The Saudi Dental Journal (2026) 38:91
https://doi.org/10.1007/s44445-026-00201-8

RESEARCH

Comparison of fracture resistance among restorative techniques for endodontically treated mandibular premolars: an in vitro study

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Received: 28 March 2026 / Accepted: 8 June 2026

Abstract

Endodontically treated teeth often have compromised tooth structure, which increases their susceptibility to fracture. This in vitro study compared the fracture resistance of endodontically treated mandibular premolars restored using the sandwich technique, Nayyar core composite, and semi-direct composite onlay. Seventy-six extracted mandibular premolars were randomly allocated into four groups ($n=19$): intact teeth (control), conventional sandwich technique, Nayyar core composite, and semi-direct composite onlay. All groups except the control teeth group underwent standardized root canal treatment and obturation, followed by composite restoration according to the group allocation. Specimens were loaded axially in a universal testing machine until fracture. Fracture resistance was recorded in kilonewtons (kN). Data were analyzed using one-way ANOVA and Dunnett T3 post-hoc tests ($p<0.05$). Mean fracture resistance was highest in the intact control group (8.70 ± 4.09 kN), followed by the sandwich technique (7.50 ± 1.55 kN), Nayyar core composite (6.10 ± 1.61 kN), and semi-direct composite onlay (4.94 ± 3.16 kN). The overall difference among the groups was statistically significant ($p=0.001$). Post-hoc analysis showed significant differences between the control and semi-direct onlay groups ($p=0.019$) and between the sandwich technique and semi-direct onlay groups ($p=0.022$). Within the limitations of this in vitro study, the sandwich technique demonstrated the highest fracture resistance when compared with Nayyar core composite restoration and semi-direct composite onlay in endodontically treated mandibular premolars with conservative access preparation and intact marginal ridges.

Keywords Fracture resistance · Endodontically treated teeth · Sandwich technique · Nayyar core composite · Semi-direct composite onlay

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1 Introduction

Root canal treatment involves access preparation and chemomechanical instrumentation of the root canal space, which may alter tooth biomechanics and increase susceptibility to fracture, particularly when substantial tooth structure has been lost (Bhuva et al. 2021; Soares et al. 2018). Consequently, restoring endodontically treated teeth (ETT) remains challenging because they are often structurally weaker than vital teeth (Belli et al. 2015).

Post-endodontic restorations should provide an effective coronal seal, restore function, and protect the remaining tooth structure (Bhuva et al. 2021; Taheri et al. 2021). Leakage into the root canal system may occur through several routes: apically externally via exposed cementum accessory or secondary canals, or surface defects and coronally through the access cavity (Limkangwalmongkol et al.

Published online: 22 June 2026

1991). Among these, apical leakage was previously thought to be the most prevalent route. However, Ray and Trope (1995) later highlighted the strong association between the quality of the coronal restoration and the periapical status of ETT, while Tronstad et al. (2000) further reported that poor coronal restoration reduces endodontic success rates.

Adhesive composite resin is widely used due to its favorable aesthetics, conservative tooth preparation, and acceptable mechanical properties. Modern resin composites have evolved through improvements in filler systems and reinforcement approaches, including nanofibre addition, to enhance their mechanical behavior and durability as restorative materials (Cho et al. 2022). Clinically, adhesive composite restorations have also demonstrated favorable longevity in ETT, with cavities involving up to three surfaces reported to have a mean survival of approximately 13 years (Dammaschke et al. 2012).

In addition to material selection, the restorative technique may influence stress distribution and fracture resistance of a tooth. Sandwich technique, Nayyar core composite, and semi-direct composite onlay are among the restorative options for endodontically treated posterior teeth, but comparative evidence for their behavior in mandibular premolars remains clinically relevant because premolars are exposed to unfavorable lateral stresses.

This study, therefore, aimed to compare the fracture resistance of endodontically treated mandibular premolars restored using these three techniques. The null hypothesis was that there would be no significant difference in fracture resistance among the tested restorative techniques.

2 Materials and methods

2.1 Study design and setting

This in vitro experimental study was conducted using permanent mandibular premolars extracted not for the purpose of this study. Ethical approval was obtained from the International Islamic University Malaysia Research Ethics Committee (IREC 2024-065).

2.2 Sample size determination

The sample size was calculated using a statistical software (G*Power version 3.1.9.7) based on the F-test family for one-way analysis of variance (ANOVA). Using an effect size of 0.4, a power of 0.80, and four study groups, the required total sample size was 76 teeth.

