EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 71, 3321:3328, October, 2025

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 22-07-2025 • Accept Date : 07-08-2025 • Available online: 01-10-2025 • DOI : 10.21608/edj.2025.406071.3561

THE IMPACT OF VARIOUS CORONAL RESTORATION CONSTRUCTION TECHNIQUES ON THE FRACTURE RESISTANCE OF POSTERIOR TEETH: AN IN VITRO STUDY

Shaimaa Rohym* *and* Hanaa Nassar**

ABSTRACT

Objective: To determine the impact of different onlay construction methods (direct-indirect versus indirect CAD/CAM method) on the resistance to fracture of posterior teeth.

Materials and Methods: 30 intact maxillary permanent molars were randomly allocated into two groups, each including 15 specimens. All the teeth were prepared into Class II onlay restorations. Group C was restored with direct/indirect Ecosite bulk fill composite, while Group O was restored with Shofu CAD/CAM composite blocks. All samples were prepared and preserved in distilled water for one day. A fracture test was done by applying occlusal compressive load after completion of thermomechanical aging. Data were collected and statistically analysed.

Results: The Indirect Shofu group exhibited greater mean fracture load values compared to the Direct-Indirect group. This was statistically significant, as indicated by ANOVA and Tukey's post-hoc testing ($p = <0.0001 < 0.05$).

Conclusion: Shofu composite blocks exhibited statistically significant superior fracture resistance compared to direct-indirect Ecosite Bulk Fill Composite.

Clinical significance: Indirect CAD/CAM onlay restorations for permanent molars outperformed direct-indirect resin composite onlays.

KEYWORDS: CAD/CAM onlays, direct-indirect resin composite restoration, fracture resistance.

* Lecturer, Department of Conservative Dentistry, Faculty of Oral and Dental Medicine, Ahram Canadian University
** Associate Professor, Department of Fixed Prosthodontics, Faculty of Oral and Dental Medicine, Ahram Canadian University

INTRODUCTION

Loss of tooth structure due to cavity preparation or caries excision compromises tooth integrity and increases the susceptibility to fractures.[1] Numerous studies focused on the impact of different cavity preparations on weakening teeth and how restorations affect the reinforcement of the remaining tissue. [2]

Even in the absence of a fracture, disruption of tooth-restoration interface may occur due to cusp deflection, leading to micro-leakage followed by recurrent caries. [3] Cavity preparation can induce significant stress concentration; however, appropriate restoration techniques can mitigate internal stresses. [4] Stress concentration is known to arise along the prepared cavity's internal line angles specifically, when restorations lack proper adhesion to the tooth and at the dentin-enamel junction. Thus, when stress levels in these areas are sufficient to initiate fractures, fatigue failure may occur during the mastication. [5]

Resin-based materials are increasingly the predominant restorative option for replacing lost tooth structure that was resulted from caries or trauma. While direct composites offer numerous advantages, such as cost-effectiveness, simplicity, superior adhesion to hard tissues, adequate abrasion resistance, and flexural strength, they also present several challenges. These include technique sensitivity, the risk of microleakage and secondary caries, and issues related to polymerization shrinkage. [6]

Recently, the rising popularity of CAD/CAM products has paved the path to more frequent use of indirectly placed composite materials for various clinical applications in replacing missing tooth structures in both anterior and posterior teeth. [7] CAD/CAM resin composite was originally developed as an alternative to ceramics and indirect restorative materials. They are manufactured under standardized conditions of temperature and high pressure, resulting in reduced polymerization shrinkage. [8]

CAD/CAM resin composite blocks provide the advantages of combining the flexibility and simplicity of use characteristic of resin composites with the durability and surface finishing capabilities akin to ceramics. They exhibit superior stain resistance from beverages and food compared to direct composite materials, attributable to the pre-polymerization of the CAD/CAM composite block. [9] In contrast to conventional laboratory techniques, CAD/CAM systems obviate the mechanical processes of sintering, embedding, and casting, which can compromise structural integrity during manufacturing. These techniques inhibit the development of minor fatigue cracks, guaranteeing that the manufactured prosthesis possesses a more uniform phase and enhanced fracture resistance. While CAD/CAM resin composite blocks offer numerous advantages, they also present certain drawbacks, such as high cost. [10,11] Therefore, the purpose of this study was to determine the impact of different onlay construction techniques (direct-indirect technique versus indirect CAD/CAM technique) on the resistance to fracture of posterior teeth. The null hypothesis was that there will be no difference in fracture resistance between the two construction techniques.

