Original Article

JHSMR Journal of Health Science and Medical Research

Effects of Shallow Retentive Designs on the Fracture Resistance of Resin Nanoceramic Overlays

Kanokrat Sapdeemongkol, D.D.S.[1,2], Boonlert Kukiattrakoon, D.D.S., M.Sc.[1], Chirayu Ruengrungsom, D.D.S., M.Sc., Ph.D.[1]

[1]Department of Conservative Dentistry, Faculty of Dentistry, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.
[2]Dental Department, Kaeng Khro Hospital, Kaeng Khro, Chaiyaphum 36150, Thailand.

Received 29 September 2025 • Revised 8 October 2025 • Accepted 9 October 2025 • Published online 27 February 2026

Abstract:

Objective: This study aimed to assess the impact of two shallow retentive designs on the fracture resistance of maxillary molars restored with resin nanoceramic overlays.

Material and Methods: Thirty extracted human maxillary molars were randomly divided into three groups (n=10): an intact control group and two experimental groups with different shallow retentive designs (shallow occlusal canal and shallow central dowel). All preparations included a standardized 1.5-mm occlusal reduction with additional cavity modifications according to the respective design. Overlays were fabricated using a resin nanoceramic and bonded with a dual-cured resin cement. Specimens underwent artificial aging through 5,000 thermal cycles and 120,000 mechanical loading cycles. Fracture resistance under axial compressive loading and failure modes were evaluated. Data were analyzed using one-way ANOVA and Tukey's post hoc test (p-value=0.05).

Results: No cracks or fractures were observed after the cyclic loading. The mean fracture resistance values of the shallow occlusal canal (2,742.88±354.37 N) and shallow central dowel groups (2,807.30±373.03 N) were significantly higher than the control group (2,309.33±341.67 N) (p-value<0.05), although no significant difference was found between the two preparation designs. Failure modes were predominantly Type II (mixed fracture within restoration and tooth structures) in both experimental groups.

Conclusion: Under the adhesive protocol, two shallow retentive designs in resin nanoceramic overlays may represent a feasible option for occlusal restoration, demonstrating mechanical properties superior to those of sound teeth in the short term and showing potential for future clinical application.

This paper was from the International Dental Collaboration of the Mekong River Region Conference (IDCMR, October 15-17, 2025).
Contact: Chirayu Ruengrungsom, D.D.S., M.Sc., Ph.D.
Department of Conservative Dentistry, Faculty of Dentistry, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.
E-mail: chirayu.r@psu.ac.th

J Health Sci Med Res 2026;44(3):e20261315
doi: 10.31584/jhsmr.20261315
www.jhsmr.org

© 2026 JHSMR. Hosted by Prince of Songkla University. All rights reserved.
This is an open access article under the CC BY-NC-ND license
(http://www.jhsmr.org/index.php/jhsmr/about/editorialPolicies#openAccessPolicy).

Keywords: fracture resistance, overlay restoration, preparation design, resin nanoceramic

Introduction

An overlay is a specific type of onlay restoration that provides complete cusp coverage[1,2]. It is particularly indicated in cases where re-establishment of the occlusal contour is necessary, such as in advanced occlusal wear. Additionally, overlays are suitable for restoring large Class II cavities with unsupported axial walls or when both marginal ridges are missing[3-5]. They are also indicated for cuspal protection in structurally compromised teeth, including endodontically treated teeth and vital teeth with cracks[2].

With advancements in adhesive systems, non-retentive designs for ceramic partial-coverage restorations have gained increasing attention[1,4]. This approach aligns with the principles of minimally invasive dentistry by maximizing the preservation of tooth structure without compromising long-term clinical performance[4,6]. However, limited peripheral enamel and compromised dentin substrates, such as sclerotic or affected dentin, pose significant challenges for adhesion-dependent restorations[6-8]. Moreover, the longevity of the adhesive interface may be negatively affected by degradation mechanisms, including thermal cycling and functional fatigue[9,10]. In addition, the absence of a definitive insertion path in non-retentive preparations may impair the accuracy of proximal contact and contour during cementation[2,3]. Therefore, combining adhesive strategies with minimal mechanical retention may remain essential for achieving predictable clinical outcomes in overlay restorations.

