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RESEARCH ARTICLE

Fracture resistance of chairside cad/cam advanced lithium disilicate maxillary canine veneers with different incisal edge designs

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Abstract

This study aimed to evaluate the fracture resistance of maxillary veneers with feather edge, butt-joint and palatal chamfer and traditional full coverage crowns fabricated out of chairside CAD/CAM advanced lithium disilicate and virgilite. Fifty-two restorations for maxillary right canine were fabricated (n = 13 per group) as follows: veneers with feather edge, veneers with butt-joint, veneers with palatal chamfer and full coverage crowns out of chairside CAD/CAM lithium disilicate and virgilite (Cerec Tessera). The restorations were bonded to 3D printed resin dies with resin cement (Variolink Esthetic LC). The cemented restorations were subjected to 10,000 thermocycles at 5 to 55 °C with a dwell time of 30 s. The specimens were loaded until fracture using a universal testing machine and the resistance was recorded in Newtons. Two-way ANOVA was used to assess the fracture resistance among veneers with different incisal edge designs and between veneers and crowns. Scanning electron microscope (SEM) images of the fractured specimens were taken and descriptive analysis was carried out. Full coverage crowns displayed higher fracture resistance (1496 ± 41 N) than any type of veneers. Veneers with palatal chamfer showed the highest value (842 ± 28 N) among veneers followed by butt joint veneers (661 ± 22 N). Feather edge veneers provided the lowest fracture resistance values (464 ± 23 N). The fracture resistance of CAD/CAM advanced lithium disilicate maxillary veneers are significantly influenced by the incisal edge design. Palatal chamfer veneers displayed higher fracture resistance than feather edge and butt joint veneers. Full coverage crowns offered higher fracture resistance than any type of veneer.

Keywords Chairside CAD/CAM · Veneers · Crowns · Lithium disilicate · Flexural strength

1 Introduction

In the past years, the use of computer-aided design and computer-aided manufacturing (CAD/CAM) has become increasingly prevalent in everyday clinical practice (Suganna et al. 2022). Although initially limited to producing small, single restorations like inlays and onlays, (Mörmann 2006) this technology now enables dentists to create more complex and multiple restorations in a faster and more reliable way compared to traditional techniques (Papaspyridakos et al. 2021; Robles et al. 2023) CAD/CAM systems provide clinicians with the ability to design and fabricate restorations digitally, using either chairside (Blatz and Conejo 2019) or laboratory (Edelhoff et al. 2024) setups based on their preferences and available equipment. Several studies in the literature outline detailed clinical protocols for using CAD/CAM technology to create restorations that meet the functional and aesthetic needs of patients (Durán Ojeda et al. 2017; Infante et al. 2014).

Chairside CAD/CAM dentistry provides the ability to create tooth-supported restorations in a single appointment (Christensen 2006). This technology has become so integrated into daily practice that it is now included in undergraduate education (Jurado et al. 2021; Brownstein et al. 2015). Chairside CAD/CAM systems offer a variety of dental ceramics for restoration fabrication, including porcelain, leucite, lithium disilicate, zirconia, and hybrid materials, allowing clinicians to choose based on their specific requirements (Moshaverinia 2020). A recent systematic review and meta-analysis assessing the clinical performance of CAD/CAM all-ceramic tooth-supported restorations reviewed all relevant studies and concluded that CAD/CAM-supported fixed dental prostheses achieve satisfactory survival and success rates for up to

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10 years.12 As a result of these positive outcomes, CAD/CAM restorations have become a widely utilized option among clinicians.

Lithium disilicate for chairside CAD/CAM restorations was first introduced in 2006, (Saravi et al. 2021) and has since become a preferred material for many clinicians. This dental ceramic is initially in a pre-crystallized form, requiring a firing process in a dental furnace to fully crystallize and enhance its fracture resistance properties (Willard and Gabriel Chu 2018). A national dental surveycollected information from 1777 dentistsregarding the most common ceramics used for single-unit restorations,, and the results indicated that lithium disilicate is the most common choice to fabricate single crowns for anterior teeth, followed by layered zirconia and leucite, and it was the third most common for crowns in the posterior region (Makhija et al. 2016). A recent study evaluated the marginal fit between CAD/CAM and hot-press lithium disilicate crowns. The study evaluated 15 crowns per material and cemented to typodont teeth and the marginal discrepancy (MD) and the absolute marginal discrepancy (AMD) for each crown were evaluated with a microscope. They found thatthe AMD were 115 µm for the CAD/CAM and 130 µm for the hot-press restorations, and for the MD measurements, 87 µm for the CAD/CAM and 90 µm for the hot-press crowns. Theauthors concluded that no significant differences between CAD/CAM and hot-press lithium disilicate crowns were found (Dolev et al. 2019).

A new iteration of CAD/CAM lithium disilicate has been introduced to the market, known as advanced lithium disilicate (CEREC Tessera, Dentsply Sirona, Charlotte, NC, USA). This innovative glass-matrix ceramic incorporates lithium aluminum silicate crystals, called virgilite, within a zirconia-based matrix (Marchesi et al. 2021; Rosentritt et al. 2022; Demirel et al. 2023). The manufacturer asserts that the inclusion of virgilite crystals has enhanced the physical and optical properties of this updated lithium disilicate. However, there is limited independent data available to support these claims.