2.3 Inclusion and exclusion criteria

Extracted mature permanent mandibular premolars with completely formed roots and a single canal were collected from patients who attended the outpatient clinic for tooth extraction due to periodontal or orthodontic reasons. The selected teeth had an average intercuspal diameter of 4.8 ± 0.5 mm, mesiodistal diameter of 6.6 ± 0.5 mm, tooth length of 22 ± 1 mm, and root length of 13 ± 1 mm. Teeth with caries, previous restorations, structural defects, clinically detectable cracks or fractures, abrasion, or primary teeth were excluded.

2.4 Sample preparation

The extracted teeth were handled using standard universal precautions in accordance with institutional laboratory biosafety procedures and the Occupational Safety and Health Administration (OSHA) bloodborne pathogen recommendations. The specimens were cleaned of any soft tissue remnants using an ultrasonic scaler (LM-ProPower™, LM-Dental™; Finland) and stored in sealed containers until experimental use. The extracted teeth were manually allocated into four groups of 19 specimens each, ensuring a macroscopically uniform distribution of tooth types across groups without formal sequence randomization. They were categorized into: Group 1: intact teeth (control group), Group 2: sandwich technique, Group 3: Nayyar core composite, and Group 4: semi-direct composite onlay.

Standardized root canal treatment was carried out for all groups except those in the control group (Group 1). Following conventional access cavity preparation, root canals were prepared to a working length 1 mm short of the anatomical apex using rotary files (HyFlex CM, COLTENE; United States) with a cordless endomotor (E-CONNECT, Eighteeth, Changzhou Sifary Medical Technology Co., Ltd.; China) to size 30/0.04. The canals were irrigated with 2.5% sodium hypochlorite (Malay-Sino Chemical Industries Sdn. Bhd., Malaysia) between files, followed by final irrigation with 17% EDTA solution (Meta Biomed MD-Cleanser, Korea), and dried with size 25 paper points.

Single-cone obturation was performed using matched-taper gutta-percha (GP) (ProTaper Universal Gutta-Percha Points, Dentsply Sirona; United Kingdom) and a resin-based sealer (Meta Biomed ADSEAL Root Canal Sealer, Korea). Excess GP was removed to 2 mm below the cemento-enamel junction (CEJ) using a portable fast pack obturation system (Fast Pack PRO, Eighteeth, Changzhou Sifary Medical Technology Co., Ltd.; China). Subsequently, teeth in Groups 2–4 were restored using a light-cured universal nano-hybrid composite resin (G-ænial® Sculpt; GC America Inc.; Alsip, IL, United States) according to the

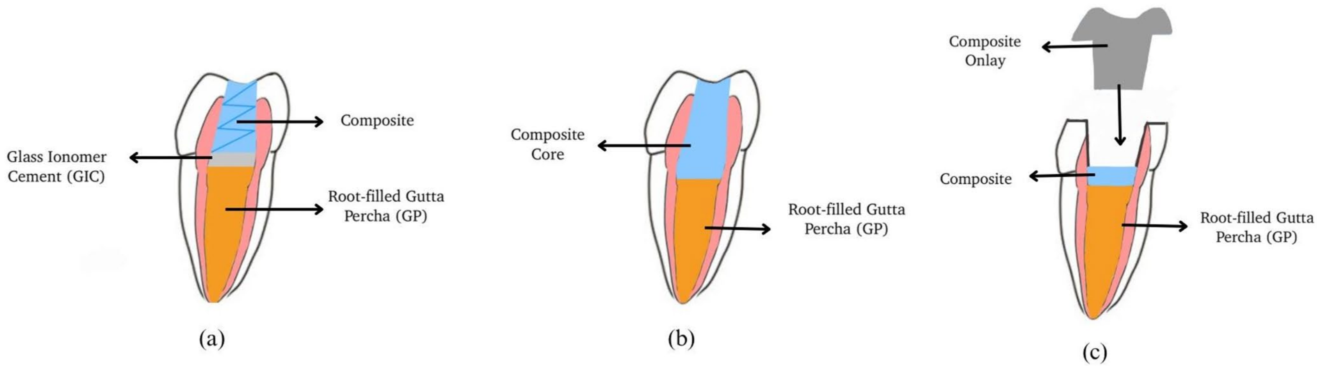

Fig. 1 Illustration of different restorative techniques: (**a**) Sandwich technique, (**b**) Nayyar core composite, and (**c**) Semi-direct composite onlay

