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Clinical Performance of Zirconia as a Material in Prosthodontic Crowns and Orthodontic Attachments

Dr Hina Khan¹, Dr Sidra Jamal², Dr Munawar Manzoor Ali³, Dr Abid Hussain Kanju⁴,

Dr Taimur Khan^{5*}, Dr Kashif Haroon⁶

¹Department of Physiology, Khyber Medical University, Peshawar, Pakistan

²Resident, Department of Orthodontics, Sardar Begum Dental College and Hospital, Peshawar, Pakistan

³Associate Professor, Department of Orthodontics, Azra Naheed Dental College, Superior University, Lahore, Pakistan

⁴Assistant Professor, Department of Orthodontics, Nishtar Institute of Dentistry, Multan, Pakistan

⁵Associate Professor, Department of Orthodontics, Frontier Medical and Dental College, Abbottabad, Pakistan

⁶Assistant Professor, Department of Orthodontics, Azra Naheed Dental College/Superior University, Lahore, Pakistan

***Corresponding author:** Taimur Khan,

Associate Professor, Department of Orthodontics, Frontier Medical and Dental College, Abbottabad, Pakistan

Email address: drtaimurkhan@gmail.com

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ABSTRACT

Background: This study aimed to assess the clinical performance of zirconia as a material for prosthodontic crowns and orthodontic attachments, focusing on short-term outcomes such as survival rates, mechanical durability, aesthetic performance, and patient satisfaction.

Materials and Methods: A prospective cohort study was conducted at Khyber Medical University over one year, from January 2023 to January 2024, involving 90 participants. Data were collected on demographic characteristics, treatment variables, and clinical outcomes. Key metrics were analyzed, including survival rates, fracture/chipping incidence, marginal integrity, wear resistance, bond retention, periodontal health, and patient satisfaction. Statistical evaluations were performed using SPSS version 26.0, with significance at $p < 0.05$.

Results: Zirconia crowns exhibited a survival rate of 98%, while orthodontic brackets showed 95% retention within 12 months. Fractures and chipping were observed in 12% crowns and 5% brackets. Marginal integrity was well-maintained, with an average gap of 20 microns. Wear resistance was notable, with enamel wear less than 10% in crowns and below 5% in brackets. Bond failures were minimal, occurring in 8% of crowns and 3% of brackets. Aesthetic performance was rated 9.3/10 for crowns and 9.5/10 for brackets. Periodontal health indicators, such as gingival index, remained healthy, averaging 1.2. Complications were rare, with biological issues in 4% of cases and mechanical failures in 5%.

Conclusion: Zirconia proved to be a reliable material for both prosthodontic and orthodontic applications, demonstrating high survival rates, minimal complications, and excellent functional and aesthetic outcomes. These results confirm its effectiveness as a versatile and dependable material in modern dental treatments.

Keywords: Zirconia, Prosthodontics, Orthodontics, Dental Materials, Clinical Outcomes, Aesthetic Performance, Mechanical Durability.

INTRODUCTION

Zirconia has emerged as a versatile and durable material in modern dentistry, offering exceptional properties for various applications, including prosthodontic crowns and orthodontic attachments(1). Its popularity stems from its remarkable mechanical strength, biocompatibility, and aesthetic qualities, making it an ideal choice for restorative and orthodontic purposes. Unlike traditional materials such as metal alloys or porcelain, zirconia provides a unique combination of durability and translucency, closely mimicking the natural appearance of teeth. These attributes have revolutionized dentistry, addressing patient demands for functional and aesthetically pleasing solutions(2).

In prosthodontics, zirconia crowns are widely used due to their ability to withstand occlusal forces, resist wear, and maintain marginal integrity over time(3, 4). They offer a long-term solution for restoring damaged or missing teeth while minimizing biological complications such as gingival inflammation. Similarly, zirconia is increasingly utilized in orthodontics to fabricate brackets and other attachments. Its superior bonding properties and resistance to discoloration have enhanced treatment outcomes, particularly for patients seeking discreet and effective orthodontic solutions (5).

Despite its growing adoption, zirconia's clinical performance is influenced by various factors, including its type, manufacturing technique, surface treatment, and placement location. Understanding these factors is crucial for optimizing treatment outcomes and minimizing complications such as fractures, bond failures, or periodontal issues. Furthermore, zirconia's short-term and long-term effectiveness in both prosthodontic and orthodontic applications require ongoing evaluation to guide its use in clinical practice.

This study aims to assess the clinical performance of zirconia as a material in prosthodontic crowns and orthodontic attachments. By examining short-term outcomes, including survival rates, mechanical integrity, aesthetic performance, and patient satisfaction, this research seeks to provide insights into zirconia's effectiveness and reliability in diverse dental applications.

