International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html

Fracture Resistance of Lithium Disilicate and Advanced Lithium Disilicate Crowns Using Different Luting Cements: An In Vitro Study

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Abstract

This in vitro study aimed to evaluate and compare the fracture resistance of lithium disilicate crowns fabricated from two CAD/CAM ceramic materials—IPS e.max CAD (Ivoclar Vivadent) and CEREC Tessera™ (Dentsply Sirona)—cemented using two different luting agents: glass ionomer cement and dual-cure self-adhesive resin cement. Thirty-two central incisor typodont teeth were prepared with a standardized 1.5 mm finish line and duplicated using cold-cure resin to produce uniform dies. Crowns were designed using Exocad software and milled via the CEREC MC XL system. Each crown was cemented using either Fuji I glass ionomer or Breeze resin cement, followed by thermal aging through 5000 thermocycles to simulate oral conditions. Fracture resistance was measured using a universal testing machine under compressive load. Statistical analysis included two-way ANOVA and independent t-tests, with significance set at $p<0.05$. No statistically significant differences were found between the two ceramic materials ($p=0.441$) or cement types ($p=0.927$). However, a significant interaction effect was observed between material and cement type ($p=0.016$, $\eta^2=0.19$), indicating that the choice of cement significantly influenced fracture resistance depending on the ceramic material used. CEREC Tessera crowns cemented with resin exhibited the highest fracture resistance (1092.6±104.3 N), while IPS e.max CAD crowns cemented with resin showed the lowest (929.3±173.8 N). Within the limitations of this in vitro study, advanced lithium disilicate (Tessera) demonstrated superior performance when bonded with resin cement, while IPS e.max CAD showed consistent results across both cement types.

Keywords: Lithium disilicate, advanced lithium disilicate, fracture resistance, resin cement, glass ionomer cement, CAD/CAM, dental ceramics

Full length article **Corresponding Author*, e-mail: dr khaledahmedhassan@hotmail.com, Doi # https://doi.org/10.62877/34-IJCBS-25-27-21-34

Submitted: 18-08-2025; Accepted: 08-09-2025; Published: 11-09-2025

1. Introduction

The evolution of dental ceramics has been driven by the increasing demand for restorations that combine esthetic excellence with mechanical durability. Among these, lithium disilicate (LDS) ceramics have emerged as a benchmark material in restorative dentistry due to their unique combination of high flexural strength, translucency, and biocompatibility. Introduced in the 1990s, LDS ceramics such as IPS e.max CAD (Ivoclar Vivadent) have demonstrated outstanding clinical performance in both anterior and posterior restorations, owing to their ability to mimic natural tooth structure and withstand occlusal forces. Their elastic modulus of approximately 100 GPa slightly exceeds that of enamel, making them particularly suitable for indirect restorations subjected to functional stress [1-6]. The development of advanced lithium disilicate (ALDS) ceramics, such as CEREC Tessera™ (Dentsply Sirona), represents a significant advancement in CAD/CAM restorative materials. These ceramics incorporate virgilite crystals ($Li_{0.5}Al_{0.5}Si_{2.5}O_6$) within a zirconia-enriched glass matrix, forming a dual-phase microstructure that enhances both mechanical and optical properties. Tessera exhibits flexural strengths up to 700 MPa and benefits from a rapid glaze firing cycle, making it highly efficient for chairside workflows [7-9].

Fracture resistance is a critical parameter in evaluating the clinical longevity of ceramic restorations. It is influenced by multiple factors, including the ceramic microstructure, the type of luting cement used, and the bonding protocol. Resin cements are widely preferred for lithium disilicate restorations due to their superior adhesive properties, which combine micromechanical interlocking and chemical bonding. These cements enhance retention and reduce the risk of debonding, particularly in minimally invasive preparations [10-11]. However, conventional cements such as glass ionomer remain relevant in clinical practice due to their ease of use, fluoride release, and chemical bonding to tooth structure. Despite the proven success of LDS ceramics, there is limited comparative data on the performance of ALDS materials under different cementation protocols. Understanding how material-cement interactions affect fracture resistance is essential for optimizing clinical outcomes. This study was designed to evaluate and compare the fracture resistance of IPS e.max CAD and CEREC Tessera™ crowns luted with glass ionomer and resin cements. By simulating intraoral conditions through

thermal aging and standardized testing, the study aims to provide evidence-based insights into the mechanical reliability of these materials and inform clinical decision-making in restorative dentistry.

