Original Article

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BOND STRENGTH ASSESSMENT OF SINGLE VERSUS DOUBLE ARM POSTERIOR RESIN-BONDED BRIDGE (IN VITRO STUDY)

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Abstract

Objective: This study aimed to evaluate the bond strength of single versus double arm posterior resin-bonded bridge. **Materials and Methods:** Fifteen sound human lower molars and lower premolars freshly extracted were chosen, then cleaned and stored in distilled water before preparation. Samples were embedded in self-cure acrylic resin to construct models with an edentulous space of premolar width. Abutment teeth were prepared as lingual coverageand divided according to retainer design: single arm (n=5) and double arm (n=5). Restorations were milled from monolithic zirconia (KATANA Zirconia HTML PLUS) and were adhesively bonded using dual-cure resin cement. The specimens were examined for a retention testutilizing a universal testing machine that applies one or two wire loops in order to perform a debonding test. **Results:** Bond strength in both the Single Arm and Double Arm Posterior Resin Bonded Bridge groups. In the Single Arm group, the bond strength values ranged from 60.80 to 85.07 N, indicating relatively low variability within this group. Conversely, the Double Arm group demonstrated substantially higher bond strength values, ranging from 361.17 to 552.84 N, reflecting a wider spread of bond strength values in this group using the Shapiro-Wilk and Kolmogorov normality test which exposed that all data originated from normal data distribution. Consequently, comparison between groups was accomplished independent t-test. The significance level was set at $p \leq 0.05$ within all tests. **Conclusion:** The Double- Arm Posterior Resin Bonded Bridge withstood higher debonding forces than single- arm resin -bonded bridge. However, single arm is still an alternative option.

Keywords: Resin bonded Bridge, Resin-bonded fixed dental prothesis, Cantilever, lingual coverage, monolithiczirconia, Bond strength, universal testing machine

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Introduction:

Over the past few years, there have been more treatment options available for replacing a single missing tooth. Implant-retained restorations or conventional metal-ceramic or all-ceramic. Fixed dental prostheses (FDPs) can be used to restore the edentulous area. The disadvantage of traditional FDPs is that crown preparation removes 50–70% of sound hard dental tissue. As a result, these choices are regarded as the optimal treatment decision when the neighboring teeth are decayed or extensively restored.[1]

Advancements in dental adhesive technologies particularly those enhancing bond strength have significantly supported the evolution of minimally invasive restorative approaches. First introduced in 1973, Resin bonded fixed dental prostheses (RBFDPs) have emerged as a conservative and effective choice forrestoring of a single missing tooth. RBFDPs are often indicated in patients for whom implant treatment is contraindicated such as those with medical or anatomical limitations, younger individuals, and after orthodontic treatment, for patients seeking conservative treatment option, relatively short treatment duration and inexpensive treatment expenses.[2,3]

The restoration can be either a 2-unit cantilevered Fixed dental protheses (FDPs) or a 3-unit FDPs, based on periodontal health of the abutment teeth, occlusal force, the location of the missing tooth, and the parafunctional habits. on the other side,Resinbonded fixed dental prostheses (RBFDPs), the advantages of cantilevered RBFDPs over3-unitRPFDPs include minimaltooth preparation, easier oral hygiene maintenance, and lower cost. They are also appropriate for patients with limited edentulous space.[4]

It was suggested that in RBFDPs with a single retainer, the pontic always moves in harmony with its abutment tooth, this might help to avoid shear and torque stresses that may arise in two retainer RBFDPs due to discrepancy The abutments' tooth movement and that have been related to an increased risk of debonding. Additionally, Single-retainer RBFDPs reduce the risk of the caries under a deboned retainer, which is frequently observed with two-retainer design. [5]

Among dental ceramics, zirconia exhibits superior fracture resistance and favorable fatigue performance, making it particularly suitable for utilize in fixed dental prostheses (FDPs). As a result, zirconia-based FDPs are commonly recommended for restorations in the posterior region, where functional loading is high[6].

