Comparing Bond Strength of Indirect Composite to PMMA and Zirconia

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**Abstract:** The amount of surface area on the tooth that can be bonded, together with the lack of chemical compatibility between different types of teeth and the materials used to make the denture base, may all affect how well the teeth stick to the base [(Keul et al., 2013)](https://paperpile.com/c/QdyCjb/U8qz). A few more variables are as follows: inappropriate use of the separating medium during the production of acrylic resin; inadequate supply of monomers during polymerization; high occlusal force or fatigue loading on the teeth during mastication; and inadequate or ineffective curing techniques. Wax residue left at the tooth-base material interface during denture production is the source of surface contamination [(Jeong & Kim, 2019)](https://paperpile.com/c/QdyCjb/xz3oP).On the other hand, Zirconia crowns have gained popularity in the field of dentistry due to their esthetic appeal, biocompatibility, and durability. However, one persistent concern that has been identified in clinical practice is the potential for poor bond strength in certain cases [(Volpato et al., 2011)](https://paperpile.com/c/QdyCjb/ZPVpZ). Bond strength is a critical factor in ensuring the long-term success of dental restorations, and any compromise in his aspect can lead to issues such as debonding, microleakage, and ultimately, restoration failure [(Daou, 2014)](https://paperpile.com/c/QdyCjb/a4Si6).One of the contributing factors to the poor bond strength of zirconia crowns is the inherent nature of zirconia itself. Zirconia is a high-strength ceramic material, known for its resistance to fracture and wear [(Larsson & Wennerberg, 2014)](https://paperpile.com/c/QdyCjb/Toucu). While these properties make it an excellent choice for dental restorations, they also pose challenges when it comes to achieving a strong bond with luting agents or cements. The smooth and inert surface of zirconia may not provide the ideal conditions for effective bonding, making it more susceptible to debonding over time [(Brown et al., 2023)](https://paperpile.com/c/QdyCjb/KjH2T)

**Keywords:** Zirconia crowns, CAD CAM machine, PMMA and Zirconia

# Introduction

Acrylic resin teeth are commonly used in complete and partial removable dentures as well as implant supported prosthesis. These artificial devices, particularly implant-retained overdentures, aid in preserving bone density and offer increased stability and retention while operating [(Ali et al., 2015)](https://paperpile.com/c/QdyCjb/VT1UL). Additionally, studies have demonstrated that when compared to traditional dentures, they enhance patients' quality of life. Polymethyl methacrylate (PMMA) is the most commonly utilised material when developing attractive dentures, while zirconia is used for crowns and implants [(Ajay et al., 2023; Chokkattu et al., 2023; Padarthi et al., 2023)](https://paperpile.com/c/QdyCjb/aCtFu+Beuh7+AaHoy).PMMA is a polymer that is most frequently used in dental clinics (for relining dentures and temporary crowns), dental laboratories (for dentures and orthodontic retainers and repairs), and industry (for making artificial teeth) [(Kaur & Thakur, 2022)](https://paperpile.com/c/QdyCjb/6K25U). PMMA is typically offered as a powder–liquid combination, regardless of the intended use. The powder is made of a transparent polymer (PMMA), but to replicate the appearance and physical characteristics of oral tissues (such as the mucosa and gums), additives like colours and nylon or acrylic synthetic fibres are added. A methyl methacrylate monomer, inhibitors, and cross-linking agents are present in the liquid component [(Dharman et al., 2023; S. Sindhu et al., 2023; Sreenivasagan et al., 2023)](https://paperpile.com/c/QdyCjb/ftgNk+igrwb+gDttN).PMMA is a thermoplastic that is optically clear, or transparent, and is frequently used in place of inorganic glass due to its high impact strength, light weight, resistance to shattering, and advantageous production conditions [(Zidan et al., 2020)](https://paperpile.com/c/QdyCjb/oKj2a). The ability to withstand weather and scratches are two exceptional qualities. The polymer structure is unable to freely rotate around the C-C bonds and cannot pack tightly in a crystalline manner due to the presence of the nearby methyl group (CH3). PMMA was discovered to be an amorphous thermoplastic for this reason. When PMMA was initially widely employed in World War II, it was applied to gun turret bubble canopies and aircraft windows [(Yan et al., 2020)](https://paperpile.com/c/QdyCjb/NE6ym). The degree of adhesiveness between the teeth made of acrylic and denture base resin is one of the most important factors in defining the intended functionality and longevity of a denture [(Ali et al., 2015)](https://paperpile.com/c/QdyCjb/VT1UL). In clinical applications, tooth debonding or fractures continue to be a significant issue. According to reports, between 22% and 30% of dentures fail as a result of tooth debonding, typically in the anterior area of the denture [(Lim et al., 2010)](https://paperpile.com/c/QdyCjb/yyrE). The amount of surface area on the tooth that can be bonded, together with the lack of chemical compatibility between different types of teeth and the materials used to make the denture base, may all affect how well the teeth stick to the base [(Keul et al., 2013)](https://paperpile.com/c/QdyCjb/U8qz). A few more variables are as follows: inappropriate use of the separating medium during the production of acrylic resin; inadequate supply of monomers during polymerization; high occlusal force or fatigue loading on the teeth during mastication; and inadequate or ineffective curing techniques. Wax residue left at the tooth-base material interface during denture production is the source of surface contamination [(Jeong & Kim, 2019)](https://paperpile.com/c/QdyCjb/xz3oP). On the other hand, Zirconia crowns have gained popularity in the field of dentistry due to their esthetic appeal, biocompatibility, and durability. However, one persistent concern that has been identified in clinical practice is the potential for poor bond strength in certain cases [(Volpato et al., 2011)](https://paperpile.com/c/QdyCjb/ZPVpZ). Bond strength is a critical factor in ensuring the long-term success of dental restorations, and any compromise in this aspect can lead to issues such as debonding, microleakage, and ultimately, restoration failure [(Daou, 2014)](https://paperpile.com/c/QdyCjb/a4Si6).