Tooth preparation design plays a pivotal role in the fracture resistance of restorative materials and directly influences the longevity of dental restorations[11,12]. Although several studies have evaluated the effects of various preparation designs on the fracture strength of teeth restored with indirect partial-coverage restorations[13-15], data remain limited regarding shallow occlusal canal and shallow central dowel configurations. These shallow preparation concepts are characterized by a minimal cavity depth of retention, typically not exceeding 1.0 mm, and by rounded line angles, combined with adhesive bonding to reduce the need for extensive mechanical preparation. Both retentive designs represent modifications that integrate the principles of conventional and non-retentive preparations, aiming to achieve a predictable clinical outcome while minimizing the compromise of tooth strength.

Resin nanoceramics (RNCs), a recently developed class of restorative materials composed of ceramic fillers embedded in a resin matrix, exhibit an elastic modulus comparable to that of natural dentin[16]. This characteristic may promote more favorable stress distribution and reduce the risk of restoration fracture or chipping[17-19]. However, evidence regarding the influence of preparation design on fracture resistance in vital teeth restored with hybrid ceramic overlays remains limited. Therefore, the aim of this study was to evaluate the effect of two shallow retentive designs on the fracture resistance of maxillary molars restored with resin nanoceramic overlays. The null hypothesis was that the two shallow preparation designs would have no difference in their effects on the fracture resistance of the tooth-restoration assembly.

Material and Methods

This in vitro study used thirty extracted human maxillary molars free from caries, restorations, or visible cracks. All extractions were performed for clinical purposes and approved by the Human Research Ethics Committee, Faculty of Dentistry, Prince of Songkla University (EC6612-056). Teeth with comparable bucco-palatal and mesio-distal widths (within ±0.5 mm) were selected using a digital caliper (Mitutoyo, Kawasaki, Japan), in accordance with previous in vitro standards[20].

Sample preparation

The teeth were cleaned of calculus and soft-tissue remnants, polished with a rubber cup and fine pumice slurry, and stored in 0.1% thymol solution at room temperature until use[1,5,13]. Each tooth was embedded in self-curing acrylic resin (UNIFAST Trad; GC Corp., Tokyo, Japan), with 2 mm of the root surface exposed below the cementoenamel junction (CEJ).

Sample size calculation was performed using G*Power 3.1.9.7 (Heinrich Heine University, Düsseldorf, Germany) with an effect size of 0.8, α=0.05, power=0.8, and number of groups =3. The analysis indicated that a minimum of 21 specimens (7 specimens per group) was required. Therefore, a total of 30 specimens (10 specimens per group) was considered appropriate, exceeding the minimum requirement suggested by the G-power calculation. Samples were randomly divided into three groups (n=10) according to the preparation design: Group 1, intact teeth (control); Group 2, shallow occlusal canal; and Group 3, shallow central dowel (Figure 1).

Tooth preparation was performed by a single operator under constant water cooling using high-speed burs as follows. An anatomic occlusal reduction of 1.5 mm was performed for Groups 2 and 3 using a round-end tapered diamond bur (size 018; 6856.FG.018, Komet, Lemgo, Germany). In Group 2, a shallow occlusal canal was prepared along the central groove, with a width of 2.5 mm and a depth of 0.8 mm, using a round diamond bur (size 023; 801.HP.023, Komet, Lemgo, Germany). In Group 3, a shallow central dowel was created at the center of the occlusal surface, with a diameter of 3.0 mm and a depth of 0.8 mm, using a round diamond bur (size 029; 801.HP.029, Komet, Lemgo, Germany). All internal line angles were rounded and finished with a flame-shaped white stone bur (Dura-White Stones FL2 [12]; Shofu Inc., Kyoto, Japan) to achieve smooth surfaces and reduce stress concentration[4].

Restoration fabrication

The prepared teeth were scanned using an intraoral scanner (CEREC Primescan; Dentsply Sirona, Charlotte, NC, USA). Overlay restorations were digitally designed with CEREC software to ensure a uniform anatomic thickness of 1.5 mm, with a maximum thickness of up to 2.3 mm at the deepest portion of the shallow retentive preparation. Restorations for each group were milled from resin nanoceramic CAD/CAM blocks (Cerasmart 270; GC Dental Products Corp., Aichi, Japan) using a milling unit (CEREC Primemill; Dentsply Sirona, Charlotte, NC, USA) (Figure 2).