The long-term durability of the adhesive bond in zirconia-based fixed dental prostheses (FDPs) is affected by many factors, such as the surface conditioning of both the zirconia and the tooth substrate (enamel and dentin), the type of luting cement used, and the distribution of functional stresses, different stresses on multiple retainers, particularly at the tooth–cement interface, have been identified as a potential cause of debonding.[7]As a promising alternative, glass ceramics have gained increasing clinical acceptance due to their excellent bonding affinity to tooth structures when used in conjunction with adhesive resin cements. This strong adhesion enables clinicians to accomplish more conservative tooth preparation.[8]

Recent evaluations of zirconia cantilevered resin bonded fixed dental prostheses (RBFDPs) for replacement of missing canines and posterior teeth have demonstrated promising outcomes, with a success rate of 96.3%, survival rate of 100%, and high retentive performance.[9]

The most common failure mode of resin-bonded fixed dental prostheses (RBFDPs) is debonding, Adhesive failure was defined as separation at the interface between the zirconia surface and the luting cement, or between the tooth structure and the luting cement. Cohesive failure was defined as fracture occurring within one of the bonded materials themselves rather than at the interface. Mixed failure referred to a combination of adhesive and cohesive patterns within the same specimen. Failures were further categorized as non-catastrophic, including debonding or failures that could be managed by re-bonding, and catastrophic, such as framework fracture, abutment fracture, or loss of abutment vitality, which require replacement of the restoration.[6]

The objective of this in vitro study was to evaluate bond strength of single-retainer versus double-retainer resin bonded fixed dental prostheses (RBFDPs) fabricated from monolithic zirconia. The null hypothesis stated that there would be no significant difference in bond strength between the single and double retainer posterior RBFDPs.

Materials And Methods:

Calculated Sample Size

Sample size calculated based on a previous study **Tagami et al, (2022)**[10]as reference. If mean ± standard deviation of group is 347 ± 92, while mean ± standard deviation of other group is 725 ± 226, with effect size (1.9), Power (80%) and α error probability (0.05) the accepted sample size is 5. Sample size was accomplished by using t test by using G. power 3.1.9.7. Total sample size = 5 of each group

Materials

The materials used in this study are shown in **Table 1**

Research ethics approval

The protocol of this in vitro study was reviewed and approved by the Ethics Committee of the Faculty of Dentistry, Cairo University, in 2023. The study was evaluated for its scientific validity and compliance with relevant research regulations and ethical standards concerning the use of human-related materials

Teeth Selection:

Fifteen sound human lower molars and premolars were extracted for orthodontic or periodontal reasons, cleaned, polished, and disinfected using diluted sodium hypochlorite. Teeth with caries or cracks were excluded. The occluso-cervical, bucco-palatal and mesio-distal dimensions of teeth were measured using a digital caliper. The dimensions were measured three times, the averages were determined average similarity in size and shape selected for this study to achieve the least variation.[11]

Storage and Mounting:

The extracted Teeth in distilled water were stored at room temperature. Teeth were embedded vertically in selfcure acrylic resin blocks using a custom-designed centralizing device to ensure standardized positioning. A 2 mm sub-CEJ embedding depth and a 6 mm edentulous span between premolar and molar were maintained to simulate a missing premolar site.[9]

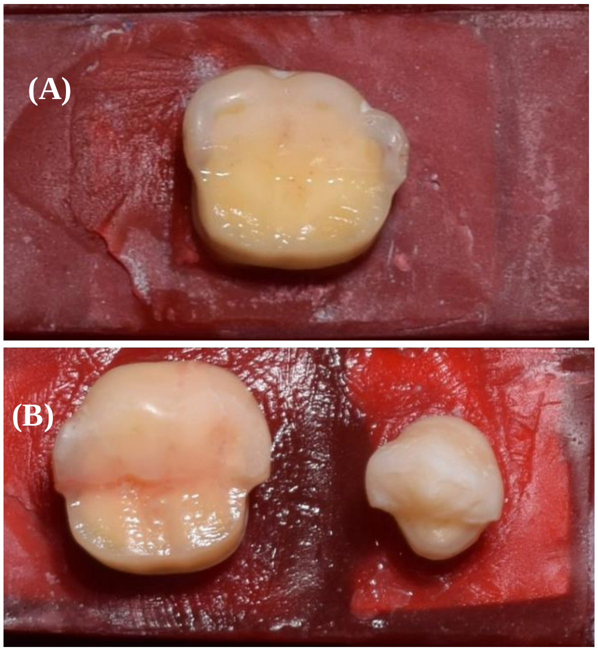
Sample Grouping:

Samples were divided into two groups:

- **Group A (Single Arm RBFDPs):** Only molar abutment used.
- **Group B (Double Arm RBFDPs):** Molar and premolar abutments with a pontic space between.