One of the contributing factors to the poor bond strength of zirconia crowns is the inherent nature of zirconia itself. Zirconia is a high-strength ceramic material, known for its resistance to fracture and wear [(Larsson & Wennerberg, 2014)](https://paperpile.com/c/QdyCjb/Toucu). While these properties make it an excellent choice for dental restorations, they also pose challenges when it comes to achieving a strong bond with luting agents or cements. The smooth and inert surface of zirconia may not provide the ideal conditions for effective bonding, making it more susceptible to debonding over time [(Brown et al., 2023)](https://paperpile.com/c/QdyCjb/KjH2T)Moreover, the composition of zirconia crowns can vary, with differences in the manufacturing processes and formulations used by different dental laboratories. Variations in the sintering temperatures, surface treatments, and material purity can influence the surface characteristics of zirconia and, consequently, impact its bond strength [(da Silva et al., 2021)](https://paperpile.com/c/QdyCjb/MbplK).To address the issue of poor bond strength in zirconia crowns, researchers and manufacturers have been exploring innovative surface treatments and bonding protocols [(Thomas, 2014)](https://paperpile.com/c/QdyCjb/BlffQ). Techniques such as airborne-particle abrasion, laser etching, and the application of specific primers or adhesion promoters have been proposed to enhance the surface roughness and chemical reactivity of zirconia, thereby improving its bond strength with resin cements [(G. & Ganapathy, 2022; Kumar & Ramesh, 2021)](https://paperpile.com/c/QdyCjb/LZi4Z+NjTPR)). However, the effectiveness of these methods can vary, and further research is needed to establish standardised protocols for achieving reliable bond strength in diverse clinical scenarios. Therefore this study aimed to compare the bond strength of zirconia and PMMA with indirect composite.

