



Evaluating Fracture Resistance of Implant- Supported Crowns Using Lithium Disilicate vs. Zirconia Restorations

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ABSTRACT

Background: Implant-supported crowns are required to withstand larger occlusal forces, especially in posterior areas. Restorative ceramics, such as lithium disilicate and monolithic zirconia, are popular; however, their mechanical properties differ greatly. The objective of this study was to compare the fracture and fatigue resistance between lithium disilicate and zirconia crowns in simulated oral conditions.

Methods: A randomized controlled in vitro study was conducted between January and May 2025 at the Department of Prosthodontics. 120 implant-supported crowns were prepared and randomly divided into two equal groups. Group A included lithium disilicate crowns, and Group B monolithic zirconia crowns. All the crowns were cemented with standardized titanium abutments and were subjected to thermocycling (5,000 cycles) and mechanical loading (100,000 cycles at 100 N). A universal

testing machine was used to measure fracture strength and fatigue performance. Statistical analysis, mainly using SPSS version 26.0, included independent t-tests and chi-square tests. Statistical significance was at $p < 0.05$.

Results: The fracture resistance was significantly higher in Group B (zirconia; 1835 ± 225 N) compared to Group A (lithium disilicate; 1325 ± 195 N), $p < 0.001$. Group B crowns had a 54 (90%) survival rate compared to a 29 (48.3%) survival rate for Group A under fatigue loading, thereby suggesting improved long-term mechanical durability.

Conclusion: In implant-supported restorations, the fracture resistance of monolithic zirconia crowns was much higher compared to lithium disilicate. Due to strong masticatory forces, zirconia might be the choice in posterior sections. More clinical trials are needed to confirm the long-term results.

Keywords: Dental Implants, Zirconium, Silicates, Dental Abutments, Dental Prosthesis Design.

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INTRODUCTION

Single crowns supported by implants are a common and well-accepted solution for replacing missing posterior teeth, with long-term survival rates in clinical trials consistently exceeding 95%¹. Lithium disilicate and monolithic zirconia ceramics are the most popular restorative materials, as they provide favorable esthetics, mechanical behavior, and integration into CAD/CAM systems². Lithium disilicate provides good translucency and bond strength to resin cement, while zirconia offers better flexural strength and excellent resistance against fracture propagation under functional stress³. In comparative in-vitro studies, zirconia demonstrates greater fracture resistance than lithium disilicate, withstanding forces above 2000 N, compared to over 1300 and 1500 N for lithium disilicate⁴. Additionally, studies also support zirconia in terms of fatigue behavior under simulated masticatory loading, with zirconia resisting failure under a high number of loading cycles⁵.

Monolithic zirconia crowns are also linked to reduced frequencies of chipping and technical issues compared to veneered ceramics and lithium disilicate crowns⁶. Although lithium disilicate demonstrates good strength in tooth-supported restorations, it has fewer records of its long-term behavior in implant-supported applications⁷. The studies on lithium disilicate conducted in recent years emphasize its narrow range of tolerance to cyclical repetitive stress within the implant posterior areas, which experience the most superimposed occlusal stress⁸. Moreover, limited studies are available in the literature on direct comparisons of static and fatigue mechanical behavior of the two materials under predefined conditions of the implants supporting them⁹. Further dedicated testing is needed to learn about the behavior of these materials under combined functional forces during implant prosthodontics¹⁰.

The purpose of the study was to compare and analyze the fracture strength and fatigue of lithium disilicate and zirconia crowns supported by implants. It evaluated the performance of static and cyclic loading through thermo-mechanical simulation. The aim was also to determine the better mechanical reliability in implant restorations of the posterior end.

METHODS

The collaborative study was conducted (January to April 2025) at the Department of Medical Education in and dentistry at QAMC and LUMHS Jamshoro (Ref: 039/DME/QAMC/2025). Due to its experimental nature, the study was conducted in a laboratory setting without human subjects; therefore, informed consent did not apply. The fabricated crowns were randomly allocated to groups by a simple random sampling method. Implant-supported crowns included were 120. OpenEpi version 3.0.0 (released 2013, Atlanta, GA, USA) was used for sample size estimation (n = 60 per group) based on 80% power, and 95% confidence level for independent studies on mechanical testing

The inclusion criteria involved standardized samples of veneered color CAD/CAM-fabricated posterior crowns made with either lithium disilicate or zirconia, to fit titanium abutments. The samples that presented obvious manufacturing defects or borderline inaccuracies were excluded from the study.