Tooth Preparation:

Standardized preparations were performed by a single clinician using depth grooves and high-speed rotary instruments. The design included 1 mm lingual cusp reduction, 0.5 mm chamfer finish line and proximal wrap-around extensions ensuring tooth structure engagement**.** Consistency was verified using preoperative putty indices Depth grooves and dental survey and digital verification via CAD software.[12] **(Figure 1).**

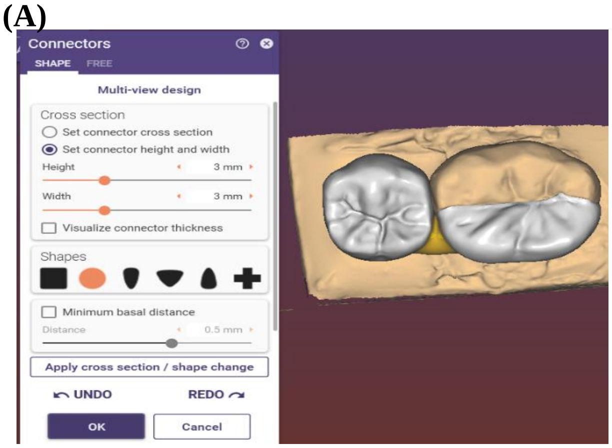


(Figure 1): Showing (A, B) teeth were prepared as lingual coverage design at both group

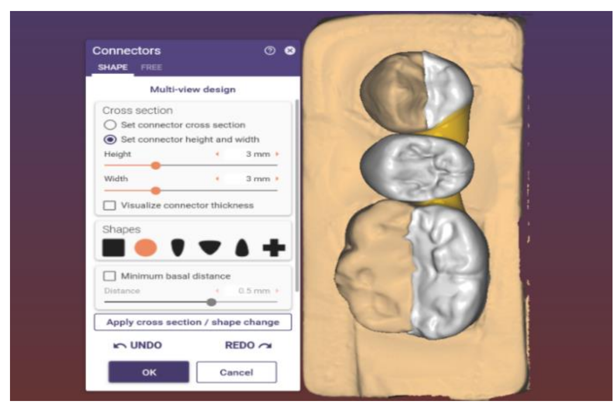
Digital Design and CAD/CAM Fabrication:

After evaluating tooth preparations, all acrylic resin blocks were steam-cleaned, dried, and scanned using the Swing extraoral scanner (DOF Inc., South Korea), producing STL files for digital processing. Restorations were designed in ExoCad Dental CAD version 2.2 (ExoCad GmbH, Germany), where abutment teeth, missing teeth, and restoration type were defined. A standardized anatomical library model was adapted for all specimens to ensure consistency. Marginal fit was set at 20 µm, cement gap at 60 µm, and connector dimensions at 3×3 mm. The pontic dimensions were also adjusted for all specimens using the ExoCad Dental Software at 7 mm bucco-lingually, 6 mm mesio-distally, 6 mm occluso-gingivally, A distance of 2 mm was left between the convex pontic base and the resin mold.[13] **(Figure 2).**

(A)



(B)



(Figure 2): (A, B) showing design of restoration

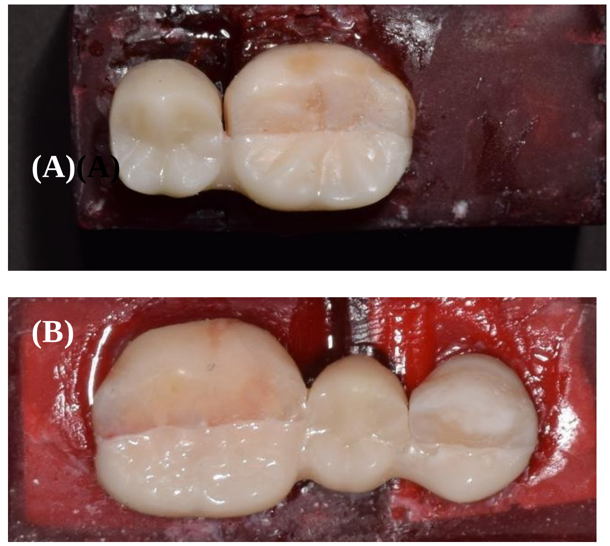
The digital restorations were fabricated through dry milling using KATANA™

zirconia blocks (Kuraray Noritake, Japan) using a 5-axis CORiTEC 150i Pro milling machine (Imes-Icore GmbH, Germany), with specific burs for rough and fine milling. Restorations were finished, cleaned, and sintered at 1550 °C in a Tabeo 1/M/Zircon 100 furnace, followed by surface glazing at 930 °C using Program at CS3 (Ivoclar Vivadent, Liechtenstein).[14]