Table 1 Fracture resistance of mandibular premolars restored using different composite restorative techniques

Group	Restorative Technique	*n*	Fracture resistance, Mean ± SD (kN)
1	Control	19	8.70 ± 4.09
2	Sandwich Technique	19	7.50 ± 1.55
3	Nayyar core Technique	19	6.10 ± 1.61
4	Semi-direct Onlay	19	4.94 ± 3.16
p-value			**0.001***

allocated restorative technique. For Group 2, Glass ionomer cement (GIC) (GC Fuji IX GP® FAST, GC Corporation; Japan) was placed above the GP to a thickness of approximately 2 mm. Total-etching was performed using 37% phosphoric acid (Eco-Etch Etching Gel, Ivoclar Vivadent; Liechtenstein), followed by application of a universal adhesive resin (G-Premio BOND, GC Corporation; Japan) according to the manufacturer's recommendation. Composite resin was then placed in 2-mm increments and light-cured for 20 s per increment until the cavity was restored to the occlusal level (Fig. 1a). In Group 3, total-etching and universal adhesive resin were performed and the cavity was restored with composite resin from the level above the GP to the occlusal surface in 2-mm increments, with each increment light-cured for 20 s (Fig. 1b). In Group 4, the same restorative procedures as described for Group 3 were performed before construction of a silicone putty index (KromopanSil Putty, LASCOD; Italy). Onlay preparation was then performed with 1.5-mm buccal cusp reduction with bevel, 1-mm lingual cusp reduction, a 1-mm occlusal shoulder with bevel, and mesial and distal boxes connected by a central isthmus. An alginate impression (Hygedent Alginate Impression Material, China) was taken and poured with die silicone (Die Silicone, VOCO GmbH; Germany) to fabricate the working cast prior to composite onlay construction. The onlay was cemented using resin luting cement (3 M™ ESPE™ RelyX™ Unicem, Germany) (Fig. 1c).

2.5 Fracture resistance testing

All specimens were subjected to thermocycling in sequential water baths at 5 °C, 37 °C, and 55 °C for 2500 cycles, with a dwell time of 30 s and a transfer time of 5 s, as described in a previous study (Lin et al. 2020). Before testing, the teeth were mounted in cold-cure acrylic resin (Denture Base Polymers Self-Curing, HUGE; Shandong, China) parallel to their long axes up to the CEJ level (Aslan et al. 2018; Lin et al. 2020). A 2.0-mm tapered conical stainless-steel tip was centrally positioned on the occlusal surface of each mandibular premolar and aligned parallel to the long axis of the tooth. All specimens were subjected to compressive axial loading using a universal testing machine (UTM) (INSTRON 5967, 30 kN) at a crosshead speed of 1.0 mm/min until fracture. The maximum load at fracture was recorded in kilonewtons (kN).

2.6 Statistical analysis

Statistical analysis was performed using a statistical software (IBM® SPSS® Statistics version 25.0, IBM Corp.; Armonk, NY, United States). Fracture resistance values were expressed as mean and standard deviation (SD). The assumption of normality was assessed using the Kolmogorov–Smirnov test, while homogeneity of variance was evaluated using Levene's test. One-way ANOVA was used to compare mean fracture resistance among the four groups. Dunnett T3 post-hoc test was performed for pairwise multiple comparisons when equal variances were not assumed. The level of statistical significance was set at $p < 0.05$.

3 Results

A total of 76 mandibular premolar teeth were divided into four groups and subjected to compressive axial loading using a UTM. Descriptive statistics for fracture resistance are presented in Table 1. The control group demonstrated

Table 2 Dunnett T3 post-hoc pairwise comparisons of fracture resistance among restorative groups

Comparison	Mean Difference	Std. Error	*p*-value
Control vs. Sandwich technique	1.20	0.91	0.791
Control vs. Nayyar core technique	1.82	0.91	0.386
Control vs. Semi-direct onlay	3.76	0.91	**0.019***
Sandwich technique vs. Nayyar core technique	0.63	0.91	0.777
Sandwich technique vs. Semi-direct onlay	2.56	0.91	**0.022***
Nayyar core technique vs. Semi-direct onlay	1.94	0.91	0.135

the highest mean fracture resistance (8.70 ± 4.09 kN), followed by the sandwich technique group (7.50 ± 1.55 kN), Nayyar core technique group (6.10 ± 1.61 kN), and semi-direct onlay group (4.94 ± 3.16 kN).