Surface treatment and cementation

Tooth surfaces were selectively etched at peripheral enamel using 35.0% phosphoric acid (K-ETCHANT Syringe;

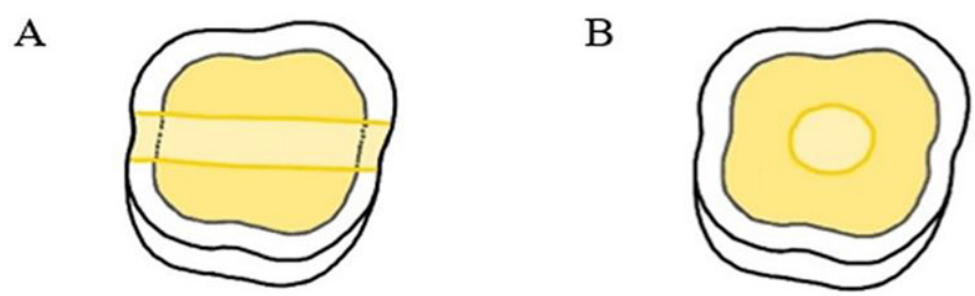

Figure 1 Shallow retentive designs: (A) shallow occlusal canal; (B) shallow central dowel

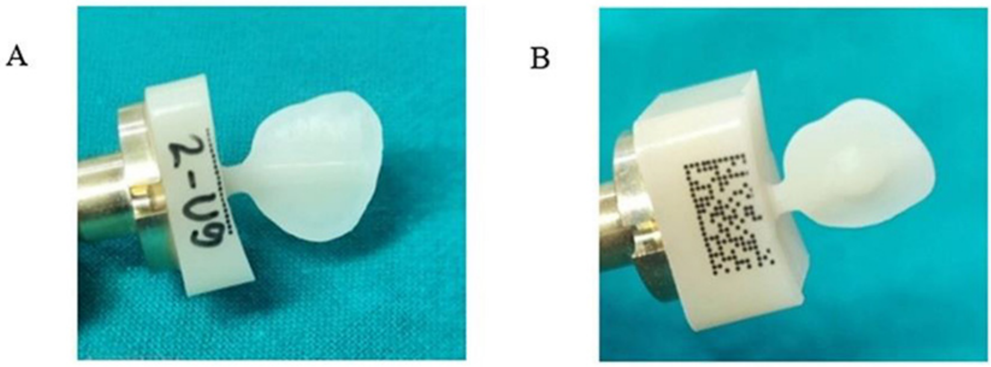

Figure 2 Overlay restorations adapted to cavity design: (A) shallow occlusal canal; (B) shallow central dowel

Kuraray Noritake Dental, Kurashiki, Japan) for 30 seconds, rinsed, and gently air-dried. A dentin primer (Tooth Primer; Kuraray Noritake Dental Inc., Tokyo, Japan) was applied for 20 seconds and lightly air-dried. The internal surfaces of the restorations were treated with airborne-particle abrasion using 25 µm aluminum oxide at 0.2 MPa, then rinsed and air-dried. A dual-cured resin cement (Panavia V5; Kuraray Noritake Dental Inc., Tokyo, Japan) was applied, and restorations were seated using finger pressure. Light polymerization was performed for 20 seconds on buccal, lingual, and occlusal surfaces using an LED curing unit (Demi Plus; Kerr Corporation, Orange, CA, USA; 1,000 mW/cm^2). After 24 hours, restorations were finished and polished using a hybrid ceramic polishing kit (EVE DIACOMP PLUS; EVE Ernst Vetter GmbH, Keltern, Germany) according to the manufacturer's instructions. Samples were stored in distilled water at 37 °C for 7 days prior to artificial aging.

Thermocycling and chewing simulation

Thermocycling was performed in water (KMITL; CWB332R, Bangkok, Thailand) between 5°C and 55°C for 5,000 cycles with a dwell time of 30 seconds[13]. Dynamic loading was conducted using a chewing simulator (CS-4.4 Professional; SD Mechatronik GmbH, Feldkirchen-Westerham, Germany) for 120,000 cycles at 6 Hz with a load of 50 N[13]. The load was applied vertically along the long axis of the tooth using a stainless-steel spherical antagonist (6.0 mm in diameter) positioned at the occlusal center of the line connecting the buccal and lingual cusps.