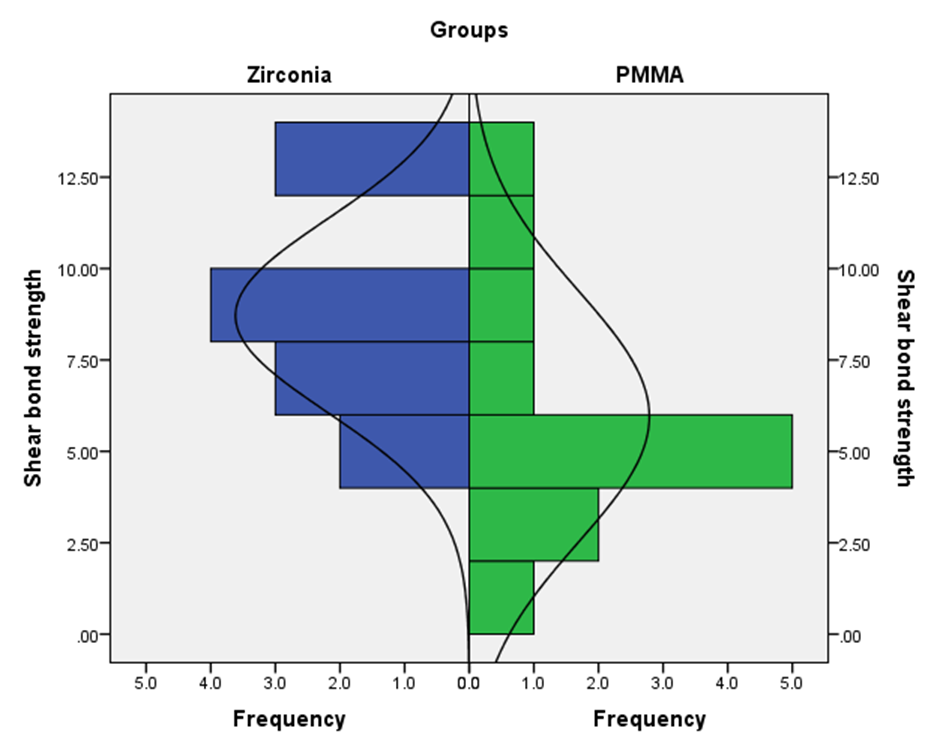
# Materials and Methods

This in vitro study was white lab associated with the department of Public Health Dentistry. The study was approved by the ethical committee of the institute. The sample size for the study was calculated to be 24 from a similar study done by Kubochi et al, 2017 with power 95 and alpha error of 5 [(Kubochi et al., 2017)](https://paperpile.com/c/QdyCjb/UdAFG).

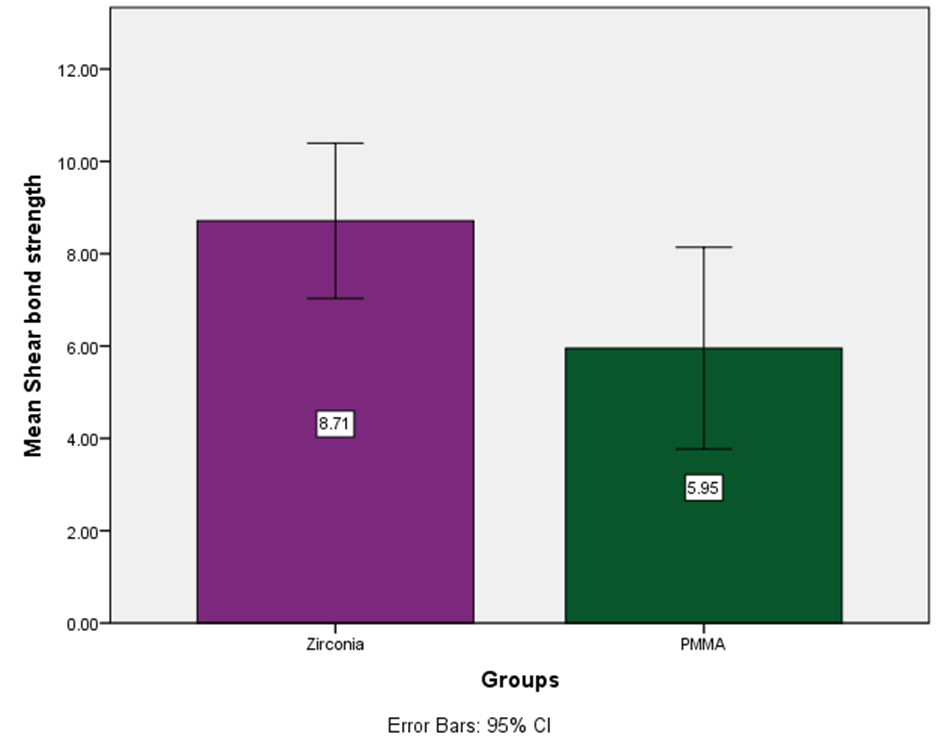
Using a CAD CAM machine, a block size of 10 mm diameter and 2mm height is designed in the form of STL file. Using a milling machine (RXP500 DSC) from Röders GmbH in Soltau, Germany (3 shape) , 12 samples of PMMA and 12 samples of zirconia were fabricated and milled. Then a disc shaped mold of silicone which is made of 10 mm was taken and indirect composite is filled in it and light cured to make 24 discs of indirect composite. After that 12 discs of PMMA were bonded to 12 indirect composite blocks (Group I) and 12 discs of zirconia were also bonded to 12 more blocks of indirect composite (Group II) using cerabond bonding agent and light cured. In order to align the bonded surface of each specimen with the testing apparatus, it was put in a mounting jig. The bonded specimen and the PMMA/zirconia interface were the points of contact where the Ultradent testing instrument (Ultradent Products Inc., South Jordan, Utah) was placed. A universal testing machine (Instron; Instron Corp, Canton, Mass.) was used to execute the shear test to failure at a load rate of 0.5 mm/min. Megapascals were used to translate kilograms of shear bond strengths.The broken specimens were inspected under a × 30 to × 1000 magnification using a scanning electron microscope (SEM; Hitachi, Japan; model SEM 4700) in order to identify the mode of failure. The test result data was tabulated in Microsoft excel. Data was analysed in SPSS software version 24.0. The shear bond strength was expressed in mean and standard deviation. Shapiro wilk test was done to analyse the normality of the data distribution. Mann Whitney U test was performed to assess the differences in the shear bond strength between the two groups with significance level less than 0.05.