MATERIALS AND METHODS

The protocol of this study was approved by Institutional Review Board Organization IORG0010866, Faculty of Oral & Dental Medicine, Ahram Canadian University.

Based on previous study [12], 22 sample size of 11 in each group yields a power of 80% required to identify a mean difference of 267.68 with an alpha significance level = 0.05 at 95% confidence intervals. The P value is set at less than 0.05 (two-tailed). Sample size was raised to 15 samples per group with a total of 30 samples. [13] The materials used for restorations in this study are shown in **Table (1):**

TABLE (1) The materials used in this study

Materials	Composition	Lot number	Manufactures
Glassbite clear VPS matrix & bite registration	Thixotropic silicone with medium fluid	070301	DETAX GMBH company,Germany
Ecosite Composite	Bis-GMA, bis-EMA, UDMA, zirconia, Filler load:76.5 wt%, 58.4 v01%.	276416	DMG; Fabrik GmbH, Germany
Etchant	37%phosphoricacid	MG0004	DENTALPLUS, Egypt
Bisco All-Bond Universal	Bisphenol A diglycidylmethacrylate, ethanol, MDP. 2 hydroxyethyl methacrylate	230011082	Bischo Dent, USA
Bisco bond porcelain	Hema free unfilled resin	LABA-223FR7	Bisco,USA, USA

Preparation of dental samples

A total of thirty sound maxillary molars from extracted teeth of diabetic or periodontal patients were selected, with all plaque, calculus, and soft tissue removed using scalers. The teeth were sterilized in 10% thymol for 24 hours and preserved in distilled water at 4°C until processing. [13]

Preparation of the Mold

Mortar was utilized and filled with a Glassbite clear VPS matrix and bite registration (DETAX GMBH Company, Germany) to create a mold and inject the resin composite restoration. A separating media was applied to the occlusal surface of each tooth. Subsequently, the insertion was included into the mortar mix until it set, and the excess was eliminated. A mark was inscribed on the block and the mold to aid in the accurate reinsertion of the block into the mold.

Cavity preparation

The cavity preparation involved reducing the palatal cusp by 1.5 mm and the buccal cusp by 1 mm. A conical diamond trunk conic bur (KG Sorensen, Barueri SP, Brazil) with a flat end was utilized to create the internal axial wall with a divergence angle of 6-10 degrees and to establish a foundation for the internal line angles. The interproximal box was crafted with a thickness of 1 mm and positioned 2 mm above the cemento-enamel junction using a flat-end diamond bur. Subsequently, a cylindrical chamfer bur was employed to create an adhesive onlay margin featuring a hollow chamfer finish line at the intersection of the occlusal inclined plane and the outer axial wall. Finishing was accomplished using fine-grit diamond burs. [14]

Following cavity preparation, all prepared samples were examined using a digital caliper and subsequently assessed with a periodontal probe. Teeth were optically scanned with an intraoral scanner (OmniCam, Dentsply Sirona GmbH, Germany), and image was superimposed with the preoperative scan for reduction verification utilizing the PrepCheck tool on CEREC 4.5 software (Dentsply Sirona GmbH, Germany); samples with discrepancies exceeding 0.2 mm were eliminated.

Preparation of the restorations

After digital scanning of the prepared teeth with OmniCam intraoral scanner, 15 composite onlays were created utilizing CEREC 4.5 software. The original restoration plan generated by the CEREC software was not altered to preserve the initial morphology prior to preparation for accurate standards. The cement spacing was established at 50μ. [5] According to the manufacturer’s guidelines,