Chairside CAD/CAM veneer restorations are frequently carried out by dentists, with clinical studies showing that veneers made from lithium disilicate can meet both the aesthetic and functional needs of patients (Zimmermann et al. 2013; Cunha et al. 2015). Clinicians can prepare teeth for anterior labial veneer restorations using various incisal edge designs, including feather edge (Imburgia et al. 2021), butt joint (Zarow et al. 2023), and palatal chamfer (Demirekin and Turkaslan 2022). However, no data has evaluated the fracture resistance of veneer restorations with different incisal edge designs (feather edge, butt joint and palatal chamfer) for maxillary canine. Therefore, the aim of this study was to evaluate the fracture resistance of chairside CAD/CAM advanced lithium disilicate veneers with three different incisal edge designs and full coverage crowns for maxillary canines. The first null hypothesis was that there is no difference in fracture resistance of veneers with feather edge, butt joint and palatal chamfer, and full coverage crowns. The second null hypothesis was that there is no difference in fracture resistance among veneers with feather edge, butt joint, and palatal chamfer.

2 Materials and methods

2.1 Specimen preparation

Four maxillary right typodont teeth (1560 Series, Columbia Dentoform, Lancaster, PA, USA) were prepared for (1) feather edge labial veneer, (2) butt joint labial veneer, (3) palatal chamfer labial veneer, and (4) full coverage crown (Fig. 1).

The tooth preparations followed the manufacturer's recommendation (CEREC Tessera, Dentsply Sirona, Charlotte, NC, USA) for labial veneers, the reduction was1.0 mm incisal, 0.6 mm labial surface and 0.4 mm chamfer finish line, and for full coverage crowns, the reduction was 1.0 mm incisal, 1.0 mm axial reduction and 1.0 mm rounded shoulder. The prepared teeth were scanned and the restorations were digitally designed following the anatomy of the preparation with a chairside CAD/CM system (Primescan, Dentsply Sirona, Charlotte, NC, USA). Fifty-two restorations (13 per group) were fabricated out of advanced lithium disilicate (CEREC Tessera, Dentsply Sirona, Charlotte, NC, USA) using a 5-axis milling machine (MCXL, Dentsply Sirona, Charlotte, NC, USA). Restorations were cleaned with a steam cleaner, glazed (Universal Spray Glaze Fluo, Dentsply Sirona, Charlotte, NC, USA) and fully crystallized with a dental furnace (CEREC SpeedFire, Dentsply Sirona, Charlotte, NC, USA) following manufacturer's recommendationat 760 °C temperature (Standby Temperature: 400 °C; Closing Time: 3:30 min; Heating Rate: 60 °C/min; Holding Time 1:30 min), and then restorations were polished with a lithium disilicate polishing kit (Dialite LD, Brasseler USA, Savannah, GA, USA). The prepared typodont teeth were scanned with a laboratory desktop scanner (Freedom HD, DOF, Seoul, Korea), and digital models were created. Then, they were used to manufacture 52 dies using a 3D printer (Formlabs 3B, Formlabs Inc, Somerville, MA, USA) from a resin to create dental models (Model Resin, Formlabs, Somerville, MA, USA).

All the ceramic restorations were cleaned in an ultrasonic unit (Sweep Ultrasonic Cleaner, Quala Dental Products, Nashville, TN, USA) with 90% isopropyl alcohol for 5 min. Then restorations were treated with 5% hydrofluoric acid (Cerec Ceramic Etch, Vita Zahnfabrik, Baden-Wurttemberg, Germany) for 30 s, rinsed, and air dried, and then a

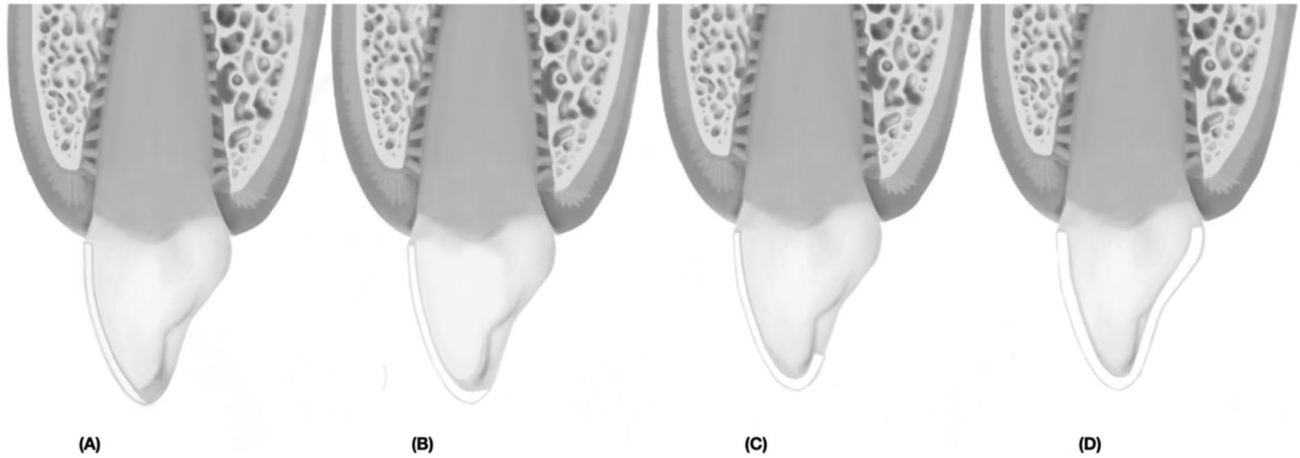

Fig. 1 Schematic drawing of the restorations evaluated in this study. (A) Veneers with feather edge; (B) veneers with butt joint; (C) veneers with palatal chamfer; and (D) full coverage crowns

silane coupling agent (Calibra, Dentsply Sirona, Charlotte, NC, USA) was applied for 60 s. Finally, restorations were cemented to the printed resin dies with resin luting cement (Calibra Veneer Esthetic Resin Cement, Dentsply Sirona, Charlotte, NC, USA), following the manufacturer's instructions using a light curing unitwith 400–500 nm wavelength (Elipar 2500, 3 M, St Paul, MN, USA)for 20 s from each direction (incisal, buccal, lingual, mesial and distal). A single experienced prosthodontist performed all cementation procedures.