Surface Treatment and Cementation:

The Zirconia restorations were immersed in distilled water,followed by air-dried for 10 minutes before bonding. The intaglio surfaces were sandblasted using 50 µm alumina particles at 0.25 MPa (1 bar) pressure from a10 mm distance for 10 seconds, followed by cleaning with 99% isopropanol and thorough drying. A single layer of MDP-containing ceramic primer (Z-Prime™, Bisco, USA) was applied, left for 1 Minute and then air dried for 5 seconds.[15]

Selective enamel etching was performed with 35% Phosphoric acid etching was applied for 30 seconds on enamel and 15 seconds on dentin followed by a 20-second rinse and 5-second gentle drying.[16] A universal adhesive containing MDP was applied and lightly air dried for 30 seconds. Dual-cure adhesive resin cement was then applied to the restoration, which was seated onto the prepared tooth. After initial light curing for 3 seconds. Residual cement was carefully removed, and final curing was completed for 40 seconds per surface at a 5 mm distance[17].**(Figure 3).**



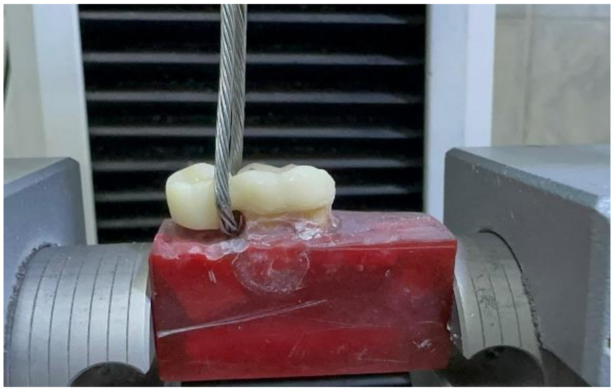
(Figure3): (A, B) showing Final Restoration of RBFDPS After Cementation

To ensure uniform pressure during curing, a custom-made loading device was used. Each specimen was placed in the lower compartment, and A 10-kilogram static load was applied to the upper compartment for 2 minutes to simulate clinical seating forces and standardize cementation[18].

De-bondingTest:

Retention was evaluated using a universal testing machine (Instron, England) in tensile mode at a crosshead speed of 2 mm/min. One or two wire loops were placed proximally between the abutment(s) and pontic, ensuring equal force distribution before testing. Each specimen was vertically pulled from an epoxy-fixed cast until debonding occurred.**(Figure 4)**.

(A)



(B)

(Figure4): (A,B) Debonding Test using Universal Testing machine

The maximum debonding force was recorded and analyzed using Blue Hill Universal software (Instron, England).[10]

Statistical Analysis

Statistical analysis was accomplished with SPSS 27®, Graph Pad Prism® and Microsoft Excel 2016. All data were examined for normality by using Shapiro Wilk and Kolmogorov Normality test which demonstrated that all data came from normal data distribution. Therefore, Comparison between groups was accomplished independent t test. The significance level was set at $p \leq 0.05$ within all test

Table (1): Material's name, Composition, Manufactures, and batch numbers

Material	Product name	Composition	Manufacturer	Batch number
Yttria -stabilized zirconia (3Y-TZP)	KATANA zirconia (HT12/T14 collar)	Zirconium oxide and yttrium oxide	KuarayNoritake,Japan	EFQPV
Dual cure polymerizing adhesive resin cement	TheraCem	Base: calcium base filler, glass filler, dimethacrylates, ytterbium fluoride, initiator, amorphous silica Catalyst: glass filler,Methacryloyloxydecyl Dihydrogen Phosphate (MDP), amorphous silica	Bisco, Schaumburg, U.S.A	D-46311P
Ceramic primer	Z-Prime	MDP, a phosphate monomer, and BPDM, a carboxylate monomer	Bisco, Schaumburg, U.S.A	B-6001P / B-6002P
Universal adhesive	All bond universal	10-MDP, BPDM, Ethanol, Bis-GMA,HEMA, Water, Initiators	Bisco, Schaumburg, U.S.A	B-72020K / B-7202P/ B-73100K
Phosphoric acid 35%	Etch-w/BAC syringe	phosphoric acid semi-gel etchant with Benzalkonium Chloride	Bisco, Schaumburg, U.S.A	E5503EBM

Results:

