 4-META, 10-MDP and MAC-10 are frequently used to bond fully sintered Y-TZP restorations [31,32,33]. Ionic and hydrogen bond created by the application of MDP primers helps in achieving durable bonds between zirconia restorations and prepared tooth surface by adhesion [34]. Air particle abraded bonding surface of Zirconia restorations when coated with MDP and subsequently using a self-adhesive resin at the interface guarantees long lasting bond of the restorations with the prepared tooth surface. This is considered as the most practical method for bonding indirect zirconia restorations [35].

So as to abridge and simplify the bonding process single bottle adhesive systems are available in the market in which adhesives with 10-MDP are constituted with other ingredients. Bonding restorations using single bottle system has also shown promising results [36]. However, various other studies have brought out that the conglomeration of various molecules with 10-MDP dispensed in a single bottle system have affected the efficacy of bond especially with zirconia substrate [37, 38, 39].

#### CONCLUSION

Proper cementation and bonding protocols are the strategic and fundamental factors that determine the durability and longer duration of success between bonded indirect restorations and prepared tooth surface. Even though, there are numerous surface treatment methods available for equipping the intaglio surface of indirect Zirconia restorations prior to bonding or

cementing, multitude of different variables like cements used, artificial aging employed in the controlled environment and deterioration and disintegration of bond in the harsh oral environment, it difficult to holistically compare and review the outcome of such surface preparations. Mechano-chemical surface pre-treatments with adequate priming of the intaglio surface of Zirconia indirect restorations along with adequate pre-treatment of prepared tooth surface is mandatory for achieving long term durable bond of indirect esthetic restorations with the prepared tooth surface.

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