2.2 Fracture strength test

All the cemented restorations were subjected to an artificial aging process with a thermocycling machine (Thermocycler THE-1100, SD Mechatronik, Feldkirchen0Westerham, Germany) for 10,000 cycles between 5 and 55 °C with a dwell time of 30 s. All the restorations were subjected to compressive load on the incisal edge with a speed of 5 mm/min until failure with a universal testing machine (ProLine ZwickRoell LP, Kennesaw, GA, USA). The fracture resistance values were recorded in Newtons.

2.3 Fractographic analysis

Scanning electron microscope (SEM) (ERA 8800 FE, Elionix, STS Elionix, Wellesley Hills, MA, USA) was taken to two specimens per group. First, a thin coat of gold was applied on the surface of the fractured samples in a sputter coater (Quick Coater Type SC-701, Sanyu Electron Co, Tokyo, Japan) in order to obtain electrical conductivity and then images with $\times 10$ and $\times 25$ magnification were taken with an accelerating voltage of 15 kV.

2.4 Statistical analysis

The sample size for this in-vitro study was calculated from a previous publication (Jurado et al. 2023) with G*Power analysis (= 0.05, power 0.8) that was determined 11 to 40 samples were needed for each group and 13 samples per group were deemed acceptable. A two-way ANOVA test was performed to evaluate differences among veneers versus crowns and among different veneers.

3 Results

3.1 Fracture strength test

The fracture resistance values of chairside CAD/CAM advanced lithium disilicate maxillary canine veneers with different incisal edge designs and full coverage crowns are shown in Table 1. The incisal design for the veneer restorations significantly influenced the fracture strength. Two-way ANOVA indicated a significant effect of restoration design on fracture strength. Full coverage crowns displayed the highest fracture resistance with 1496 ± 41 N, while palatal chamfer

Table 1 Fracture strength (Standard deviation) of chairside CAD/CAM advanced lithium disilicate restorations

Type of Restoration	Number of specimens	Mean Fracture Resistance in Newtons
Feather edge Veneers	13	$464 \pm (23)^{a}$
Butt-joint Veneers	13	$661 \pm (22)^{b}$
Palatal Chamfer Veneers	13	$842 \pm (28)^{c}$
Full Coverage Crowns	13	$1496 \pm (41)^{d}$

Different superscript letter indicates significant difference veneers provided the highest value with 842 ± 28 N, followed by butt joint veneers with 661 ± 22 N. The lowest values were registered with the feather edge veneers with 464 ± 23 N.

3.2 Fractographic analysis

Representative SEM images of fractured specimens of chairside CAD/CAM advanced lithium disilicate veneers and crowns are shown in Fig. 2, with annotations highlighting key features. The analysis shows clear differences in crack patterns across the various designs. Veneers with a feather edge incisal design (Fig. 2, Row 1: 1A-1D) displayed the most irregular and numerous cracks, suggesting greater vulnerability to fracture under stress. In comparison, veneers with butt joint (Fig. 2, Row 2: 2A-2D) and palatal chamfer (Fig. 2, Row 3: 3A-3D) designs had significantly fewer cracks, indicating better stress distribution along the facial surface. Full coverage crowns (Fig. 2, Row 4: 4A-4D) showed the least and cleanest cracks, demonstrating their superior fracture resistance. These results emphasize the role of design selection in improving the durability and performance of dental restorations.

A flowchart describing the steps of the workflow implemented in this study can be seen in Fig. 3.