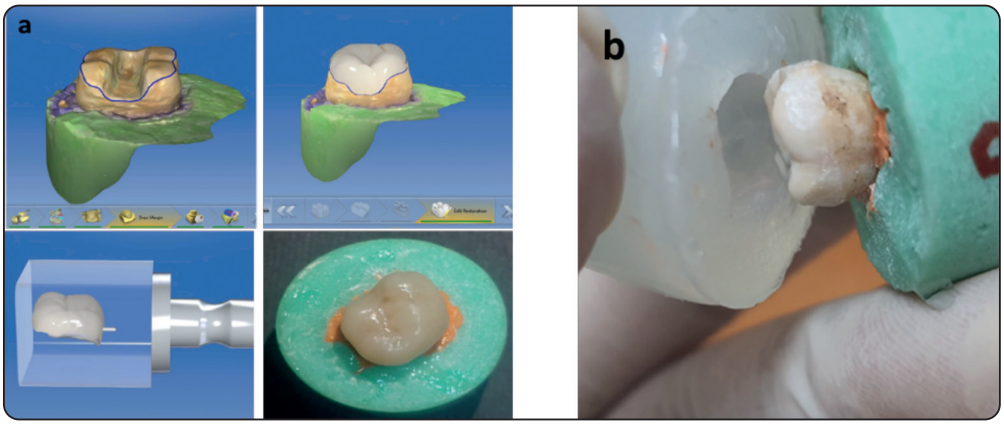

Fig. (1) Finished onlay restorations: a. Indirect CAD/CAM group, b. direct-indirect group.

onlay restoration milling was performed using the 4-axis wet grinding machine MCXL (Dentsply Sirona GmbH, Germany) using Hybrid Shofu HC Blocks (Shofu, Japan). **Figure (1-a)**

In the direct/indirect restoration group, a 37% phosphoric acid etch (Dentalplus; Egypt) was applied to the enamel surface for thirty seconds, followed by rinsing and drying. Then, Bisco All-Bond Universal light-cured adhesive bond was applied to all tooth surfaces and light-cured for twenty seconds using an LED polymerization device (Elipar™ , 3M ESPE, USA) at an intensity of 1,200 mW/cm². Injectable resin composite (Ecosite bulk fill, DMG, Germany) was introduced into the mold, followed by the insertion of the tooth with constant pressure. Light curing was applied, and excess composite was eliminated. **Figure (1-b)**

Cementation of the CAD/CAM onlay restorations

Etching of CAD/CAM resin composite blocks was performed with 9.5% hydrofluoric acid gel (Bisco porcelain, USA) for 30 seconds, followed by rinsing and drying. A pre-hydrolyzed silane coupling agent (Bisco porcelain primer, USA) was applied to the restoration intaglio surface and left for 60 seconds. Same procedures for tooth bonding protocol were performed for direct/indirect group. Luting cement (Duo-Link Universal, Bisco, USA) was applied to the restoration surface, followed by gentle pushing of the composite restoration into position, then; excess cement was eliminated using a bond brush.

Thermomechanical aging:

To replicate 6 months in an oral environment, samples received a 5000 thermal cycles between 5°C and 55°C, with a 25 seconds dwell duration and 10 seconds lag time, utilizing ROBOTA automated thermal cycle (BILGE, Turkey). The chewing simulator (ROBOTA, Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY) subjected the samples to 75,000 cycles of 50 N occlusal stresses at a frequency of 1.6 Hz. [14]

Fracture resistance assessment

Each sample was mounted on universal testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a load-cell of 5 kN, and secured to the lower fixed compartment by tightening screws. Data were recorded using computer software (Bluehill Lite Software, Instron®). The fracture test was conducted with a compressive loading applied occlusally. A metal rod with a spherical tip (8.6 mm in diameter) was attached to the testing machine's upper movable compartment and the cross-head speed was set to 1 mm/min. A tin foil sheet was interposed to ensure uniform stress distribution and to mitigate the transmission of localized force peaks. The failure load was indicated by an audible crack and corroborated by a significant decline in the load-deflection curve recorded with Bluehill Lite Software from Instron® Instruments. The force necessary to induce fracture was measured in Newtons.

RESULTS

Descriptive statistics representing mean values and standard deviation of fracture resistance load (N) test results measured after thermo-mechanical aging for all groups are summarized in **table (2)** and graphically drawn in **figure (2).** It was found that *Indirect Shofu group* recorded higher fracture load values than the *Direct-indirect group*. This was statistically significant as demonstrated by ANOVA followed by Tukey's post-hoc tests (p=<0.0001<0.05).