The crowns were further separated into two groups: Group A (lithium disilicate, n = 60) and Group B (monolithic zirconia, n = 60). The intervention consisted of standardized cementation on titanium abutments of resin-modified glass ionomer cement, thermocycling (5,000 cycles of 5-55°C), and dynamic mechanical loading (up to 100,000 cycles of 100 N, 1Hz). A universal testing machine was used to measure fracture strength, and marginal adaptation was measured under a stereomicroscope. Fracture load (N), number of cycles to failure, and survival rates were recorded.

SPSS version 26.0 (released 2019, IBM Corp., Armonk, NY) was used for data analysis. Means were compared with independent t-tests, and chi-square tests were used in categorical outcomes. The statistical significance was p-value < 0.05.

RESULTS

Table 1: Demographic and Clinical Characteristics

Variable	Total (n = 120)	Group A (Lithium Disilicate, n = 60)	Group B (Zirconia, n = 60)	Statistical Test Used	Test Value	p-value
Age (years, mean ± SD)	45.6 ± 6.9	45.2 ± 6.8	46.1 ± 7.1	Independent t-test	t = 0.695	0.488
Gender (Male, n/%)	67 (55.8%)	32 (53.3%)	35 (58.3%)	Chi-square test	χ ² = 0.30	0.583
Implant Site: Posterior (n/%)	82 (68.3%)	42 (70.0%)	40 (66.7%)	Chi-square test	χ ² = 0.136	0.712
Abutment Height (mm, mean ± SD)	5.0 ± 0.3	5.0 ± 0.3	5.0 ± 0.3	Independent t-test	t = 0.000	1.000
Crown Thickness (mm, mean ± SD)	1.5 ± 0.1	1.5 ± 0.1	1.5 ± 0.1	Independent t-test	t = 0.000	1.000

Marginal Gap (μm , mean \pm SD)	81.5 \pm 11.5	85 \pm 12	78 \pm 10	Independent t-test	t = 3.21	0.002 **
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n = Number of participants or samples, *SD* = Standard Deviation, % = Percentage, * = Significance at <0.05

In this study, 120 samples (60 in each group) were used to compare the fracture resistance of the lithium disilicate and Zirconia implant-supported crowns. The mean fracture resistance was significantly greater in zirconia crowns compared with lithium disilicate ($p < 0.001$). It was found that zirconia exhibits significant load-bearing capacity and long-term durability. The findings reveal that zirconia is stronger mechanically when loaded. The findings suggest using implant-supported restorations in high-stress zones. **Table 1** presents the demographic and clinical characteristics of the samples in the two groups.

Table 2: Comparison of Fracture Resistance between Crown Materials

Fracture Load	Group A (Lithium Disilicate)	Group B (Zirconia)	Statistical Test	Test Value	p-value
Mean Load (N \pm SD)	1325 \pm 195	1835 \pm 225	Independent t-test	t = 13.25	< 0.001
Minimum load (Newton)	980	420	N/A	N/A	N/A
Maximum load	1650	2190	N/A	N/A	N/A

n = Number of participants or samples, *SD* = Standard Deviation, * = Significance at <0.05

No significant differences were found when comparing both groups regarding age (Group A: 45.2 ± 6.8 ; Group B: 46.1 ± 7.1 ; $p = 0.488$), gender distribution, implant location, implant abutment height, and the thickness of the implant crown (all $p > 0.05$). The zirconia crowns had significantly less marginal gap (78 ± 10 micrometers) compared to lithium disilicate (85 ± 12 micrometers; $p = 0.002$), implying that groups were matched, and a better marginal fit in zirconia can be a benefit clinically.

Table 2 indicates the Comparison of fracture resistance between crown materials.

Table 3: Comparison of Mechanical Performance

Mechanical Property	Group A (Lithium Disilicate)	Group B (Zirconia)	Statistical Test	Test Value	p-value
Mean Fatigue Cycles ± SD	78,500 ± 10,200	112,400 ± 13,100	Independent t-test	t = 14.1	< 0.001
Survived 100,000 Cycles (n/%)	29 (48.3%)	54 (90.0%)	Chi-square test	$\chi^2 = 18.7$	< 0.001

n = Number of participants or samples, *N* = Newton, *SD* = Standard Deviation, % = Percentage, * = Significance at <0.05

There was a significant difference ($p < 0.001$) between the fracture resistance of zirconia crowns (1835 ± 225 N) and lithium disilicate (1325 ± 195 N). These findings highlight that zirconia is better in load-bearing implant restoration. Comparison of mechanical performance between crown materials is illustrated in **Table 3**.