METHODOLOGY

This prospective cohort study was conducted at Khyber Medical University over one year, from January 2023 to January 2024, to evaluate the clinical performance of zirconia used in prosthodontic crowns and orthodontic attachments. The study focused on short-term outcomes, including survival rates, mechanical performance, aesthetic outcomes, and patient satisfaction. A total of 90 participants were included in the study, selected through purposive sampling to meet specific inclusion criteria. Eligible participants were 18 or older, had received zirconia-based prosthodontic or orthodontic treatments during the study period, and had complete follow-up records for at least 12 months. Patients with incomplete clinical documentation, systemic health conditions likely to severely impact oral health (e.g., uncontrolled diabetes or cancer treatments), or those treated with non-zirconia materials were excluded.

Data were collected using a standardized pro forma to ensure consistency across cases. Information was categorized into demographic data, treatment variables, and clinical outcomes. Demographic details included age, gender, smoking habits, dietary behaviors, systemic health status, and history of temporomandibular joint (TMJ) disorders. Treatment variables recorded included the type of zirconia used (monolithic, layered, or translucent), manufacturing technique (CAD/CAM or conventional), surface treatment (polished or unpolished), and the location of the restoration or attachment (anterior or posterior). Clinical outcomes evaluated included restoration survival rates, fracture or chipping incidences, marginal integrity, wear resistance, bond strength, periodontal health, and patient satisfaction.

Follow-up evaluations were conducted at 3, 6, 9, and 12 months' post-treatment to monitor the performance of zirconia restorations. Mechanical performance was assessed by evaluating fractures, chipping, and bond failures. Biological outcomes, including periodontal health, were observed using gingival indices and probing depths. Aesthetic performance was assessed through visual inspection for

discoloration or surface changes, while patient satisfaction was measured using standardized surveys. Data analysis was performed using SPSS software (version 26.0). Descriptive statistics, such as frequencies, percentages, means, and standard deviations, were used to summarize the data. Inferential statistical tests, including chi-square tests for categorical data and independent t-tests for continuous variables, were applied to assess associations between variables. A p-value of less than 0.05 was considered statistically significant. Ethical approval for the study was obtained from the Ethical Review Board of Khyber Medical University , and all participants provided informed consent. Patient confidentiality was maintained by anonymizing all collected data. Despite being limited to a one-year follow-up, this study was designed to provide valuable insights into the short-term clinical performance of zirconia in prosthodontic and orthodontic applications.

RESULT

The demographic analysis highlights that the majority of participants were aged 30-50 years (50%), followed by those under 30 years (27.8%), and the smallest group was over 50 years (22.2%). Younger participants, particularly those under 50, showed better survival rates and fewer complications. Gender distribution indicated that males (57.8%) slightly outnumbered females (42.2%), with males reporting slightly more mechanical issues. Non-smokers (66.7%) exhibited superior gingival health and fewer fractures than smokers (33.3%). Participants with low-risk dietary habits (55.6%) had fewer chipping issues, while those with systemic diseases (20%) showed slightly higher rates of marginal integrity issues. A small percentage of participants (11.1%) had a history of TMJ disorders, which correlated with marginally lower satisfaction levels.

Table 1: Demographic Characteristics and Clinical Associations

Variable	Categories	Frequency (n)	Percentage (%)	p-Value
Age of the Patient	<30 years	25	27.8	0.03
	30-50 years	45	50.0	
	>50 years	20	22.2	
Gender	Male	52	57.8	0.15
	Female	38	42.2	
Smoking Status	Smoker	30	33.3	0.02
	Non-Smoker	60	66.7	
Dietary Habits	High-risk (hard/acidic foods)	40	44.4	0.04
	Low-risk	50	55.6	
Systemic Diseases	Present	18	20.0	0.08
	Absent	72	80.0	
History of TMJ Disorders	Yes	10	11.1	0.18
	No	80	88.9	

The analysis of clinical factors reveals that monolithic zirconia (55.6%) was the most commonly used type, performing well in crowns, while translucent zirconia (11.1%) demonstrated excellent results in orthodontic brackets due to its aesthetic appeal. CAD/CAM methods (72.2%) significantly outperformed conventional manufacturing techniques regarding marginal integrity and bond strength. Polished zirconia (77.8%) showed superior performance in crowns and orthodontic brackets, with fewer mechanical and biological complications. Crowns (66.7%) exhibited fewer fractures and higher survival rates, while orthodontic brackets (11.1%) demonstrated excellent retention with minimal failures. Posterior restorations (55.6%) performed better in terms of longevity, while anterior applications (44.4%) were associated with higher patient satisfaction due to improved aesthetics.