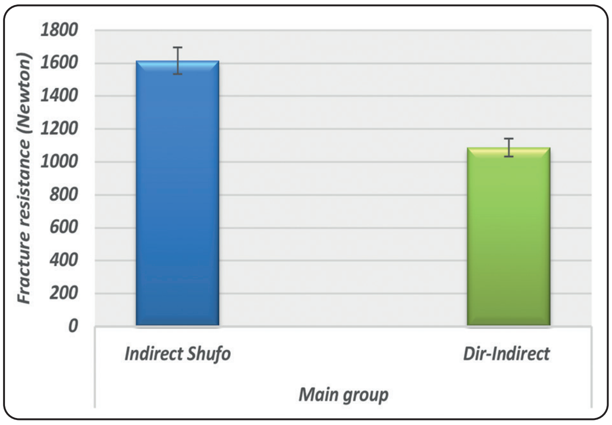

Fig. (2) Column chart comparing between fracture resistance load mean values for both groups after thermo-mechanical aging

TABLE (2) Comparison of fracture resistance results (Mean values± SDs) between all groups after thermo-mechanical aging:

Variables		*Mean ± SDs*	*95% CI* Low - High	*Statistics*
Main group	***Indirect Shofu***	1615.09^{A}±170.03	1529.04-1701.14	***P value***
	Dir-Indirect	1087.42^{C}±225.18	973.46-1201.37	<0.0001*

*; significant ($p < 0.05$); ns; non-significant (p>0.05); least significant difference (LSD) = 175.3

DISCUSSION

A fracture was defined as whole or partial rupture in a restoration caused by the exertion of excessive force. Fracture resistance is a critical attribute directly associated with cracking. Both experimental and theoretical endeavors have been undertaken to correlate a material's strength with its fracture resistance, alongside structural characteristics. [15]

As minimally invasive treatment methods were primarily developed to provide a reliable restoration for large cavities, this study aimed to assess and compare the fracture resistance of onlay restorations produced via the direct-indirect approach and computer-aided design and manufacturing (CAD/CAM) technologies to determine the appropriate restorative material for posterior onlays.

The intraoral posterior zone endures substantial stresses during mastication of average 300 to 600 Newtons. Consequently, providing a restoration with optimum fracture resistance is essential for success and maximum tooth structure conservation in this zone. [16] A static loading test was conducted to evaluate the performance of the restorations until failure. The restorations underwent artificial thermo-mechanical aging prior to the loading test. This aging process was employed to assess the durability and stability of the restorations in conditions simulated to resemble the oral cavity. [17] In this study, to replicate six months in an oral environment, samples underwent heat cycling of 5,000 cycles and cyclic loading of 75,000 cycles. [18]

The null hypothesis for this study was rejected, fracture resistance test findings indicated that hybrid composite (CAD/CAM) blocks exhibited superior performance compared to direct-indirect composite resin. The variation in fracture resistance values among the tested materials may be attributed to their various compositions and microstructures [19]. The chemical composition varies between the composite resin Ecosite bulk fill, which consists of a Bis-GMA matrix and 82% weight and 65% volume barium glass, [12] and the hybrid composite SHOFU Blocks HC, a nanoceramic resin composite (NCRC) comprising Bis-GMA, UDMA, Bis-EMA, and TEGDMA monomers that form its polymer network, along with 61% weight and 71% volume zirconium silicate. [19,20] This distinction elucidates the majority of their in vitro behavior. It was found that increasing filler content while decreasing particle size and inter-particle spacing will enhance the fatigue limit due to the augmented barriers to crack propagation. Furthermore, it was determined that nanocluster particles exhibit distinct mechanical properties in contrast to filler particles having spheroidal or irregular morphologies. The integration of nanocluster particles into a traditional resin matrix may alter the ensuing failure mechanisms and offer improved damage tolerance specific to nanocluster-reinforced resin-based composites. [21]

The primary factors contributing to the exceptional fatigue behavior of the CAD/CAM nano-hybrid resin blocks in this study are as follows: Firstly, the elevated filler content enabled by a hybrid structure comprising minuscule discrete nanoscale particles and nanoparticle clusters; Secondly, the digital CAM process utilizes blocks manufactured under standardized parameters, resulting in an extra-homogeneous, dense, and dependable material. Lastly, the similarities in restorative material elastic modulus and the abutment's effective modulus with resin cement require notably high indentation stress to start flexural-induced radial cracks at the cementation interface. [22]