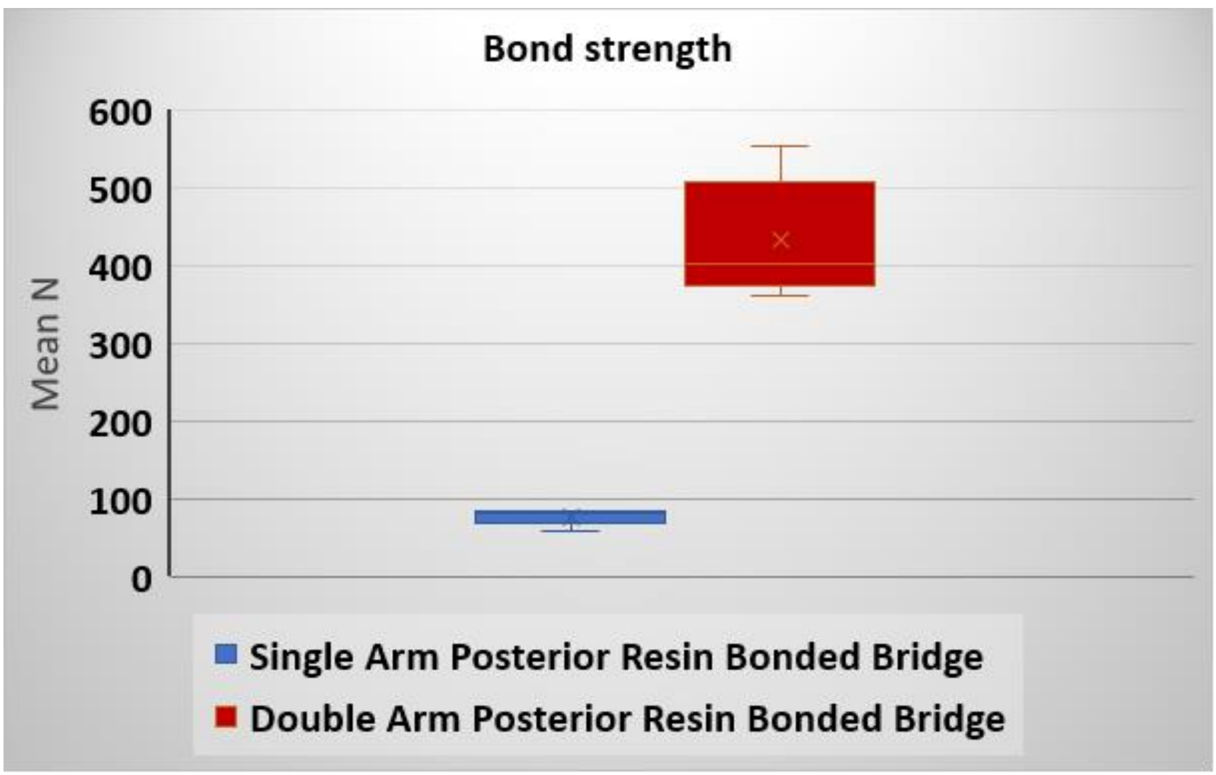
Data were collected, tabulated, and statistically analyzed, and the result can be described as **(Table 2 and figure 5)** presents the descriptive statistics for bond strength in both the Single Arm and Double Arm Posterior Resin Bonded Bridge groups. In the Single Arm Posterior Resin Bonded Bridge group, the bond strength values ranged from 60.80 to 85.07 N, with a median of 82.39 N, a mean of 78.36 N, and a standard deviation of 9.99 N, indicating relatively low variability within this group. Conversely, the Double Arm Posterior Resin Bonded Bridge group demonstrated significantly higher bond strength values, ranging from 361.17 to 552.84 N, with a median of 402.26 N, a mean of 433.26 N, and a notably larger standard deviation of 76.04 N, reflecting a wider spread of bond strength values in this group

(Table 3 and figure 6) display the results of an independent t-test comparing the bond strength between the Single Arm and Double Arm Posterior Resin Bonded Bridge groups. The mean bond strength in the Single Arm group was 78.36 N (SD = 9.99), while the Double Arm group demonstrated a substantially higher mean of 433.26 N (SD = 76.04). The mean difference between the two groups was -354.90 N (± 34.30), with a 95% confidence interval ranging from -434.00 N to -275.81 N.

The t-test revealed a statistically significant difference ($P < 0.0001$) in bond strength between two designs, confirming that the Double Arm Posterior Resin Bonded Bridge provides significantly greater bond strength compared to the Single Arm design.