Fracture resistance testing and failure mode analysis

Fracture resistance was measured using a universal testing machine (LRX-Plus; Lloyd Instruments, AMETEK Ltd., Hampshire, UK) with a round-end stainless steel bar (6.0 mm in diameter) at a crosshead speed of 1.0 mm/min[1]. The static load was applied vertically along the long axis of the tooth at the occlusal center of the line connecting the buccal and lingual cusps. The maximum load at fracture (N) was recorded for each sample. Failure modes were classified, with modifications from Burke et al.[21] and Gierthmuehlen et al.[22], as follows: Type I – visible crack or cohesive fracture within the restoration; Type II – mixed fracture involving both the restoration and tooth structure; Type III – extensive fracture involving the restoration, tooth structure, and root (Figure 3).

Statistical analysis

Data were analyzed after confirming normality using the Shapiro-Wilk test and homogeneity of variance with

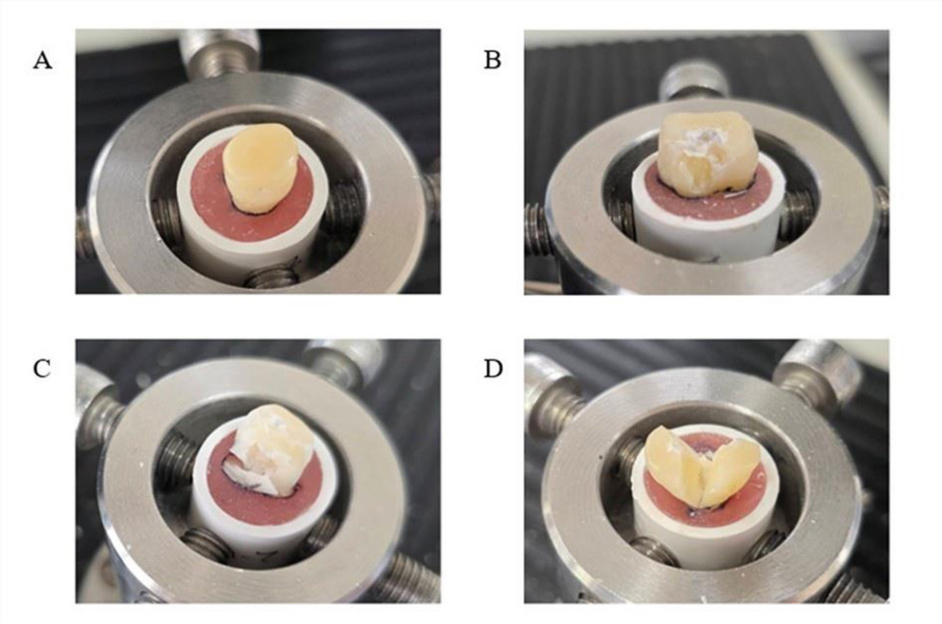

Figure 3 Failure modes (A) type I; (B) type II; (C and D) type III

Levene's test. One-way analysis of variance (ANOVA) was performed to compare group means, followed by Tukey's honestly significant difference (HSD) post hoc test for pairwise comparisons. Statistical significance was set at p-value=0.05.

Results

No visible cracks or fractures were observed in any sample following cyclic loading. The mean fracture resistance values for each group are presented in Table 1. One-way analysis of variance (ANOVA) revealed a statistically significant difference among the groups (p-value=0.008). According to Tukey's honestly significant difference (HSD) post hoc test, no significant difference was found between Group 2 (shallow occlusal canal; 2,742.88±354.37 N) and Group 3 (shallow central dowel; 2,807.30±373.03 N) (p-value=0.914). However, both experimental groups (Groups 2 and 3) exhibited significantly higher fracture resistance than the control group (Group 1; 2,309.33±341.67 N) (p-value=0.029 and 0.011, respectively).