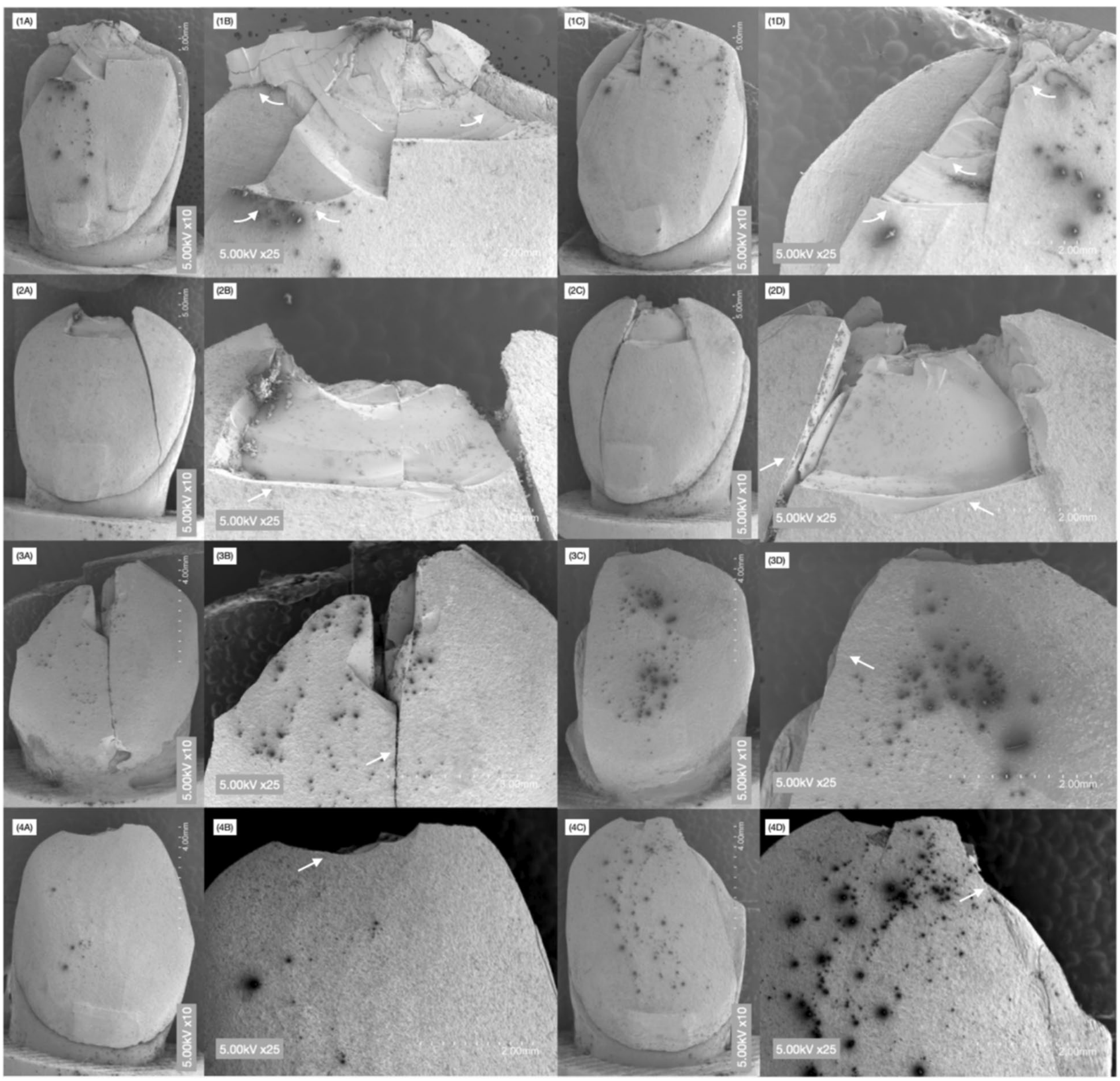

Fig. 2 Scanning electron microscope (SEM) images of fractured (1A—D) veneers with feather edge, (2A-D) butt joint; (3A-D) palatal chamfer; and (4A-D) with 10 × and 25 × magnification. Straight arrows pointing cleaner cracks while curved arrows display irregular cracks

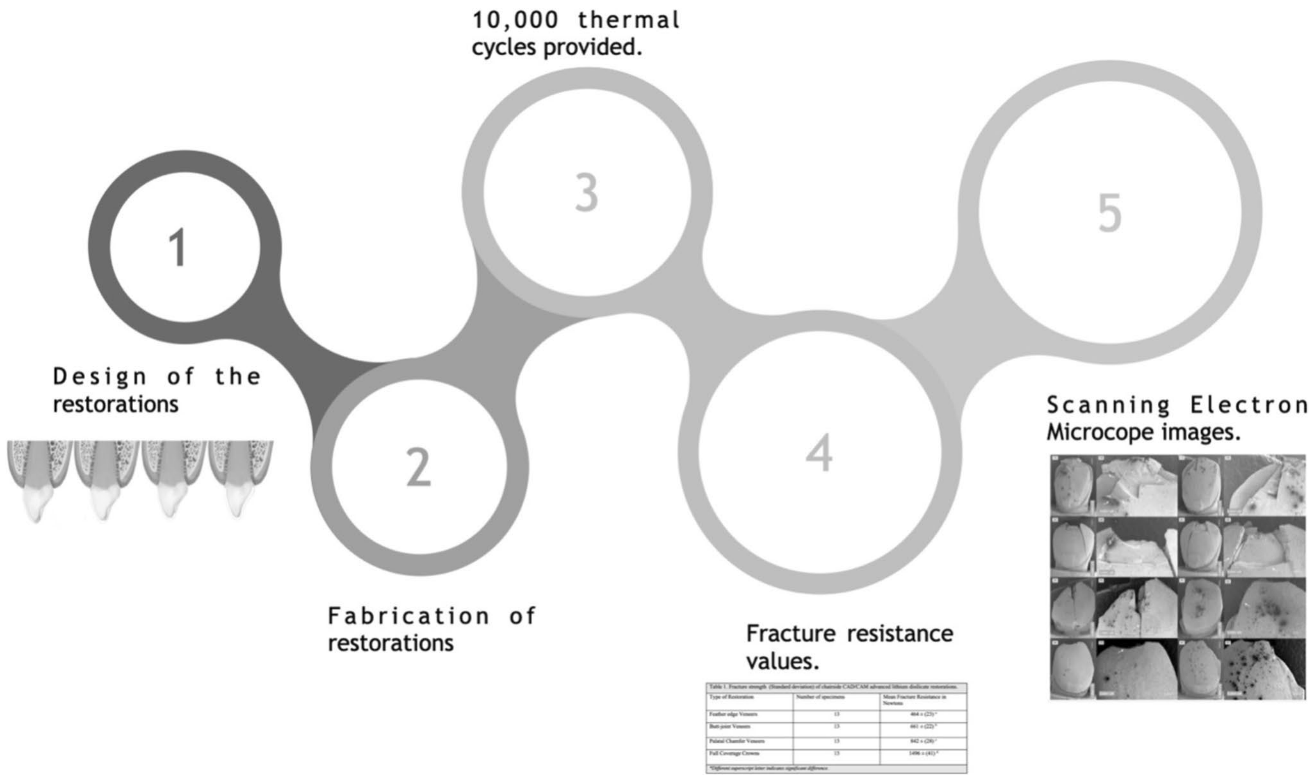

Fig. 3 Workflow implemented in this study. (1) Design and (2) fabrication of the restorations, (3) artificial aging provided with 10,000 thermal cycles, (4) fracture testing and (5) SEM evaluation