Data are presented as mean ± standard deviation. One-way ANOVA showed a statistically significant difference in fracture resistance among the four groups ($p = 0.001$). Post-hoc Dunnett T3 comparisons are presented in Table 2. SD = standard deviation; kN = kilonewton.

Mean fracture resistance differed significantly among the four groups ($p = 0.001$). Compared with the control group, mean fracture resistance was 13.79% lower for the sandwich technique, 29.89% lower for Nayyar core composite, and 43.22% lower for the semi-direct composite onlay (Fig. 2). Dunnett T3 post-hoc analysis (Table 2) showed significant differences between the control and semi-direct onlay groups ($p = 0.019$) and between the sandwich technique and semi-direct onlay groups ($p = 0.022$).

Mean difference was calculated as the first group minus the second group. Pairwise comparisons were performed using Dunnett T3 post-hoc test. *$p < 0.05$ indicates a statistically significant difference.

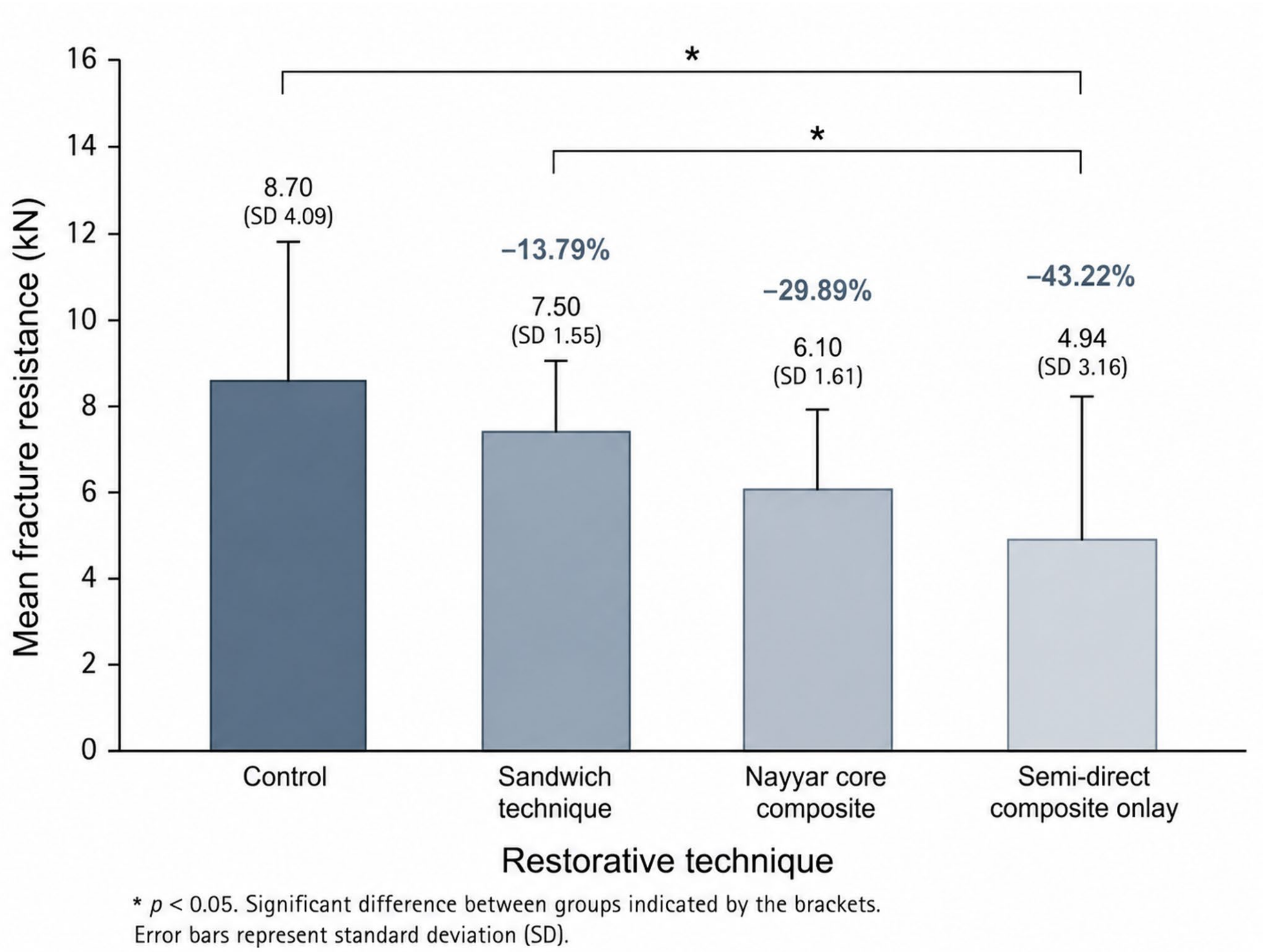

Fig. 2 Mean fracture resistance of mandibular premolars restored using different composite restorative techniques