Table 1 Fracture resistance values (N) (n=10)

Groups	Mean±S.D. (N)
Group 1: Control	2,309.33±341.67[a]
Group 2: Shallow occlusal canal	2,742.88±354.37[b]
Group 3: Shallow central dowel	2,807.30±373.03[b]

Groups with the same superscript letters are not significantly different (p-value>0.05)
S.D.=standard deviation, N=newton

The distribution of failure modes for each group is illustrated in Figure 4. Type II failure, characterized by mixed fracture involving both the restoration and tooth structure, was the most frequently observed mode in both shallow retentive design groups.

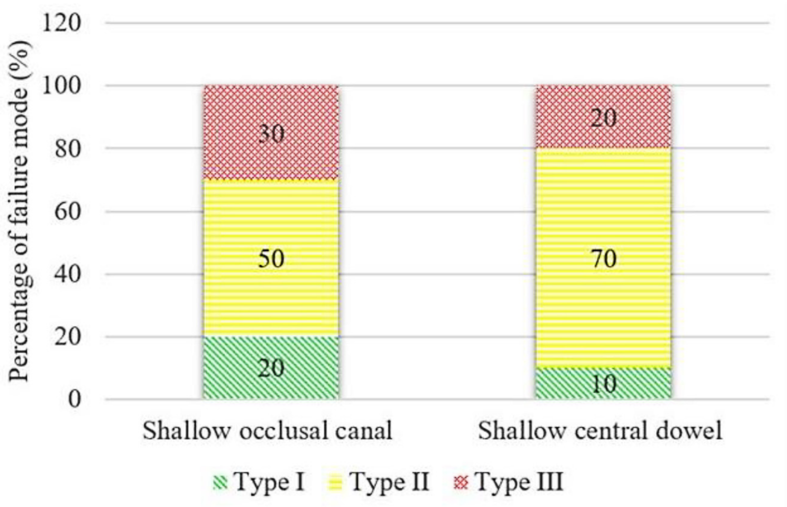

Figure 4 Distribution of failure modes (n=10)

Discussion

The present study evaluated the effect of shallow retentive preparation designs on the fracture resistance of molar teeth restored with resin nanoceramic overlay restorations. No statistically significant difference was observed between the two experimental designs. However, both groups exhibited significantly higher fracture resistance than the control group. Therefore, the null hypothesis was accepted. These findings suggest that, under the tested conditions, adhesive restorations incorporating shallow retentive features may provide fracture resistance greater than that of sound teeth.

To date, no studies have directly evaluated the effect of shallow occlusal canal and shallow central dowel designs on the fracture resistance of restored molars, thereby limiting direct comparisons with previous literature. Nevertheless, the present findings demonstrated no significant difference in fracture resistance between the two shallow retentive designs. This result is consistent with previous studies that reported variations in preparation design, particularly those related to axial wall height, which did not significantly influence fracture strength[13,23].

The adhesive system likely played a key role in the enhanced fracture resistance observed in this study. Resin luting agents with high bond strength have been shown to reduce stress concentration by absorbing occlusal forces at the tooth-restoration interface. This stress modulation promotes the formation of a cohesive tooth-restoration complex, which may help explain the favorable mechanical outcomes reported in this study[13,24,25]. Another contributing factor is the occlusal thickness of the restorations. Previous studies have demonstrated that increased occlusal thickness is positively associated with higher fracture load capacity[26,27]. In the present study, the restorations were fabricated with a standardized minimum thickness of 1.5 mm, as recommended by the manufacturer for hybrid ceramic materials to ensure sufficient mechanical performance in load-bearing areas. Furthermore, the design-specific increase in material volume at the central region achieved through both shallow retentive designs may have further enhanced fracture resistance. These designs avoided sharp internal angles and were positioned directly beneath the point of load application, thereby improving the restoration's ability to distribute occlusal stress and resist failure[2-4].

Collectively, the combination of adhesive bonding, adequate material thickness, and favorable internal geometry likely contributed to the mechanical integrity observed in both experimental groups.

These results are further supported by the preliminary data obtained using a similar experimental framework, which evaluated the same shallow retentive designs with lithium disilicate as the restorative material. In that study, fracture resistance values reached approximately 2,900 N, closely matching those observed in the present investigation using a resin nanoceramic. This similarity suggests that when preparation geometry, adhesive protocol, and occlusal thickness are standardized, the type of restorative material, whether resin nanoceramic or lithium disilicate, may have only a limited effect on overall fracture resistance.