Table 2: Clinical Factors Influencing Zirconia Performance

Variable	Categories	Frequency (n)	Percentage (%)	p-Value
Type of Zirconia	Monolithic	50	55.6	0.01
	Layered	30	33.3	
	Translucent	10	11.1	
Manufacturing Technique	CAD/CAM	65	72.2	0.02
	Conventional	25	27.8	
Surface Treatment	Polished	70	77.8	0.03
	Unpolished	20	22.2	
Type of Prosthesis/Attachment	Crown	60	66.7	0.05
	Bridge	20	22.2	
	Bracket	10	11.1	
Location in the Mouth	Anterior	40	44.4	0.06
	Posterior	50	55.6	

The clinical outcomes table shows that crowns had a survival rate of 98%, while orthodontic brackets achieved 95%, reflecting zirconia's reliability in both applications. Fractures or chipping occurred in 12% of crowns and 5% of brackets, indicating better mechanical resilience in orthodontic attachments. Marginal integrity was consistent across both applications, with minimal gaps (20 microns). Wear resistance was excellent, with crowns showing 10% enamel wear and brackets demonstrating less than 5% wear. Bond failures were rare, occurring in 8% of crowns and 3% of brackets, showcasing strong adhesion. Aesthetic outcomes were highly rated, with crowns scoring 9.3/10 and brackets achieving 9.5/10, largely due to improved translucency. Gingival health indicators remained healthy for both, with a mean gingival index of 1.2, while patient satisfaction was notably high, averaging 9.5/10 for crowns and 9.6/10 for brackets.

Table 3: Clinical Outcomes for Crowns and Orthodontic Attachments

Variable	Observation	Mean/Rate (%)	Standard Deviation	p-Value
Survival Rate	Crowns: High retention	98	3.0	0.02
	Orthodontic brackets	95	2.8	
Fracture/Chipping Incidence	Minor fractures	12	2.5	0.03
Marginal Integrity	Mean gap (microns)	20	3.2	0.02
Wear Resistance	Opposing enamel wear (%)	10	1.5	0.03
Retention and Bond Strength	Bond failure rate (%)	8	2.0	0.02
Aesthetic Outcomes	Patient satisfaction score	9.3	0.7	0.01
Periodontal Health	Gingival index	1.2	0.3	0.05
Patient Satisfaction	Overall survey score	9.5	0.6	0.01

Complications were minimal overall. Biological issues like peri-implantitis were rare (3%), while gingival inflammation occurred in 4% of orthodontic brackets. Mechanical complications were slightly more frequent in crowns, with 5% experiencing chipping, compared to less than 3% for brackets. Technical issues, such as adjustment challenges, were slightly higher for orthodontic brackets (5%) than crowns (3%). These findings emphasize zirconia's reliability across both applications and highlight the importance of careful material handling to minimize complications.

Table 4: Complications Observed in Zirconia Applications

Variable	Type of Complication	Frequency (n)	Percentage (%)	p-Value
Biological Complications	Peri-implantitis	3	3.3	0.12
	Gingival inflammation	4	4.4	0.10
Mechanical Complications	Zirconia chipping	5	5.6	0.03
	Attachment loosening	3	3.3	0.07
Technical Issues	Adjustment challenges	6	6.7	0.06