4 Discussion

Chairside CAD/CAM lithium disilicate veneer restorations have become widely used by clinicians due to their high accuracy (Soares-Rusu et al. 2021), reduced fabrication time (Sannino et al. 2015), and favorable optical (Jurado et al. 2022; Ziyad et al. 2021) and mechanical properties (Zarone et al. 2019). Clinicians can perform veneer preparations with various incisal edge designs, such as feather edge, butt joint, and palatal chamfer (overlapped). The current in vitro study assessed the fracture resistance of maxillary canine veneers with feather edge, butt joint, and palatal chamfer, as well as full coverage crowns made from chairside CAD/CAM advanced lithium disilicate ceramic.Based on the results, the first null hypothesis that there was no difference in fracture resistance of veneers with feather edge, butt joint and palatal chamfer, and full coverage crowns is rejected. Full coverage crowns displayed 1496 N that is significantly higher fracture resistance than any type of the veneer restorations that ranged from 464 to 842 N. Moreover, the second null hypothesis that there is no difference in fracture resistance among veneers with feather edge, butt joint and palatal chamfer is also rejected. The fracture resistance values obtained by chairside CAD/CAM advanced lithium disilicate veneers with feather edge (464 N), butt joint (661 N) and palatal chamfer (842 N) weresignificantly different among them.

The tooth preparations for the veneer restorations followed the manufacturer's recommendations (CEREC Tessera, Dentsply Sirona, Charlotte, NC, USA) with 1.0 mm incisal reduction and 0.6 mm at the labial surface and 0.4 mm for chamfer finishing line, and for full coverage crown was 1.0 mm incisal reduction, and 1.0 mm axial reduction and 1.0 mm shoulder with angles rounded.The maxillary right canine was selected in this in vitro study to evaluate the fracture resistance of veneers with different incisal designs because this tooth is commonly included in dental esthetic treatments with labial veneers (Cunha et al. 2015; Schmitter and Seydler 2012) Labial veneer restorations for maxillary canine teeth have shown positive clinical results.A recent retrospective study evaluated the performance and longevity of 114 veneers, including 37 veneers for central incisors, 41 for laterals and 36 for canine placed 7 to 14 years earlier, andthe findings demonstrated a survival rate of 98% with a low failure rate (Arif et al. 2019). Due to the popularity and positive clinical studies of labial veneers for maxillary canines, this tooth was selected for the in vitro study.

The use of chairside CAD/CAM technology for the fabrication of dental restorations has significantly increased worldwide. A recent survey of dentists in Austria indicates that 51.8% of them use CAD/CAM technology, and 70.7% of them believe that CAD/CAM is important toincreasethe number of patients (Krastev et al. 2023). Another survey of clinicians in Saudi Arabia evaluated the dentists' perception and utilization of CAD/CAM systems, and the results indicated that 57% of them have a CAD/CAM system in their dental office, and 81% of them deem that the quality of this type of restorations is as good as those fabricated with traditional techniques by dental technicians (Nassani et al. 2021). Lastly, a recent cross-sectional study evaluated Egyptian dentists' knowledge, awareness, and perception of digital dentistry.This study evaluated 402 participants, including general dentists and specialists. The results indicated that 75.9% of them had a high perception of practicing digital dentistry (Hall et al. 2023). Therefore, due to its popularity among clinicians, the restorations evaluated in this study were fabricated with a chairside CAD/CAM system (CEREC Dentsply Sirona, Charlotte, NC, USA) that included an intraoral scanner and a milling machine.

Unfortunately, no data has evaluated the fracture resistance of veneers and full coverage crowns for maxillary canines. However, our findings concur with studies performed on veneers and crowns for other anterior teeth. A recent in vitro study evaluated the effect of incisal preparation design for maxillary central incisor veneers fabricated out of zirconia-reinforced lithium disilicate In that study, the restorations evaluated were veneers with feather edge, butt-joint and palatal chamfer, and full coverage crowns. After that,the restorations were subjected to artificial aging with 10,000 thermal cycles, and then fractured. As a result, the crowns showedthe highest fracture resistance (781 N) than the veneers with feather edge (194 N), butt joint (385 N) and palatal chamfer 618 N) (Jurado et al. 2024). The present study also evaluated the fracture resistance for maxillary canines and the results indicated the highest fracture resistance for crowns with1496 N than any types of veneers that ranged from 464 to 842 N.

The current study also analyzed the fracture resistance of veneers with various incisal edge designs, such as feather edge, butt joint, and palatal chamfer. While the literature lacks a comparison for maxillary canines, it provides studies on central incisors, and the results align with our findings. One study assessed the fracture resistance of porcelain veneers with incisal bevel, butt joint, and palatal chamfer. In this study, the restorations were bonded to natural maxillary central incisor teeth and subjected to loading until fracture. The results indicated that palatal chamfer offers the highest fracture resistance (0.93 ± 0.10KgN) than both veneers with incisal bevel (0.61 ± 0.02 KgN) and veneers with butt joint (0.89 ± 0.09 N) (Jankar et al. 2014). Another study evaluated the fracture resistance of ceramic veneers with and without palatal chamfer on non-worn and worn teeth, the leuciteceramic veneers were loaded until fractured, and the results indicated that palatal chamfer offered higher fracture resistance for both non-worn (166 N) and worn (119 N) teeth than restorations without palatal chamfer for non-worn (131 N) and worn (90 N) teeth, and the authors concluded that using palatal chamfer finish line significantly increases the fracture resistance of ceramic veneers (Schmidt et al. 2011). Another study also evaluated the fracture resistance of veneer restorations with palatal chamfer, feather edge, and bevel. The restorations were made out of resin composite and cemented to maxillary central incisors, and received load at 45° angle to the long axis until fracture, and the results displayed the higher resistance ofoverlap-palatal chamfer (122 N) than the feather (107 N) and bevel (100 N) preparations, and the authors stated at the end that overlap-palatal chamfer preparation design significantly increases the fracture resistance (Zlatanovska et al. 2016). The findings in the present in-vitro study also found that lithium disilicate veneers with palatal chamfer (841 N) offered higher fracture resistance than veneers with feather edge (464 N) and butt joint (661 N).