In the present study, both shallow retentive designs predominantly exhibited mixed failure modes involving the tooth-restoration structure. This pattern may be attributed to the similar elastic modulus between the resin nanoceramic and dentin, combined with the adhesive and stress-distributing properties of the resin cement. Such mechanical compatibility likely supports the formation of a monoblock structure, enabling efficient stress distribution across the bonded complex[24]. When occlusal forces are applied, the restoration may transmit and dissipate stress effectively along the underlying dentin, allowing the bonded interface to share the functional load until the collective strength is exceeded, resulting in a mixed fracture mode[27,28].

Interestingly, the restored groups exhibited significantly higher fracture resistance than the intact group. This outcome may be attributed to the comparable elastic modulus among the restorative components, which facilitates the formation of a structurally unified complex capable of efficient stress distribution[24,29]. In contrast, intact teeth possess a high-modulus enamel layer that differs markedly from the underlying dentin, potentially limiting their ability to absorb and dissipate stress along the tooth's long axis[30]. Additionally, the use of Panavia V5 resin cement, which exhibits high microtensile bond strength, likely enhanced the durability of the adhesive interface and contributed to the integrity of the tooth–restoration monoblock, offering superior mechanical performance compared to the unaltered natural tooth[9]. The application of selective enamel etching may have further optimized enamel bond strength, particularly at the margins, contributing to improved stress transfer and overall fracture resistance[31,32].

It is also noteworthy that the intact specimens were primarily third molars, which are known to exhibit irregular occlusal topography and a greater number of accessory grooves than first or second molars[33]. These anatomical features have been associated with increased stress concentration and reduced fracture resistance[34, 35]. Although the occlusal morphology of the control and experimental groups was not identical, the restorations were designed to enhance fracture resistance rather than reproduce the exact occlusal anatomy of natural teeth. This emphasis on biomechanical performance is more clinically relevant for long-term success. Moreover, the use of standardized biogeneric design protocols helped minimize variability and may have contributed to more favorable stress distribution under loading conditions compared with the irregular occlusal features of third molars.

From a clinical perspective, the shallow occlusal canal design may provide enhanced resistance to dislodgement due to increased mechanical interlocking, albeit at the expense of greater tooth structure removal. In contrast, the shallow central dowel design is more conservative but offers comparatively lower retentive stability. Given that both designs demonstrated comparable fracture resistance and failure patterns, the choice of design should be guided by specific clinical circumstances. For instance, in teeth with existing MOD cavities, the occlusal canal design may provide better adaptation to compromised structures while enhancing mechanical retention.

This study was limited to two preparation designs and a single hybrid ceramic material. Simulated intraoral aging was performed to approximate six months of clinical service using 5,000 thermocycles and 120,000 mechanical loading cycles. However, the exclusive use of vertical loading, the absence of periodontal ligament supports due to acrylic resin embedding, and the lack of oral variables, such as saliva and pH fluctuations that may influence adhesive performance and fracture resistance, limit the direct translation of these findings to clinical conditions. These limitations should be considered when interpreting the results. Future studies should incorporate a broader range of designs, restorative materials, extended aging protocols, and more clinically relevant testing conditions.

Conclusion

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. No statistically significant difference in fracture resistance was found between the shallow occlusal canal and shallow central dowel designs, indicating that both preparation approaches offer comparable mechanical performance.

2. Both modified retentive designs demonstrated fracture resistance greater than that of intact molars, suggesting that resin nanoceramic overlays with shallow retentive features may be a clinically acceptable option for occlusal rehabilitation.

Acknowledgement

The authors would like to express their sincere appreciation to the staff and personnel of the Research Laboratory, Office of Research and Innovation Development, Faculty of Dentistry, Prince of Songkla University, for their valuable assistance and support throughout the experimental procedures and data collection. The authors also acknowledge GC Corporation (Tokyo, Japan) for providing the hybrid ceramic materials at a research-discounted rate.

Author contributions

Kanokrat Sapdeemongkol: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Project administration. Boonlert Kukiattrakoon: Conceptualization, Methodology, Resources, Data curation, Writing – review & editing, Supervision, Project administration. Chirayu Ruengrungsom: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – review & editing, Supervision, Project administration.