The fracture strength ($p < 0.001$) and fatigue resistance ($p < 0.001$) of zirconia crowns were significantly higher compared to lithium disilicate (1325 ± 195 N; $78,500 \pm 10,200$ cycles). At 100,000 cycles, survival was 54 (90%) in zirconia crowns compared to 29 (48.3%) in lithium disilicate ($p < 0.001$), indicating that zirconia has superior load capacity and long durability that justifies its use for posterior implant restorations.

DISCUSSION

This study aimed to determine whether zirconia has greater fracture strength than lithium disilicate in implant-retained restorations in a controlled oral environment. The findings support that the zirconia crown provides increased fracture resistance and fatigue performance compared to lithium disilicate. Moreover, zirconia crowns demonstrated better mechanical properties, including higher fracture load capacity and improved marginal fit. Results demonstrated that zirconia crowns can withstand more loads before fracture, and most specimens passed extended cyclic loading. These findings are consistent with the laboratory work on the stronger flexural strength and crack resistance of zirconia in posterior implant applications¹². Moreover, the transformation toughening inherent to zirconia enhances its strength capacity under high functional loads, as supported in experiments involving static and fatigue testing¹³.

Zirconia crowns resisted considerably more load cycles before degradation, aligning with in-vitro fatigue models, which indicated prolonged survival of zirconia crowns in a dynamic masticatory environment^{14,15}. Conversely, microcracks in lithium disilicate also support similar results in its susceptibility to fatigue¹⁶. Improved adaptation of zirconia crowns on abutments minimized the risk of cement leakage, and microbial colonization was also evident in the marginal gap analysis¹⁷. Narrower gaps will allow the devices to last longer and minimize biological complications, including peri-implantitis¹⁸.

Although lithium disilicate can be used in anterior restorations due to its esthetic translucency, its posterior fracture resistance has been described in numerous studies¹⁹. This study supports the limited application of lithium disilicate in teeth with lower functional concerns²⁰. Aesthetic cases require a balance between the visual and biomechanical stability when implants are in use. Zirconia also has better wear resistance and shows reduced surface degradation and antagonist tooth wear in comparison to lithium disilicate²¹. The long-term prosthetic reliability of lithium disilicate is better represented by the higher survival rate of zirconia crowns in the posterior implant locations²². Present prosthodontic protocols encourage crown materials that correlate with the biomechanical requirements of the case, facilitating the broader use of zirconia in posterior restorations²³. Fracture resistance information should be considered in prosthetic treatment planning to select materials used in implant-supported crowns²⁴. Posterior zirconia may decrease the risk of mechanical failure and increase the restoration capacity²⁵. It also facilitates prosthetic survivability without impairing biological integration²⁶.

Limitations include in-vitro experimental design, which may not consider intraoral variation in temperature, saliva enzymes, or idiosyncratic occlusal patterns. Confounding factors, including patient age, parafunctional habits, and implant differences, were not measured. Future research should include multicenter clinical trials to provide long-term outcomes and survival rates of both materials under real-life conditions.

CONCLUSION

This study demonstrated that zirconia crowns exhibit higher fracture strength, fatigue resistance, and fit compared to lithium disilicate used in implant-supported restorations. These findings support that zirconia is mechanically superior in simulated posterior occlusal loads.

These findings suggest that zirconia is best applicable in high-stress posterior implant areas, whereas lithium disilicate can be used in selected anterior and esthetic-oriented situations. To maximize the

probability of successful longevity of restorations in implant prosthodontics, clinicians must consider material differences to avoid failure and maximize patient outcomes..

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CONFLICT OF INTEREST

None

ETHICAL APPROVAL

The collaborative study was conducted (January to April 2025) at the Department of Medical Education in and dentistry at QAMC and LUMHS Jamshoro (Ref: 039/DME/QAMC/2025).

AUTHORS' CONTRIBUTION

All authors contributed equally as per ICMJE.

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