Table 2: Descriptive results of Bond strength in Single Arm Posterior Resin Bonded Bridge and Double Arm Posterior Resin Bonded Bridge:

Group	Minimum	Maximum	Median	Mean	Standard Deviation
Single Arm Posterior Resin Bonded Bridge	60.80	85.07	82.39	78.36	9.99
Double Arm Posterior Resin Bonded Bridge	361.17	552.84	402.26	433.26	76.04

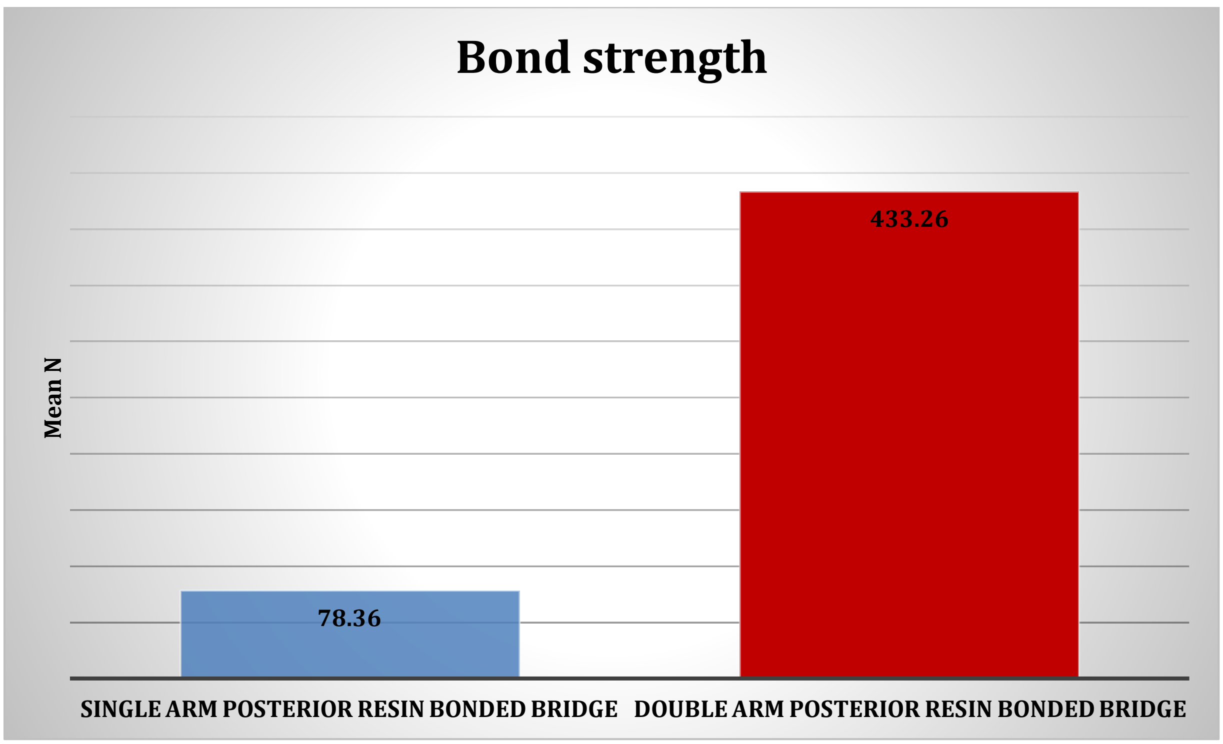


(Figure 5): Box plot represents bond strength in Single Arm Posterior Resin Bonded Bridge and Double Arm Posterior Resin Bonded Bridge

Table 3: Comparison between Bond strength in Single Arm Posterior Resin Bonded Bridge and Double Arm Posterior Resin Bonded Bridge using Independent t test:

Group	Mean	Std. Deviation	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P value
					Lower	Upper	
Single Arm Posterior Resin Bonded Bridge	78.36	9.99	-354.90	34.30	-434.00	-275.81	<0.0001*
Double Arm Posterior Resin Bonded Bridge	433.26	76.04					

*Significant difference as P ≤ 0.05.



(Figure 6): Bar chart represents bond strength in Single Arm Posterior Resin Bonded Bridge and Double Arm Posterior Resin Bonded Bridge.