The diminished fracture resistance of direct resin composite materials can be attributed to the polymerization shrinkage that happens inherently during the curing process. This contraction may result in the formation of gaps between the composite and the dental structure, compromising the material's initial fracture resistance. [16] A study by Silva et al. revealed that extensive direct conventional composite restorations had a markedly higher susceptibility to fracture from polymerization shrinkage pressures than CAD/CAM composite restorations. [23]

The findings align with prior research comparing direct bulk-fill composite restorations to indirect CAD/CAM composite restorations. Papadopoulos et al, correspondingly emphasized that CAD/CAM inlays represent a viable restorative option, demonstrating satisfactory outcomes in enhancing the survival of large MOD restorations, specifically regarding fracture resistance. It was noted that, though the bulk-fill resin restorations showed lower fracture resistance compared to CAD/CAM resin blocks, they remain suitable for large posterior restorations, as these restorations suffered from failure at significantly higher stresses than those encountered in the oral cavity. The fracture mode indicated that most failures documented for both direct and indirect restorations were amenable to intraoral repair. [24]

Furthermore, the findings of our research were aligning with another previously published study, indicating that the groups receiving milled onlays exhibited enhanced fracture resistance than the direct application of resin composite restorations. [16] It can be stated that indirect onlay restorations for permanent molars demonstrates superior performance compared to direct-indirect resin composite materials.

Among the limitations of this research is the in-vitro design, which doesn't completely simulate the complex oral environment. Moreover, only two composite materials (direct and indirect CAD/CAM blocks) were investigated in this study, which may reduce the generalizability of findings since other CAD/CAM materials are available to be used for the same restoration design.

CONCLUSIONS

Within the limitations of this study, the following can be concluded:

1. Onlay fabrication technique significantly influences the fracture resistance of posterior onlay-tooth complex.
2. Indirect CAD/CAM resin onlays exhibited significantly higher fracture resistance than direct-indirect composite resin onlays after thermomechanical aging.
3. Both tested groups demonstrated fracture resistance mean values that exceeded the normal masticatory limits for maxillary molars.

REFERENCES

1. Saleem N, Elkaffas A, Ali A, Mahmoud S. Do different Cavity Preparation Designs Influence Fracture Resistance of CAD/CAM Fabricated Ceramic Inlay and Onlay?. Mans J Dent. 2023; 11(2): 107-114.
2. Salama RM, Hamama HH, Mahmoud SH. Fracture Resistance of Maxillary Premolars With Class II MOD Cavities Restored With Direct and Indirect Resin Composite Restorative Systems. Journal of Esthetic and Restorative Dentistry. 2025 Jul;37(7):1791-801.
3. Vieira S, Marto CM, Coelho A, Amaro I, Francisco I, Vale F, Paulo S, Ferreira MM, Carrilho E, Paula A. In Vitro Techniques for Microleakage Evaluation of Coronary Restorative Materials: A Scoping and Mapping Review. Journal of Functional Biomaterials. 2025 Jun 4;16(6):210.
4. Liu T, Huang Y, Li Y, Meng J, Liu Y, Wei Y, Huang Y, Zhou Q, Yang W, Yan F, Wang X. Effect of different restorative design and materials on stress distribution in cracked teeth: a finite element analysis study. BMC Oral Health. 2025 Jan 7;25(1):31.
5. Hanaa Nassar. "Internal fit and marginal adaptationof CAD/CAM lithium disilicate endocrowns fabricatedwith conventional impression and digital scanning protocols. An in-vitro study", Egyptian Dental Journal, 2022
6. Bingül A, Nezir M, Atilla AO, Özcan S, Evis Z. A Review: Resin–Based Dental Materials and Their Characterization. Polymers for Advanced Technologies. 2025 Jun;36(6):e70239.
7. Ille CE, Jivănescu A, Pop D, Stoica ET, Flueras R, Talpoş-Niculescu IC, Cosoroabă RM, Popovici RA, Olariu I. Exploring the properties and indications of chairside CAD/CAM materials in restorative dentistry. Journal of functional biomaterials. 2025 Feb 1;16(2):46.
8. Haridy MF, Ahmed HS, Ahmed RN, Elhusseiny SE. Effect of different cavity designs and CAD/CAM blocks on fracture resistance of maxillary premolars with MOD cavities. Odontology. 2025 Mar 18:1-3.
9. Alharbi A, Ardu S, Bortolotto T, Krejci I. Stain susceptibility of composite and ceramic CAD/CAM blocks compared to direct resin composites with varying resin matrices. Odontology. 2017; 105(2): 162-169. doi:10.1007/s10266-016-0258-1
10. Hickel R, Manhart J. Durability of restorations in posterior teeth and causes of failure. J AdheDent. 2001; 3: 45–64. https://doi.org/10.1038/sj.bdj.2012.137.
11. Manhart J, Chen H, Hamm G, Hickel R. Buonocore Memorial Lecture. Evaluation of the clinical longevity of direct and indirect restorations in the posterior teeth of the permanent dentition. Operative Dentistry. 2004; 29: 481–508.
12. Gaviria-Martinez, Andrea, et al. "Control of Surface Roughness and Oxygen-Inhibited Layer in Bulk-Fill and Conventional Nanohybrid Resin Composites With and Without Polishing: An In Vitro Study." BMC Oral Health 22.1 (2022): 258
13. Simsek H, Derelioglu S. In Vitro Comparative Analysis of Fracture Resistance in Inlay Restorations Fabricated using CAD-CAM and Various Systems in Primary Teeth. Biomedical Research International. 2016; 2016(1): 4292761.
14. Nassar HS, Eliwa ME. Impact of Proximal Box Elevation utilizing two distinct Resin Composite viscosities on