4 Discussion

Restoration of ETT is important for providing a coronal seal and protecting the remaining tooth structure from fracture (Bhuva et al. 2021). Cuspal protection in posterior teeth has been reported to reduce fracture incidence and improve clinical outcomes, although reported outcomes vary according to tooth type, amount of remaining tooth structure, and restorative design (Suksaphar et al. 2017). In addition to the mechanical properties of the restorative material, tooth position and remaining tooth structure should also be considered. Premolars, for instance, may be more susceptible than molars to damaging lateral stresses because of their occlusal loading pattern and position in the dental arch (Schwartz and Robbins 2004).

Compared with intact teeth, the lower fracture resistance observed in the restored ETT groups was expected, as root canal treatment and restorative procedures reduce the amount of remaining tooth structure and may alter stress distribution. Loss of coronal and radicular tooth structure is a major factor affecting fracture resistance and restoration planning in ETT (Faria et al. 2011; Soares et al. 2018). The present findings support this concept, as all restored ETT groups showed lower mean fracture resistance than intact teeth. The higher fracture resistance observed in the sandwich technique group may be associated with the use of GIC as an intermediate base beneath the composite restoration. They act as a stress-absorbing layer, which may help reduce marginal stress generated by polymerization shrinkage (Ferracane 2008; Jung et al. 2024). Meanwhile, the Nayyar core group demonstrated a moderate level of fracture resistance among the restored groups. This finding may be related to the intracoronal extension of composite resin into the pulp chamber and coronal canal space, which can improve restoration retention when used with contemporary adhesive protocols (Patel et al. 2025). This approach may be particularly useful in teeth with narrow crown morphology, as it increases the internal bonded surface area. The stress concentrated at the coronal cavity margin will reduce, thus strengthening the restoration structure (Bhuva et al. 2020; Ulusoy and Alagoz 2021). The semi-direct onlay group showed the lowest mean fracture resistance in the present study. However, the present findings contrast with a previous study, which reported significantly higher fracture resistance in endodontically treated premolars restored with composite onlays compared with direct composite restorations, suggesting that cuspal coverage may improve reinforcement of weakened tooth structure (Mohd Mutalabisin et al. 2025).

In general, the differences in fracture resistance outcomes could be explained by several limitations of the present study. Thermocycling was used to simulate intraoral temperature changes and artificial aging; however, thermocycling protocols vary widely across studies, which limits direct comparison with other investigations (Eliasson and Dahl 2020). In addition, the specimens were mounted in cold-cure acrylic resin, which does not fully reproduce the biomechanical behavior of alveolar bone and periodontal ligament support. This method was selected because acrylic resin mounting is commonly used in in vitro fracture-resistance studies and provides practical advantages, including specimen stabilization, dimensional stability, cost-effectiveness, and accessibility within the available laboratory setting (Aslan et al. 2018; Lin et al. 2020). Several studies have used elastomeric material such as polyurethane resin with simulated periodontal ligament as mounting material (Lopes-Olhê et al. 2025; Soares et al. 2005). The absence of periodontal ligament simulation may have resulted in a more rigid stress distribution pattern than that observed under physiological conditions, potentially affecting fracture behavior and load distribution. Moreover, the loading tip used was not customized to the occlusal morphology of mandibular premolars; therefore, the compressive force may have been concentrated over a limited contact area rather than distributed across the cuspal inclines and occlusal surface. This may have influenced the fracture resistance values, as the geometry and contact area of the load application device have been shown to affect the behavior of restored premolars during mechanical fracture testing (da Silva et al. 2012). Lastly, the present study was limited to mandibular premolars with occlusal access preparation only and intact marginal ridges, whereas many fracture resistance studies commonly use MOD or proximal cavity designs to simulate greater structural compromise (Alshiddi and Aljinbaz 2016; Mincik et al. 2016; Mohd Mutalabisin et al. 2025). Under such compromised conditions, restorations with greater cuspal coverage, such as onlay restorations, may offer additional biomechanical advantages by reducing cuspal deflection. As minimally invasive endodontic and restorative concepts are gaining popularity, it is important to assess the need for cuspal coverage of ETT (Bhuva et al. 2020). The present study contributes to this area by evaluating the fracture resistance of endodontically treated mandibular premolars with occlusal access preparation only and intact marginal ridges.