Discussion:

This study focuses on assessing bond strength of different design of Resin bonded fixed dental prostheses (RBFDPs). Resin bonded fixed dental prostheses (RBFDPs) provide a minimally invasive treatment for restoring missing teeth, particularly in caries-resistant, minimally restored dentitions. Though two-retainer RBFDPs offer strong retention, they are more prone to debonding.[4]

Advances in adhesive dentistry and CAD/CAM technology have expanded the range of restorative materials; Dental ceramics offer favorable properties such as biocompatibility, esthetics, low plaque accumulation, and high strength with varying mechanical properties affecting clinical performance[19].Zirconia, selected in this study, is widely used for its high tensile strength and long-term clinical success.[8]To overcome the common complication of veneering ceramic chipping, especially at the pontic, So According to the used material type monolithic zirconia has been introduced as a promising alternative, combining strength, durability, and esthetic potential for reliable posterior RBFDPs.[18]

Single-retainer designs of anterior teeth have shown fewer technical complications and a lower failure rate. The strength of prostheses is influenced by several factors, including the applied load, cementation technique, and the elastic modulus of the supporting structure.[20]Consequently, this study aimed to assess the viability of single-retainer resin-bonded fixed dental prostheses as a reliable alternative for posterior tooth replacement.

In this study using natural teeth as abutments more closely mimics clinical conditions with same dimensions, standardization of preparation was achieved using a dental surveyor, putty index, periodontal probe, and CAD software to ensure consistent preparation parameters and restoration thickness across specimens.[21]

This study utilized extracted teeth stored in distilled water to preserve their structural and biological integrity. Rigid acrylic resin blocks, with an elastic modulus similar to human bone, were used to simulate the clinical support environment and ensure appropriate stress distribution.[22]

Zirconia RBFDPs exhibit high mechanical strength and are clinically durable; however, debonding remains more common than fracture. This is largely due to stress concentrations at the bonding interface, influenced by functional loading and retainer design. Despite its stiffness and resistance to distortion, zirconia's performance is highly dependent on the design of the restoration and precision in cementation.[23]

Retainer and preparation design play an important role in the performance of resin bonded fixed dental prostheses (RBFDPs). Studies have shown that the D-shaped retainer offers the maximum force of retention and most favorable stress distribution, making it superior to L-shaped designs, which demonstrated lower retention and higher fracture rates.[24]

Preparation designs with larger bonding surfaces, such as the OC (occlusal coverage) design, significantly improved fracture resistance and reduced debonding but less conservative. Conversely, designs like OW (one-wing) and TW (two-wing) showed high debonding rates due to limited adhesive surface area. Consequently, The LC (lingual coverage) design was a chosen as ideal preparation design for RPFDPs, as a conservative design and offered large surface for bonding, and transmitted minimal stress to the tooth and avoided catastrophic failures.[25]

The use of a 5-axis milling system in fabricating monolithic zirconia RBFDPs enables precise reproduction of complex geometries with improved fit and marginal adaptation while minimizing post-processing and preserving optimal bonding surfaces for durable adhesion.[26]

Airborne-particle abrasion combined with MDP-containing primer provides synergistic enhancement of zirconia–resin adhesion by promoting micromechanical interlocking and durable chemical coupling. This dual protocol consistently achieves higher and more stable bond strengths, especially after aging, and is considered the most reliable approach for zirconia bonding.[27]

Using Selective enamel etching protocol enhances adhesion by combining phosphoric acid etching of enamel for micromechanical retention with limited dentin etching to preserve hybrid layer integrity. When followed by an MDP-containing adhesive, this protocol provides stronger and more durable bonds than self-etch alone.[28]

In this study TheraCem, a dual-cure self-adhesive resin cement, was selected for its effective bonding to enamel and dentin, particularly when combined with selective enamel etching. It demonstrated superior shear bond strength to caries-affected dentin and enhanced tubule mineralization compared to Panavia SA.[29] A durable resin bond to zirconia is achievable through air abrasion and the application of primers or adhesives containing MDP.[30]

The success of RBFDPs is strongly influenced by material choice, bonding protocol, elastic modulus of the supporting structure, restoration thickness, and framework design., and clinical performance, operator technique errors, and functional stress with long-term survival dependent on achieving a strong and stable adhesive interface.[31,32]

The primary concern for posterior RBFDPs is resistance to debonding under high debonding forces. A Universal Testing Machine (UTM) with stainless-steel wire loops was used to assess the tensile bond strength of RBFDPs. Single-loop loading allowed axial testing of single-retainer designs, while a double-loop setup for two-retainer designs ensured symmetrical force distribution and minimized rotational stresses, providing a reliable representation of debonding forces as recommended in previous studies[24].