2. Materials and Methods

2.1. Study Design

This in vitro study evaluated the fracture resistance of two types of lithium disilicate ceramic crowns—IPS e.max CAD and CEREC Tessera—each with a standardized thickness of 1.5 mm. Crowns were cemented using either glass ionomer or dual-cure self-adhesive resin cement. A total of 32 samples were divided into four subgroups (n=8 each): EG (e.max + glass ionomer), ER (e.max + resin), TG (Tessera + glass ionomer), and TR (Tessera + resin).

2.2. Materials

The materials used included:

- Lithium disilicate blocks: IPS e.max CAD (Ivoclar Vivadent, USA), shade A2 HT.
- Advanced lithium disilicate blocks: CEREC Tessera (Dentsply Sirona, Germany), shade A2 HT.
- Glass ionomer cement: Fuji I capsule (GC Corporation, Japan).
- Resin cement: Breeze self-adhesive dual-cure resin cement (Pentron Clinical).
- Auxiliary materials: Porcelain primer, hydrofluoric acid etchant (9.5%), cold-cure acrylic (Acrostone), and condensation silicone (Zetaplus).

2.3. Sample Preparation

Typodont central incisors were prepared with a 1.5 mm shoulder finish line using sequential diamond burs. Impressions were taken using a two-step putty and light-body addition silicone technique. Acrylic dies were fabricated using cold-cure resin and standardized curing protocols.

2.4. Digital Workflow

All dies were scanned using the MEDIT T310 scanner. Crown designs were created using Exocad DentalCAD 3.0 and milled using the CEREC inLab MC XL system. IPS e.max CAD crowns underwent crystallization and glazing, while Tessera crowns were glazed and fired per manufacturer instructions.

2.5. Cementation Protocol

Glass ionomer cementation was performed using Fuji I capsules under a 1 kg axial load. Resin cementation involved HF etching (20s for e.max, 30s for Tessera), silane application, and bonding with Breeze cement. All restorations were light-cured for 40 seconds per surface.

2.6. Aging and Testing

Specimens were stored in distilled water at 37°C for 24 hours, followed by 5000 thermocycles between 5°C and 55°C. Fracture resistance was tested using a universal testing machine (Instron Model 3345) with a 5.6 mm metallic sphere applying compressive load at 1 mm/min until failure. The fracture load was recorded in Newtons.

3. Results and discussion

3.1. Results

3.1.1. Descriptive Statistics

Fracture resistance values were analyzed across four experimental groups: IPS e.max CAD and CEREC Tessera crowns, each cemented with either glass ionomer or resin cement. The highest mean fracture resistance was observed in the Tessera–Resin group (1092.6 N), while the lowest was in the Emax–Resin group (929.3 N). This 163 N difference is clinically relevant, as it exceeds the typical range of posterior occlusal forces (500–900 N).

As illustrated in Figure 1 (box plot with individual data points), the distribution of fracture resistance values highlights the variability within each group. Notably, the Emax groups exhibited higher standard deviations (SD = 168.2 N and 173.8 N), indicating less predictable mechanical performance. In contrast, the Tessera–Glass Ionomer group demonstrated the lowest variability (SD = 80.9 N), suggesting more consistent behavior.

Figure 2 (bar plot with confidence intervals) further emphasizes the comparative performance across groups, reinforcing the superior and more reliable fracture resistance of Tessera crowns when bonded with resin cement.

3.1.2. ANOVA Analysis

Two-way factorial ANOVA was conducted to evaluate the effects of material type, cement type, and their interaction on fracture resistance. Assumption testing confirmed normality and homogeneity of variance across all groups. As shown in Table 1 – ANOVA Results, the analysis revealed:

- No significant main effect for material ($p = 0.441$) or cement ($p = 0.927$).

A statistically significant interaction between material and cement type ($F(1,28) = 6.608$, $p = 0.016$, $\eta^2 = 0.19$), indicating that the effect of cement type depends on the ceramic material used.