Ethical approval

The research study obtained ethical approval (EC6612-056) from the Faculty of Dentistry, Prince of Songkla University, Thailand.

Funding sources

This study was supported by the Basic Research Grant, Fiscal Year 2024 (grant reference code 25313, DEN6702049S) from Prince of Songkla University, Thailand.

Conflict of interest

There are no potential conflicts of interest to declare.

References

1. Falahchai M, Babaee Hemmati Y, Neshandar Asli H, Rezaei E. Effect of tooth preparation design on fracture resistance of zirconia-reinforced lithium silicate overlays. J Prosthodont 2020;29:617–22.
2. Ferraris F. Posterior indirect adhesive restorations (PIAR): preparation designs and adhesthetics clinical protocol. Int J Esthet Dent 2017;12:482–502.
3. Veneziani M. Posterior indirect adhesive restorations: updated indications and the morphology driven preparation technique. Int J Esthet Dent 2017;12:204–30.

4. Politano G, Van Meerbeek B, Peumans M. Nonretentive bonded ceramic partial crowns: concept and simplified protocol for long-lasting dental restorations. J Adhes Dent 2018;20:495–510.
5. Schlichting LH, Maia HP, Baratieri LN, Magne P. Novel-design ultra-thin CAD/CAM composite resin and ceramic occlusal veneers for the treatment of severe dental erosion. J Prosthet Dent 2011;105:217–26.
6. Shams P. Narrative review of posterior overlay preparation designs: evolution, trends, and insights. J Dentomaxillofac Radiol Pathol Surg 2024;13:20–34.
7. Xie C, Han Y, Zhao X-Y, Wang Z-Y, He H-M. Microtensile bond strength of one-and two-step self-etching adhesives on sclerotic dentin: the effects of thermocycling. Oper Dent 2010;35:547–55.
8. Perdigão J. Dentin bonding: variables related to the clinical situation and the substrate treatment. Dent Mater 2010;26:e24–37.
9. Vergano EA, Baldi A, Comba A, Italia E, Ferrero G, Femiano R, et al. Bond strength stability of different dual-curing adhesive cements towards cad-cam resin nanoceramic: an in vitro study. Appl Sci 2021;11:3966.
10. Magne P, Cheung R. Numeric simulation of occlusal interferences in molars restored with ultrathin occlusal veneers. J Prosthet Dent 2017;117:132–7.
11. Fernandes N, Vally Z, Sykes L. The longevity of restorations: a literature review. S Afr Dent J 2015;70:410–3.
12. Amesti-Garaizabal A, Agustín-Panadero R, Verdejo-Solá B, Fons-Font A, Fernández-Estevan L, Montiel-Company J, et al. Fracture resistance of partial indirect restorations made with CAD/CAM technology. A systematic review and meta-analysis. J Clin Med 2019;8:1932.
13. Channarong W, Lohawiboonkij N, Jaleyasuthumkul P, Ketpan K, Duangrattanaprathip N, Wayakanon K. Fracture resistance of bonded ceramic overlay restorations prepared in various designs. Sci Rep 2022;12:16599.
14. Alberto Jurado C, Kaleinikova Z, Tsujimoto A, Alberto Cortés Treviño D, Seghi RR, Lee DJ. Comparison of fracture resistance for chairside CAD/CAM lithium disilicate crowns and overlays with different designs. J Prosthodont 2022;31:341–7.
15. Ferraris F, Sammarco E, Romano G, Cincera S, Marchesi G. Comparison of posterior indirect adhesive restorations (PIAR) with different preparation designs according to the adhesthetics classification. Part 1: Effects on the fracture resistance. Int J Esthet Dent 2021;16:144–67.
16. Gracis S, Thompson VP, Ferencz JL, Silva NR, Bonfante EA. A new classification system for all-ceramic and ceramic-like restorative materials. Int J Prosthodont 2015;28: 227–35.
17. Guess PC, Schultheis S, Wolkewitz M, Zhang Y, Strub JR. Influence of preparation design and ceramic thicknesses on fracture resistance and failure modes of premolar partial coverage restorations. J Prosthet Dent 2013;110:264–73.
18. Goujat A, Abouelleil H, Colon P, Jeannin C, Pradelle N, Seux D, et al. Mechanical properties and internal fit of 4 CAD-CAM block materials. J Prosthet Dent 2018;119:384–9.
19. Kim S-Y, Kim B-S, Kim H, Cho S-Y. Occlusal stress distribution and remaining crack propagation of a cracked tooth treated with different materials and designs: 3D finite element analysis. Dent Mater 2021;37:731–40.
20. Andrade JP, Stona D, Bittencourt HR, Borges GA, Burnett LHJ, Spohr AM. Effect of different computer-aided design/computer-aided manufacturing (CAD/CAM) materials and thicknesses on the fracture resistance of occlusal veneers. Oper Dent 2018;43:539–48.
21. Burke FJ. The effect of variations in bonding procedure on fracture resistance of dentin-bonded all-ceramic crowns. Quintessence Int 1995;26:293–300.
22. Gierthmuehlen PC, Spitznagel FA, Koschate M, Bonfante EA, Prott LS. Influence of ceramic thickness and dental substrate on the survival rate and failure load of non-retentive occlusal veneers after fatigue. J Esthet Restor Dent 2024;36:373–80.
23. Hoopes W, Cushen S, DuVall N, Wajdowicz M, Brewster J, Roberts H. Failure load effect of molar axial wall height with CAD/CAM ceramic crowns with moderate occlusal convergence. J Esthet Restor Dent 2018;30:249–53.
24. Fonseca RB, Fernandes-Neto AJ, Correr-Sobrinho L, Soares CJ. The influence of cavity preparation design on fracture strength and mode of fracture of laboratory-processed composite resin restorations. J Prosthet Dent 2007;98:277–84.
25. Pilecco RO, da Rosa LS, Pereira GKR, Tribst JPM, May LG, Valandro LF. The loss of resin cement adhesion to ceramic influences the fatigue behavior of bonded lithium disilicate restorations. J Mech Behav Biomed Mater 2023;148:106169.
26. Zhang Y, Lai H, Meng Q, Gong Q, Tong Z. The synergetic effect of pulp chamber extension depth and occlusal thickness