Full coverage crowns demonstrated higher fracture resistance than any type of labial veneer, irrespective of the incisal edge design. The difference in fracture resistance values in this study can be attributed to the variations in thicknesses: the facial thickness of the veneer was 0.6 mm, while for the crown it was 1.0 mm, and the finish chamfer for the veneer was 0.4 mm, compared to 1.0 mm for the crown. Some studies have shown that the thicker the restoration the higher the fracture resistance provided (Jurado et al. 2022; Lin et al. 2020). Regarding the veneers with different incisal edge designs, the palatal chamfer veneer offered the highest fracture resistance, and it could be explained that the fracture force was provided in the incisal edge at 90 angle so the compressive force was transferred to the palatal overlap, creating a more homogenously distributed than the other type of veneers that all the force is concentrated at the incisal edge. A computerized 3D-finite element analysis evaluatedthe influence of tooth preparation designs for maxillary central incisor with veneers with window and palatal chamfer design, the study evaluated chewing static forces with an angulation of 60 and 125° to the long axis of the tooth, and the results indicated that the restorations with a window design had higher stress values. In addition,veneers with an overlap design offered a more favorable geometry for stress distribution, and they can perform better under functional loading (Zarone et al. 2005).

In this study, 10,000 thermal cycles were applied as an artificial aging process before fracturing the ceramic restorations. The literature indicates that 10,000 thermal cycles simulate one year of clinical service (Thermal cycling procedures for laboratory testing of dental restorations. xxxx; Aljanobi and Al-Sowygh 2020). Furthermore, several studies assessing margin integrity, bond strength, fracture resistance, and other properties of dental ceramic restorations have used the same number of cycles (Lopez et al. 2024; Alrabeah et al. 2023; Ziębowicz et al. 2023). Therefore, this methodology is in line with current literature.

A limitation of our study is the use of printed resin dies rather than natural teeth. While this approach ensures standardization and consistency, it presents challenges for direct clinical application. Natural teeth have anatomical variations that printed resin dies do not fully replicate, which could affect the generalizability of our results. Nevertheless, using printed resin dies greatly reduces variability, improving the reproducibility and reliability of our findings. This method is widely supported in the literature and helps avoid ethical and practical issues associated with obtaining uniform natural teeth (Jurado et al. 2023; Kashkari et al. 2019; Sayed Ahmed et al. 2024). Despite these advantages, we acknowledge the need for additional studies using natural teeth to better validate our results in clinical settings. Although artificial aging processes were included in our study, incorporating simulated chewing forces would offer more clinically relevant insights into the performance of different restoration designs. These steps will help bridge the gap between our controlled experimental setup and real-world clinical scenarios. Lastly, a more in-depth analysis of the fracture patterns displayed in the SEM images should be provided.

5 Conclusions

The fracture resistance of chairside CAD/CAM advanced lithium disilicate veneer restorations is affected by the incisal edge design. Veneers with a palatal chamfer exhibited greater fracture resistance compared to those with feather edge or butt joint designs. Full coverage crowns showed superior fracture resistance compared to any veneer. According to the findings of this study, if a clinician is concerned about occlusal forces or a patient's parafunctional habits, veneers with a palatal chamfer are recommended due to their enhanced fracture resistance.

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Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

Suganna M, Kausher H, Tarek Ahmed S, Sultan Alharbi H, Faraj Alsubaie B, Ds A, Haleem S, Meer Rownaq Ali AB (2022) Contemporary Evidence of CAD-CAM in Dentistry: A Systematic Review. Cureus 14(11):e31687. https://doi.org/10.7759/cureus.31687.

Mörmann WH (2006) The evolution of the CEREC system. J Am Dent Assoc 137(Suppl):7S-13S. https://doi.org/10.14219/jada.archive.2006.0398

Papaspyridakos P, De Souza A, Bathija A, Kang K, Chochlidakis K (2021) Complete Digital Workflow for Mandibular Full-Arch Implant Rehabilitation in 3 Appointments. J Prosthodont 30(6):548–552. https://doi.org/10.1111/jopr.13356

Robles M, Jurado CA, Azpiazu-Flores FX, Villalobos-Tinoco J, Afrashtehfar KI, Fischer NG (2023) An Innovative 3D Printed Tooth Reduction Guide for Precise Dental Ceramic Veneers. J Funct Biomater 14(4):216. https://doi.org/10.3390/jfb14040216

Blatz MB, Conejo J (2019) The Current State of Chairside Digital Dentistry and Materials. Dent Clin North Am 63(2):175–197. https://doi.org/10.1016/j.cden.2018.11.002

Edelhoff D, Schubert O, Stimmelmayr M, Schweiger J (2024) CAD/CAM full-mouth rehabilitation of an elderly patient: One-piece digital complete denture meets multilayered zirconia with gradient technology. J Esthet Restor Dent 36(1):174–185. https://doi.org/10.1111/jerd.13031

Durán Ojeda G, Henríquez Gutiérrez I, Guzmán Marusic Á, Báez Rosales A, Tisi Lanchares JP (2017) A Step-by-Step Conservative Approach for CAD-CAM Laminate Veneers. Case Rep Dent 2017:3801419. https://doi.org/10.1155/2017/3801419

Infante L, Yilmaz B, McGlumphy E, Finger I (2014May) Fabricating complete dentures with CAD/CAM technology. J Prosthet Dent 111(5):351–355. https://doi.org/10.1016/j.prosdent.2013.10.014

Christensen GJ (2006) Is now the time to purchase an in-office CAD/CAM device? J Am Dent Assoc 137(2):235–6, 238. https://doi.org/10.14219/jada.archive.2006.0149. Erratum in: J Am Dent Assoc. 137(3):309.