3.1.3. Post Hoc and Pairwise Analysis

LSD post hoc tests identified two significant pairwise differences (see Table 2 – t-test Results):

- Tessera–Resin vs. Emax–Resin ($p = 0.039$)
- Tessera–Resin vs. Tessera–Glass Ionomer ($p = 0.015$)

These results suggest that CEREC Tessera crowns perform significantly better with resin cement, while IPS e.max CAD shows consistent performance across both cement types.
Independent t-tests further confirmed:

- Tessera's fracture resistance is significantly higher with resin cement ($d = –1.39$).
- Resin-cemented Tessera crowns outperform resin-cemented Emax crowns ($d = –1.14$).

3.2. Discussion

Lithium disilicate ceramics have become a cornerstone in restorative dentistry due to their excellent mechanical properties, biocompatibility, and esthetic performance. IPS e.max CAD, in particular, has demonstrated superior ability to replicate natural tooth structure through its light diffusion, color fidelity, and translucency.

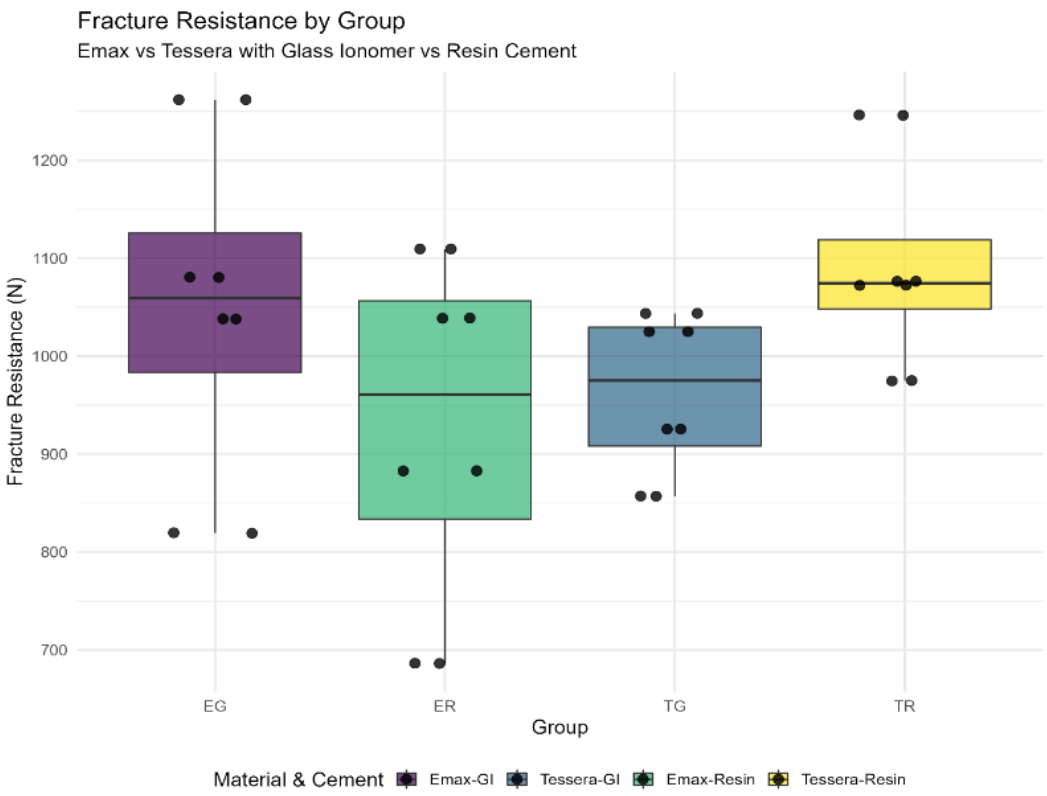

Figure 1. Box plot with individual points

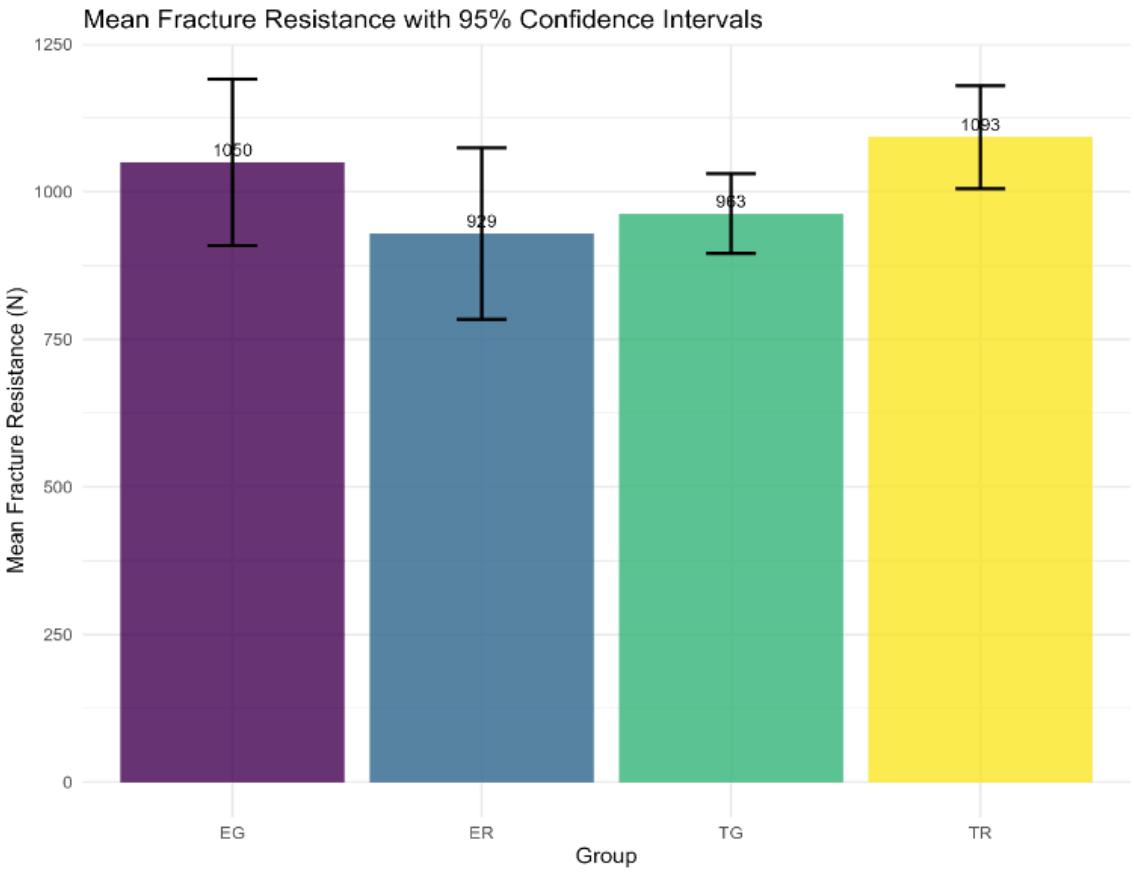

Figure 2. Bar plot with confidence intervals.

Table 1. ANOVA Results

Source	DF	Sum_Sq	Mean Sq	F Value	P-Value	Eta2 (partial)	95% CI for Effect Size
material	1	11581.084	11581.1	0.610	0.441	0.02	[0.00, 1.00]
cement	1	163.926	163.926	0.009	0.927	0	[0.00, 1.00]
material: cement	1	125470.807	125470.8	6.608	0.016	0.19	[0.02, 1.00]
Residuals	28	531624.754	18986.6				

Table 2. t-test Results

Comparison	Mean Difference	T Statistic	DF	P-Value	CI Lower	CI Upper	Cohens D	Effect Size
Emax: GI vs Resin	120.709	1.412	14	0.180	-62.707	304.124	0.706	Medium
Tessera: GI vs Resin	-129.762	-2.779	14	0.015	-229.906	-29.618	-1.390	Large
GI: Emax vs Tessera	87.187	1.321	14	0.208	-54.392	228.766	0.660	Medium
Resin: Emax vs Tessera	-163.283	-2.278	14	0.039	-316.989	-9.577	-1.139	Large