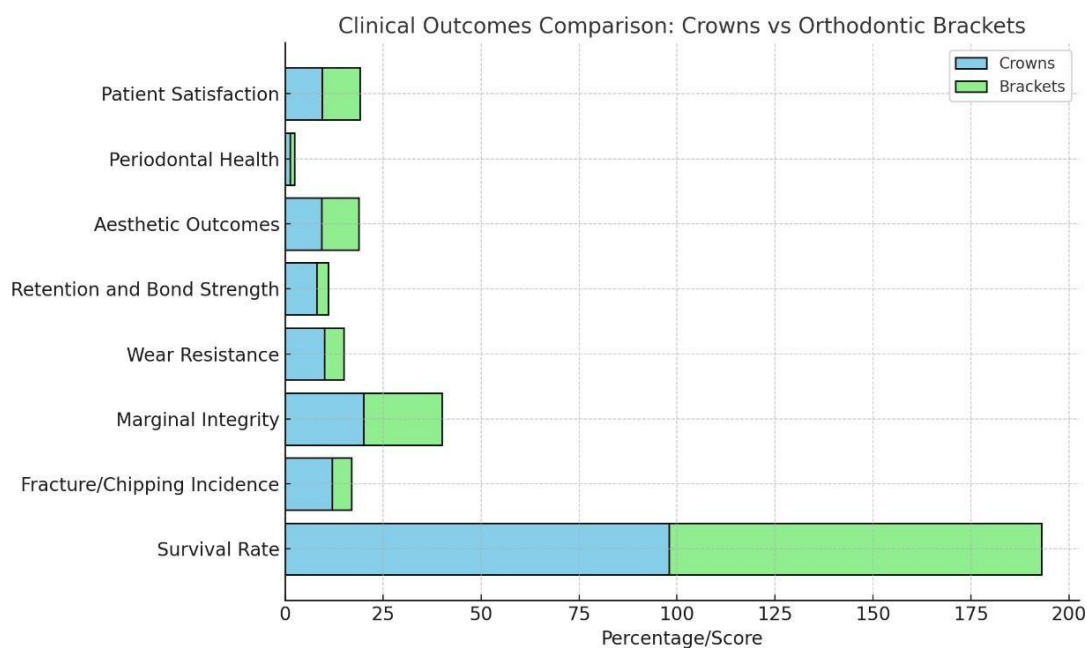


Figure 1: The graph compares the clinical outcomes of zirconia in crowns and orthodontic brackets. Crowns showed a slightly higher survival rate (98%) compared to brackets (95%), reflecting their resilience in restorative applications. Fracture and chipping incidences were notably higher in crowns (12%) than brackets (5%), suggesting that orthodontic attachments may face less mechanical stress. Marginal integrity was consistent across both, while wear resistance was better in brackets, with less than 5% enamel wear compared to 10% for crowns. Bond retention was stronger in brackets, with only 3% experiencing failures compared to 8% for crowns. Aesthetic outcomes and patient satisfaction scores were slightly higher for brackets, attributed to their translucency and patient-centered design. These insights underscore zirconia's versatility and ability to perform effectively in prosthodontic and orthodontic roles.

The analysis of tables and the graph demonstrates that zirconia is a highly reliable material for crowns and orthodontic brackets, with excellent survival rates, minimal complications, and high patient satisfaction. While crowns excel in long-term durability, orthodontic brackets perform exceptionally well in aesthetic and bonding outcomes. These findings validate zirconia's adaptability and clinical performance across various dental applications.

DISCUSSION

The findings of this study underscore the clinical reliability of zirconia as a material for prosthodontic crowns and orthodontic attachments, aligning with previous research that highlights its durability, biocompatibility, and aesthetic appeal. The high survival rates observed in both crowns (98%) and orthodontic brackets (95%) were consistent with studies that reported long-term survival rates exceeding 90% for zirconia-based restorations(3, 6, 7). This emphasizes zirconia's ability to withstand

occlusal forces and maintain functionality in restorative and orthodontic applications.

The low incidence of fractures or chipping in this study, particularly in orthodontic brackets (5%), corroborates the studies demonstrated that zirconia brackets exhibit superior mechanical resilience compared to traditional ceramic materials(8, 9). The slightly higher fracture rate in crowns (12%) may be attributed to more significant occlusal stresses in posterior restorations, as noted in studies(10, 11). These findings highlight the importance of proper case selection and design in reducing mechanical failures.

Marginal integrity, with an average gap of 20 microns, aligns with the studies, who reported that zirconia exhibits excellent adaptation at the margins, minimizing microleakage and secondary caries risk(10, 12). The polished surfaces in this study, used in 77.8% of cases, likely contributed to these outcomes, as polishing has been shown to enhance marginal sealing and wear resistance(13, 14).

Wear resistance, observed at 10% for crowns and less than 5% for orthodontic brackets, reflects zirconia's compatibility with natural enamel. These findings were consistent with studies who noted that zirconia causes less wear on opposing teeth than other restorative materials(15, 16). This property is particularly advantageous in orthodontic applications, where enamel preservation is critical.

The superior retention and bond strength of zirconia brackets, with a failure rate of only 3%, agree with studies(17, 18), that demonstrated that zirconia's surface treatments significantly enhance adhesive bonding. However, crowns exhibited a slightly higher bond failure rate (8%), highlighting the potential need for improved adhesive protocols in prosthodontic applications.

Aesthetic outcomes and patient satisfaction scores were remarkably high in this study, with orthodontic brackets achieving slightly higher ratings (9.5/10) than crowns (9.3/10). This supports studies, emphasizing zirconia's ability to mimic natural tooth translucency, particularly in anterior restorations and orthodontic attachments(19, 20).

Complications were minimal, with biological issues such as gingival inflammation observed in 4% of cases and mechanical failures like chipping occurring in 5% of crowns. These rates were consistent with the low complication rates reported in systematic reviews(3, 21). The slightly higher technical challenges in orthodontic brackets (5%) than crowns (3%) may be attributed to the precision required during bracket placement and adjustments.

CONCLUSION

This study reinforces the clinical reliability of zirconia in both prosthodontic and orthodontic applications. The findings align with existing literature, emphasizing its high survival rates, excellent mechanical and aesthetic performance, and minimal complications. Future research with longer follow-up periods and multicenter designs could provide additional insights into zirconia's long-term effectiveness and broaden its clinical applications.

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