the marginal adaption of CAD/CAM ceramic overlays exposed to Thermomechanical Aging. A study conducted in vitro. Journal of Egyptian Dentistry. January 1, 2024; 70(1): 599-609.

15. Hamouda, Ibrahim M., and Salah H. Shehata. "Fracture resistance of posterior teeth restored with contemporary restorative materials." Journal of Biomedical Research 25.6 (2011): 418-424.
16. Tsertsidou V, Mourouzis P, Dionysopoulos D, Pandoleon P, Tolidis K. "Fracture Resistance of Class II MOD Cavities Restored Using Direct and Indirect Techniques with Various Material Combinations." Polymers 15.16 (2023): 3413.
17. Gale, M.; Darvell, B. Thermal cycling protocols for laboratory evaluation of dental restorations. J. Dent. 1999, 27, 89–99
18. Theisen, Catherine ER, et al. "Quality of CAD-CAM Inlays Placed on Aged Resin-Based Composite Restorations Utilized as Deep Margin Elevation: A Laboratory Study." Clinical Oral Investigations 27.6 (2023): 2691-2703.
19. Saad, Maram Hassan, E. L. Mahmoud, and Rania Reda Afifi. "Fracture Resistance of Various CAD/CAM Ceramic Inlays (In Vitro Study)." Alexandria Dental Journal 47.1 (2022): 122-126.
20. Koenig, Andreas, et al. "Characterization of the filler fraction in CAD/CAM resin-based composites." Materials 14.8 (2021): 1986.
21. Atiyah, Aws H., and Luma M. Baban. "Fracture resistance of endodontically treated premolars with extensive MOD cavities restored using various composite materials: an in vitro study." Journal of Baghdad College of Dentistry 325.2212 (2014): 1-9.
22. Shembish, Fatma A., et al. "Fatigue Resistance of CAD/CAM Resin Composite Molar Crowns." Dental Materials 32.4 (2016): 499-509.
23. Batalha-Silva, Silvana, et al. "Fatigue Resistance and Crack Propensity of Large MOD Composite Resin Restorations: Direct Versus CAD/CAM Inlays." Dental Materials 29.3 (2013): 324-331.
24. Papadopoulos, C.; Dionysopoulos, D.; Tolidis, K.; Kouros, P.; Koliniotou-Koumpia, E.A.; Tsitrou, E. Assessment of Structural Integrity in Extensive MOD Restorations Constructed with Bulk-Fill and CAD/CAM Resin Composite Materials. Operation. Dent. 2019, 44, 312–321