Monolithic LS2 blocks are widely used in chairside workflows for their high strength and esthetics, making them ideal for minimally invasive restorations [9]. In this study, both IPS e.max CAD and newer advanced lithium disilicate (ALDS) material, CEREC Tessera, were evaluated. Tessera incorporates virgilite crystals within a zirconia-enriched glass matrix, contributing to its enhanced flexural strength and reduced firing time [7]. According to Hölken et al. [9], ALDS materials can be both adhesively bonded and conventionally cemented due to their superior mechanical properties, offering clinical flexibility. Resin cementation remains preferred method for lithium disilicate restorations due to its dual bonding mechanism—micromechanical interlocking & chemical adhesion—which enhances retention and reduces the risk of debonding [10-11]. Mobilio et al. [12] found that lithium disilicate crowns cemented with resin exhibited higher failure loads than those cemented with glass ionomer, supporting use of adhesive protocols for improved performance. To ensure standardization, typodont teeth were used in this study, allowing consistent preparation and minimizing anatomical variability [13]. Each tooth was scanned and replicated using 3D-printed resin dies made from Rigid 10K resin, which closely mimics dentin in terms of tensile strength and elastic modulus [14]. Resin-based dies were selected over metal or natural teeth to avoid misleading results due to differences in stiffness and bonding behavior [15-16]. Standardized preparations followed clinical guidelines for occlusal veneers. Both materials were tested under simulated oral conditions using thermal cycling, which mimics the temperature fluctuations encountered in vivo and contributes to stress corrosion in silicate ceramics [17-18]. Fracture resistance testing using occlusal loading with a metallic sphere provided clinically relevant insights into material performance. The results showed that both materials exceeded typical masticatory forces (600–800 N), confirming their suitability for high-stress applications. Although ALDS group exhibited slightly higher mean fracture resistance (3280.46 ± 328.12 N) compared to the LDS group (3252.47 ± 388.46 N), difference was not statistically significant. This may be attributed to optimized crystal growth in e.max CAD and the zirconia reinforcement in Tessera, which enhance fracture toughness and reduce crack propagation [4].

These findings align with previous studies. [19] reported no significant difference in fracture resistance between crystallized CEREC Tessera and IPS e.max CAD crowns. Fayed et al. [19] found slightly higher values for Tessera, while [20] reported significantly higher fracture resistance for ALDS materials. However, Jurado et al. [21] also observed higher performance in traditional lithium disilicate under certain conditions, highlighting the influence of preparation design and die material. Mohammed et al. [22] confirmed the superior performance of Tessera in endocrown applications. While some studies suggest minimal impact of cement type on fracture resistance [23-24], others emphasize role of resin cement's elastic properties in enhancing durability under stress. Failure mode analysis revealed a predominance of catastrophic fractures in both groups, consistent with the high modulus of elasticity of ceramic materials [25-26]. This observation is supported by [25] and [2], who noted similar failure patterns in silicate-based ceramics. Understanding fracture modes provides valuable clinical insight into restorability of failed restorations. Despite controlled in vitro conditions, limitations remain. The use of resin dies may affect bonding behavior, and static loading does not fully replicate fatigue-related failures. Future research should explore long-term performance under cyclic loading and compare ALDS with emerging materials such as high-translucency zirconia and hybrid ceramics.

4. Conclusions

Considering the limitations of this in vitro study, the subsequent conclusions can be inferred:

1. Material-Cement Interaction Is Clinically Significant: A strong interaction effect ($p = 0.016$, $\eta^2 = 0.19$) was observed, indicating that the choice of cement significantly influences fracture resistance depending on the ceramic material used.
2. Tessera Shows Cement Sensitivity: Tessera crowns demonstrated significantly higher fracture resistance with resin cement compared to glass ionomer ($p = 0.015$,

d = -1.39), highlighting the importance of selecting resin cement for optimal performance.

3. Emax Demonstrates Consistent Performance: IPS e.max CAD showed stable fracture resistance across both cement types, suggesting it is less sensitive to cement choice & offers greater flexibility in clinical applications.
4. Tessera Outperforms Emax with Resin Cement: When resin cement is used, Tessera significantly outperforms Emax ($p = 0.039$, $d = 1.14$), indicating that material selection becomes critical when using adhesive cementation protocols.
5. Effect Sizes Highlight Clinical Relevance: Large effect sizes in key comparisons reinforce the practical importance of matching the right ceramic material with the appropriate cement to enhance mechanical outcomes and treatment longevity.
6. All evaluated parameters for both materials fell within clinically acceptable ranges, supporting their reliability and suitability for clinical applications in restorative dentistry.

5. Acknowledgments

The authors would like to thank the Faculty of Dentistry, Ain Shams University, for providing the facilities and support for this study.

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