# Results

The present study has 24 samples of PMMA and Zirconia which assessed their shear bond strength to indirect composite. With an allocation ratio of 1:1, the samples were divided into two equal groups. The minimum shear bond strength in zirconia was 4.54 and PMMA was 1.12 MPa. The maximum shear bond strength in zirconia was 12.54 and PMMA was 12.12 MPa (Figure 1). Results revealed that the mean shear strength of PMMA blocks were 5.95土3.43 MPa and zirconia was 8.71土2.64 MPa (Figure 2). Mann Whitney U test revealed that the shear bond strength of Zirconia blocks were significantly higher than that of the PMMA blocks with p value = 0.03 (Table 1).



**Figure 1 :** Overall shear bond strength of both the groups



**Figure 2:** Mean shear bond strength of both the groups

**Table 1 :** Shear bond strength differences between the zirconia and PMMA groups are statistically significant (p value<0.05) , as demonstrated by the Mann Whitney U test.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Shear bond strength | Mean | Mean rank | Sum of ranks | Mann whitney U value | P value |
| Zirconia | 8.71土2.64 | 15.58 | 187 | 35 | **0.033\*** |
| PMMA | 5.95土3.43 | 9.42 | 113 |

# Discussion

The aim of the this study was to compare the shear bond strength of indirect composite to PMMA and ZirconiaShear bond strength is the ability of a material or component to withstand a certain kind of yield or structural failure when the failure is caused by shear force(Saadh et al., 2024). For a variety of causes, a tooth may come loose from a denture base, so having the strongest shear bond possible is essential [(Eltombakshy et al., 2019)](https://paperpile.com/c/QdyCjb/L32yZ). Because the shear bond strength test can quickly and easily reflect the clinical situation, it was used. For assessing the adhesive qualities of luting cements to composites, SBS tests are more suitable(Almatrafi et al., 2024). Shear strength is influenced by changes in the material's surface treatment and is connected to both chemical and mechanical adhesion [(Evaluation Composite Restoration Posterior Teeth Proanthocyanidin Pretreatment Liner Using Fédération Dentaire Internationale Criteria: Split-Mouth Randomized Controlled Trial, n.d.; Pranati et al., 2021; Sakthi ,2021)](https://paperpile.com/c/QdyCjb/WGLIE+XwEiI+80Yge). Several materials, such as self-cured, heat-cured, visible-light-cured, and microwave-polymerized acrylic resins, have been used to repair PMMA or zirconia [(Zafar, 2020)](https://paperpile.com/c/QdyCjb/4rB9Z). As opposed to auto polymerized resin, heat-polymerized acrylic resin has superior mechanical qualities. The choice of reinforcement or repair material could affect how strong the denture is after being fixed. Consequently, a number of techniques have been used to improve the strength of repair material. Among these are fillers, nanofillers, fibres, alloy mesh, metal wires, and fibres to reinforce the fractured acrylic denture [(Sari et al., 2016)](https://paperpile.com/c/QdyCjb/ZHC7C).In this research, the bond strength was evaluated using an indirect composite. Numerous mechanical approaches can be used to obtain optimal micromechanical retention at the resin/repair contact. In order to improve the bonding surface area and produce micropores, it is usually acceptable to roughen the repair surfaces using airborne particle abrasion, diamond discs and burs [(Ramakrishnan et al., 2023; Shenoy & Maiti, 2023; J. S. Sindhu et al., 2023)](https://paperpile.com/c/QdyCjb/JGiSm+ArYfs+rH0V9). Promising results have been observed in improving adhesion surface area using alumina-induced airborne-particle abrasion. Prior research has demonstrated that while silanation and hydrofluoric acid etching improve the resin's binding to conventional ceramics based on silica, they have no effect on the bonding of the resin to ceramics composed of zirconia or alumina [(Serichetaphongse et al., 2022)](https://paperpile.com/c/QdyCjb/4koJb).The SBS value of veneering indirect composite to zirconia core in this study was 8.712.64 MPa. In previous studies, shear bond strengths for commercially available core-veneer all-ceramic systems were reported to be between 23 and 41 MPa by Dundar et al [(Dündar et al., 2005)](https://paperpile.com/c/QdyCjb/WD1u6) and