Jurado CA, Tsujimoto A, Punj A, Aida N, Miyazaki M, Watanabe H (2021) Successful development and implementation of a digital dentistry curriculum at a US dental school. J Oral Sci 63(4):358–360. https://doi.org/10.2334/josnusd.21-0070

Brownstein SA, Murad A, Hunt RJ (2015) Implementation of new technologies in U.S. dental school curricula. J Dent Educ 79(3):259–64.

Moshaverinia A (2020) Review of the Modern Dental Ceramic Restorative Materials for Esthetic Dentistry in the Minimally Invasive Age. Dent Clin North Am 64(4):621–631. https://doi.org/10.1016/j.cden.2020.05.002

Saravi B, Vollmer A, Hartmann M, Lang G, Kohal RJ, Boeker M, Patzelt SBM (2021) Clinical Performance of CAD/CAM All-Ceramic Tooth-Supported Fixed Dental Prostheses: A Systematic Review and Meta-Analysis. Materials (Basel) 14(10):2672. https://doi.org/10.3390/ma14102672

Willard A, Gabriel Chu TM (2018) The science and application of IPS e.Max dental ceramic. Kaohsiung J Med Sci 34(4):238–242. https://doi.org/10.1016/j.kjms.2018.01.012.

Makhija SK, Lawson NC, Gilbert GH, Litaker MS, McClelland JA, Louis DR, Gordan VV, Pihlstrom DJ, Meyerowitz C, Mungia R, McCracken MS (2016) National Dental PBRN Collaborative Group. Dentist material selection for single-unit crowns: Findings from the National Dental Practice-Based Research Network. J Dent 55:40–47. https://doi.org/10.1016/j.jdent.2016.09.010

Dolev E, Bitterman Y, Meirowitz A (2019) Comparison of marginal fit between CAD-CAM and hot-press lithium disilicate crowns. J Prosthet Dent 121(1):124–128. https://doi.org/10.1016/j.prosdent.2018.03.035

Marchesi G, Camurri Piloni A, Nicolin V, Turco G, di Lenarda R (2021) Chairside CAD/CAM materials: current trends of clinical uses. Biology 10(11):1170

Rosentritt M, Schmid A, Huber C, Strasser T (2022) In Vitro Mastication Simulation and Wear Test of Virgilite and Advanced Lithium Disilicate Ceramics. Int J Prosthodont 35(6):770–776. https://doi.org/10.11607/ijp.7820

Demirel M, DikenTürksayar AA, Donmez MB (2023) Translucency, color stability, and biaxial flexural strength of advanced lithium disilicate ceramic after coffee thermocycling. J Esthet Restor Dent 35(2):390–396. https://doi.org/10.1111/jerd.12960

Zimmermann R, Seitz S, Evans J, Bonner J (2013) CAD/CAM and lithium disilicate: an anterior esthetic case study. Tex Dent J 130(2):141–144

da Cunha LF, Mukai E, Hamerschmitt RM, Correr GM (2015) Fabrication of lithium silicate ceramic veneers with a CAD/CAM approach: a clinical report of cleidocranial dysplasia. J Prosthet Dent 113(5):355–359. https://doi.org/10.1016/j.prosdent.2014.10.004

Imburgia M, Lerner H, Mangano F (2021) A Retrospective Clinical Study on 1075 Lithium Disilicate CAD/CAM Veneers with Feather-Edge Margins Cemented on 105 Patients. Eur J Prosthodont Restor Dent 29(1):54–63. https://doi.org/10.1922/EJPRD_2248Mangano10

Zarow M, Hardan L, Szczeklik K, Bourgi R, Cuevas-Suárez CE, Jakubowicz N, Nicastro M, Devoto W, Dominiak M, Pytko-Polończyk J, Bereziewicz W, Lukomska-Szymanska M (2023) Porcelain Veneers in Vital vs. Non-Vital Teeth: A Retrospective Clinical Evaluation. Bioengineering (Basel) 10(2):168. https://doi.org/10.3390/bioengineering10020168

Demirekin ZB, Turkaslan S (2022) Laminate veneer ceramics in aesthetic rehabilitation of teeth with fluorosis: a 10-year follow-up study. BMC Oral Health 22(1):42. https://doi.org/10.1186/s12903-022-02079-4

Jurado CA, Lee D, Cortes D, Kaleinikova Z, Hernandez AI, Donato MV, Tsujimoto A (2023) Fracture Resistance of Chairside CAD/CAM Molar Crowns Fabricated with Different Lithium Disilicate Ceramic Materials. Int J Prosthodont 36(6):722–729. https://doi.org/10.11607/ijp.7802

Soares-Rusu I, Villavicencio-Espinoza CA, de Oliveira NA, Wang L, Honório HM, Rubo JH, Francisconi P, Borges A (2021) Clinical Evaluation of Lithium Disilicate Veneers Manufactured by CAD/CAM Compared with Heat-pressed Methods: Randomized Controlled Clinical Trial. Oper Dent 46(1):4–14. https://doi.org/10.2341/19-233-C.Erratum.In:OperDent.2021May1;46(3):348-349

Sannino G, Germano F, Arcuri L, Bigelli E, Arcuri C, Barlattani A (2015) CEREC CAD/CAM Chairside System. Oral Implantol (Rome) 7(3):57–70

Jurado CA, El-Gendy T, Hyer J, Tsujimoto A (2022) Color stability of fully- and pre-crystalized chair-side CAD-CAM lithium disilicate restorations after required and additional sintering processes. J Adv Prosthodont 14(1):56–62. https://doi.org/10.4047/jap.2022.14.1.56

Ziyad TA, Abu-Naba'a LA, Almohammed SN (2021) Optical properties of CAD-CAM monolithic systems compared: three multi-layered zirconia and one lithium disilicate system. Heliyon 7(10):e08151. https://doi.org/10.1016/j.heliyon.2021.e08151