The predominance of cohesive failures observed in this study indicates that the adhesive interface between zirconia and resin cement was sufficiently strong, such that the weakest link shifted to the internal structure of the cement or, in some instances, the zirconia substrate itself. As cohesive failure can be regarded as a favorable outcome compared to adhesive failure, as it suggests that debonding is not primarily attributable to interfacial weakness but rather to material fatigue or stress concentration within the cement layer. [17]

The study's findings revealed a notable variation in the bond strength between posterior resin-bonded fixed dental prosthesis (RBFDPs) with a single arm and those with double arm. As double arm exhibits more retention forces than single arm.

These results also supported by **Botelho et al. (2020**,[33]**)**who evaluated the long-term clinical performance of two-unit resin bonded fixed dental prostheses (RBFDPs) has been evaluated with respect to retention, survival, and success rates. Findings indicate that 2-unit RBFDPs represent a durable treatment option with favorable longevity and high levels of patient satisfaction

These results confirmed report **by Tagami et al. (202,**[9]**1)**Whom concluded that having two retainer wings results in greater retention than having just one or none. Thus, two retainer wings are highly advised for effective clinical applications, and the number of retainer wings has greater impact on retention.

These findings correspond with **Tagami et al. (2022**[10]**)**, reported that two retainer RBFDPs exhibited significantly greater tensile retention forces than single retainer designs due to increased bonding surface area. Despite improved retention, the risk of undetected debonding in two-retainer RBFDPs may lead to secondary caries.

In contrast to the results **Mine et al., (2021)**[1], assessed cantilever Resin Bonded Fixed Dental Prostheses (RBFDPs) of the anterior teeth, particularly maxillary lateral incisors, showed better clinical results than two-retainer designs because they eliminate stress at the bonding interface, which typically results from the unequal movement of abutment teeth in two-retainer RBFDPs. Such differential mobility may introduce shear forces that increase the risk of debonding and has been closely linked to the development of secondary caries when one of the retainers loses retention. however, the difference in results might be explained as their studies were on anterior teeth that have different surface area for bonding

These results are conflicting to what **Habibzadeh et al. (2024)** [34] **,**demonstrated that the cantilever design of anterior resinbonded fixed dental prostheses (RBFDPs) is superior to the two-abutment design, exhibiting a lower failure rate. This increased failure rate in two-abutment designs is likely due to differences in functional movement between the abutment teeth, especially during protrusive and lateral excursions. In contrast, the cantilever configuration minimizes shear and to rsional forces on the pontic and connectors by allowing coordinated movement between the pontic and its single abutment tooth. while the discrepancy in outcomes might be caused by varying bonding surface area of the anterior teeth restored with zirconia restoration.

The results of this study revealed a significant difference in the bond strength between single and double retainer posterior resin bonded fixed dental prostheses (RBFDPs); consequently, the null hypothesis was rejected

Limitations:

1. This study was conducted under controlled laboratory conditions without the application of mechanical or thermal cycling, which are important methods for simulating clinical conditions that may influence bond strength.
2. Although the sample size was determined using a statistical equation, *Future studies with larger samples are needed to strengthen the validity of findings.*
3. Only one preparation design was evaluated, limiting the ability to compare the influence of different preparation designs on bond strength.

4. A single ceramic material was utilized, limiting the generalize ability of the results to other restorative materials with different mechanical and adhesive properties.

Conclusions:

Within the limitations of this study, the following conclusions can be drawn:

1. Double-arm posterior resin-bonded fixed dental prostheses (RBFDPs) demonstrated greater resistance to debonding forces compared with single-arm designs.
2. Despite lower retention values, single-arm designs remain a clinically promising option due to their ability to withstand debonding forces while offering a minimally invasive treatment alternative in appropriately selected cases.
3. Zirconia, as a high-strength ceramic material, can be successfully utilized for RBFDP restorations when combined with proper bonding protocols.

Recommendations

For dental clinician:

1. Select cases with single missing teeth, sound abutments, and healthy periodontium.
2. Prefer minimal tooth preparation; limit to enamel when required.
3. Use high-strength ceramics (zirconia or lithium disilicate) with proper surface conditioning.
4. Consider double-retainer designs in posterior regions where occlusal loads are higher.

For further studies:

1- Additional investigations, particularly in vitro and clinically simulated studies(in vivo) with greater clinical resemblance, are recommended to better replicate the oral environment.

2- Assess different preparation designs to determine the most effective and conservative approach for RBFDPs.

3- Utilizing other materials, such as ceramics made of zirconia reinforced lithium silicate glass (ZLS).

4- Using various resin cements to establish the most durable bonding protocol

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