on stress distribution of molar endocrowns: a 3-dimensional finite element analysis. J Mater Sci Mater Med 2022;33:56.
27. Albelasy E, Hamama HH, Tsoi JKH, Mahmoud SH. Influence of material type, thickness and storage on fracture resistance of CAD/CAM occlusal veneers. J Mech Behav Biomed Mater 2021;119:104485.
28. Lauvahutanon S, Takahashi H, Shiozawa M, Iwasaki N, Asakawa Y, Oki M, et al. Mechanical properties of composite resin blocks for CAD/CAM. Dent Mater J 2014;33:705–10.
29. Ausiello P, Apicella A, Davidson CL. Effect of adhesive layer properties on stress distribution in composite restorations: a 3D finite element analysis. Dent Mater 2002;18:295–303.
30. Chun KJ, Choi H, Lee J-Y. Comparison of mechanical property and role between enamel and dentin in the human teeth. J Dent Biomech 2014;5:1758736014520809.
31. Frankenberger R, Lohbauer U, Roggendorf MJ, Naumann M, Taschner M. Selective enamel etching reconsidered: better than etch-and-rinse and self-etch? J Adhes Dent 2008;10:339–44.
32. Kumagai RY, Takagaki T, Sato T, Nikaido T, Giannini M, Reis A, et al. Resin cement/enamel interface: a morphological evaluation of the acid-base resistant zone, enamel etching pattern, and effect of thermocycling on the microshear bond strength. J Adhes Dent 2023;25:71–8.
33. Hasiuk PA, Vorobets AB, Demkovych AY, Tkachenko IM, Klitynska OV, Rosolovska SO, et al. Features of occlusal correlations of molars in the dental clinic. Wiad Lek 2021;74:1130–3.
34. Wan B, Shahmoradi M, Zhang Z, Shibata Y, Sarrafpour B, Swain M, et al. Modelling of stress distribution and fracture in dental occlusal fissures. Sci Rep 2019;9:4682.
35. Kim H-W, Choi B-H, Bae E-J, Lim J-Y. Comparison of stress distribution in dental crown with different cusp angles: 3D finite element analysis. Comput Methods Biomech Biomed Engin 2019;22:251–8.