Zarone F, Di Mauro MI, Ausiello P, Ruggiero G, Sorrentino R (2019) Current status on lithium disilicate and zirconia: a narrative review. BMC Oral Health 19(1):134. https://doi.org/10.1186/s12903-019-0838-x

Schmitter M, Seydler BB (2012) Minimally invasive lithium disilicate ceramic veneers fabricated using chairside CAD/CAM: a clinical report. J Prosthet Dent 107(2):71–74. https://doi.org/10.1016/S0022-3913(12)00012-1

Arif R, Dennison JB, Garcia D, Yaman P (2019) Retrospective evaluation of the clinical performance and longevity of porcelain laminate veneers 7 to 14 years after cementation. J Prosthet Dent 122(1):31–37. https://doi.org/10.1016/j.prosdent.2018.09.007

Krastev T, Payer M, Krastev Z, Cardelles JFP, Vegh A, Banyai D, Geczi Z, Vegh D (2023) The Utilisation of CAD/CAM Technology Amongst Austrian Dentists: A Pilot Study. Int Dent J 73(3):430–434. https://doi.org/10.1016/j.identj.2022.09.004

Nassani MZ, Ibraheem S, Shamsy E, Darwish M, Faden A, Kujan O (2021) A Survey of Dentists' Perception of Chair-Side CAD/CAM Technology. Healthcare (Basel) 9(1):68. https://doi.org/10.3390/healthcare9010068

Hall MA, Karawia I, Mahmoud AZ, Mohamed OS (2023) Knowledge, awareness, and perception of digital dentistry among Egyptian dentists: a cross-sectional study. BMC Oral Health 23(1):963. https://doi.org/10.1186/s12903-023-03698-1

Jurado CA, Sadid-Zadeh R, Watanabe H, Robbins CE, Afrashtehfar KI, Fischer NG, Lee DJ (2024) Effect of incisal preparation design on the fracture strength of monolithic zirconia-reinforced lithium silicate laminate veneers. J Prosthodont 33(3):281–287. https://doi.org/10.1111/jopr.13689

Jankar AS, Kale Y, Kangane S, Ambekar A, Sinha M, Chaware S (2014) Comparative evaluation of fracture resistance of Ceramic Veneer with three different incisal design preparations - An In-vitro Study. J Int Oral Health 6(1):48–54

Schmidt KK, Chiayabutr Y, Phillips KM, Kois JC (2011) Influence of preparation design and existing condition of tooth structure on load to failure of ceramic laminate veneers. J Prosthet Dent 105(6):374–382. https://doi.org/10.1016/S0022-3913(11)60077-2

Zlatanovska K, Guguvcevski L, Popovski R, Dimova C, Minovska A, Mijoska A (2016) Fracture resistance of composite veneers with different preparation designs. Blk J Dent Med 20(2):99–103. https://doi.org/10.1515/bjdm-2016-0016

Jurado CA, Pinedo F, Trevino DAC, Williams Q, Marquez-Conde A, Irie M, Tsujimoto A (2022) CAD/CAM lithium disilicate ceramic crowns: Effect of occlusal thickness on fracture resistance and fractographic analysis. Dent Mater J 41(5):705–709. https://doi.org/10.4012/dmj.2022-018

Lin ZX, Pan ZX, Ye QQ, Zheng ZQ, Lin J (2020) [Effect of occlusal thickness design on the fracture resistance of endocrowns restored with lithium disilicate ceramic and zirconia]. Hua Xi Kou Qiang Yi Xue Za Zhi. 38(6):647–651. Chinese. https://doi.org/10.7518/hxkq.2020.06.007

Zarone F, Apicella D, Sorrentino R, Ferro V, Aversa R, Apicella A (2005) Influence of tooth preparation design on the stress distribution in maxillary central incisors restored by means of alumina porcelain veneers: a 3D-finite element analysis. Dent Mater 21(12):1178–1188. https://doi.org/10.1016/j.dental.2005.02.014

Thermal cycling procedures for laboratory testing of dental restorations. Gale MS, Darvell BW. J Den. 1999;27:89–99. https://doi.org/10.1016/s0300-5712(98)00037-2.

Aljanobi G, Al-Sowygh ZH (2020) The Effect of Thermocycling on the Translucency and Color Stability of Modified Glass Ceramic and Multilayer Zirconia Materials. Cureus 12(2):e6968. https://doi.org/10.7759/cureus.6968

Lopez D, Ziada H, Abubakr NH (2024) Influence of thermal aging on the marginal integrity of computer aided design/computer aided manufacturing fabricated crowns. J Dent Sci 19(2):971–977. https://doi.org/10.1016/j.jds.2023.07.009

Alrabeah G, Alomar S, Almutairi A, Alali H, ArRejaie A (2023) Analysis of the effect of thermocycling on bonding cements to zirconia. Saudi Dent J 35(6):734–740. https://doi.org/10.1016/j.sdentj.2023.07.009

Ziębowicz A, Oßwald B, Kern F, Schwan W (2023) Effect of Simulated Mastication on Structural Stability of Prosthetic Zirconia Material after Thermocycling Aging. Materials (Basel) 16(3):1171. https://doi.org/10.3390/ma16031171

Kashkari A, Yilmaz B, Brantley WA, Schricker SR, Johnston WM (2019) Fracture analysis of monolithic CAD-CAM crowns. J Esthet Restor Dent 31(4):346–352. https://doi.org/10.1111/jerd.12462

Sayed Ahmed A, Lawson NC, Fu CC, Bora PV, Kee E, Nejat AH (2024) The Effect of Die Material on the Crown Fracture Strength of Zirconia Crowns. Materials (Basel) 17(5):1096. https://doi.org/10.3390/ma17051096

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