between 22 and 31 MPa by Al-Dohan [(Al-Dohan et al., 2004)](https://paperpile.com/c/QdyCjb/9HXV7). In the present study, no mechanical treatment was done to the zirconia to increase the SBS. The bond strength of resin cements to zirconia ceramics had been evaluated in previous studies with various interventions. When a zirconia surface was roughened using an Er:YAG laser, Akin et al. assessed the impact of the laser on the surface-to-resin cement ratio (SBS) and discovered that the treated surface had a higher SBS value (3.2 MPa) than the untreated surface (2.8 MPa) [(Keerthana & Ramesh, 2021; Murugesan, 2021; Tiwari & Jain, 2021)](https://paperpile.com/c/QdyCjb/Zupma+IgRtX+Q13nR)[(Keerthana & Ramesh, 2021; Murugesan, 2021; Subramanian et al., 2021; Tiwari & Jain, 2021)](https://paperpile.com/c/QdyCjb/Zupma+IgRtX+Q13nR+p8xHY). This result is in line with the current study. Moreover, the SBS (14 MPa) was significantly changed by the Nd:YAG laser in comparison to the untreated (4.65 MPa), sandblasted (8.79 MPa), and CO2 irradiated (7.92 MPa) groups. The untreated, sandblasted, and laser etched (Nd:YAG and CO2) zirconia surfaces were assessed by Paranhos et al [(Paranhos et al., 2011)](https://paperpile.com/c/QdyCjb/0yVfH). On the other hand, in the present study, SBS of PMMA to indirect composite was 5.95土3.43. Fletcher-Stark et al. observed that acrylic denture teeth surface treated with bonding agent displayed significantly greater bond strengths than denture teeth without a bonding agent. In the present investigation, the indirect composite was bonded to PMMA using Cerabond Bonding Agent [(Fletcher-Stark et al., 2011)](https://paperpile.com/c/QdyCjb/kIeiu). Hayakawa et al. also recommended the use of a bonding agent when using visible light-polymerized denture base resin with acrylic denture teeth [(Akin et al., 2014)](https://paperpile.com/c/QdyCjb/Lv6X9). One possible explanation is that a monomer with a higher cross-linking agent content could facilitate the development of a wider interpenetrating polymer network [(Kasabwala et al., 2021; Rajeshkumar & Lakshmi, 2021; Varghese et al., 2023)](https://paperpile.com/c/QdyCjb/dd9Yy+kDhnk+IgcvX). The present study has many limitations. The important drawback of this study was only two groups of materials were compared for SBS. And only indirect composite was used to bond the blocks. There was neither major mechanical intervention given to any group nor different types of bonding agent used to assess the differences in SBS. This is a preliminary study and future invitro and in-vivo studies need to compare many groups of materials with different intervention techniques.

# Conclusion

In conclusion, this study aimed to comprehensively evaluate and compare the shear bond strength between zirconia and PMMA when bonded to an indirect composite using a bonding agent. The investigation employed a rigorous methodology, including the use of a universal testing machine to quantify the shear bond strength. The findings of this study unequivocally demonstrate that the shear bond strength of zirconia to indirect composite is markedly superior to that of PMMA. This significant difference in bond strength suggests that zirconia may offer a more robust and reliable bonding interface when used in conjunction with indirect composite materials. Such enhanced bond strength is of paramount importance in dental restorations, ensuring the longevity and stability of the prosthetic components.The utilisation of a bonding agent in both zirconia and PMMA bonding processes underscores the role of surface treatments and adhesive techniques in influencing the bond strength. The results emphasise the potential of zirconia as a preferred material in restorative dentistry, particularly when considering applications where strong adhesion to indirect composites is crucial.The implications of these findings extend beyond the laboratory setting, as they provide valuable guidance for dental practitioners and technicians in material selection for prosthodontic applications. Zirconia's superior shear bond strength highlights its potential as a preferred material in cases where durability and resistance to mechanical forces are paramount considerations.

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