Future studies should evaluate the fracture behavior of endodontically treated premolars under more clinically relevant conditions, including cyclic loading and its fracture pattern, anatomically customized loading tips, improved mounting methods that better simulate periodontal ligament and alveolar bone support, and thermomechanical aging protocols to more accurately reproduce intraoral functional stresses.

5 Conclusion

Within the limitations of this in vitro study, the sandwich technique demonstrated superior fracture resistance compared with Nayyar core composite restoration and semi-direct composite onlay in endodontically treated mandibular premolars with minimally invasive endodontic access and intact marginal ridges. Therefore, it may represent a favorable restorative option for teeth with comparable clinical conditions.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s44445-026-00201-8.

Acknowledgements The authors would like to thank Mr. Muhammad Halim Paboh, a technical staff member from the Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA), for his assistance during the laboratory testing procedures. The authors are also grateful to Asst. Prof. Dr. Mohamad Shafiq Mohd Ibrahim, statistician, for his statistical advice.

Author contributions M. H. M. H: Conceptualization, Methodology, Supervision, Project administration, Writing – review and editing. D. Q. Z: Conceptualization, Methodology, Supervision, Writing – review and editing. U. Z: Investigation, Data curation, Formal analysis, Writing – original draft.S. N.H. M. N: Investigation, Data curation, Formal analysis, Writing – original draft.

Funding The authors did not receive funding support from any organization for the submitted work.

Data availability All data supporting the findings of this study are available within the paper and its Supplementary Information.

Declarations

Ethics approval Ethical approval was obtained from the International Islamic University Malaysia Research Ethics Committee (IREC 2024-065).

Competing interests The authors declare no competing interests.

References

Alshiddi IF, Aljinbaz A (2016) Fracture resistance of endodontically treated teeth restored with indirect composite inlay and onlay restorations – An in vitro study. Saudi Dent J 28(1):49–55. https://doi.org/10.1016/j.sdentj.2015.09.001

Aslan T, Sagsen B, Er Ö, Ustun Y, Cinar F (2018) Evaluation of fracture resistance in root canal-treated teeth restored using different techniques. Niger J Clin Pract 21(6):795–800. https://doi.org/10.4103/njcp.njcp_330_17

Belli S, Eraslan O, Eskitascioglu G (2015) Direct restoration of endodontically treated teeth: a brief summary of materials and techniques. Curr Oral Health Rep 2(4):182–189. https://doi.org/10.1007/s40496-015-0068-5

Bhuva B, Giovarruscio M, Rahim N, Bitter K, Mannocci F (2021) The restoration of root filled teeth: a review of the clinical literature. Int Endod J 54(4):509–535. https://doi.org/10.1111/iej.13438

Cho K, Rajan G, Farrar P, Prentice L, Prusty BG (2022) Dental resin composites: A review on materials to product realizations. Compos B Eng 230:109495. https://doi.org/10.1016/j.compositesb.2021.109495

da Silva GR, da Silva NR, Soares PV, Costa AR, Fernandes-Neto AJ, Soares CJ (2012) Influence of different load application devices on fracture resistance of restored premolars. Braz Dent J 23:484–489. https://doi.org/10.1590/S0103-64402012000500003

Dammaschke T, Nykiel K, Sagheri D, Schäfer E (2012) Influence of coronal restorations on the fracture resistance of root canal-treated premolar and molar teeth: A retrospective study. Aust Endod J 39(2):48–56. https://doi.org/10.1111/aej.12002

Eliasson ST, Dahl JE (2020) Effect of thermal cycling on temperature changes and bond strength in different test specimens. Biomater Investig Dent 7(1):16–24. https://doi.org/10.1080/26415275.2019.1709470

Faria ACL, Rodrigues RCS, de Almeida Antunes RP, de Mattos MGC, Ribeiro RF (2011) Endodontically treated teeth: characteristics and considerations to restore them. J Prosthodont Res 55(2):69–74. https://doi.org/10.1016/j.jpor.2010.07.003

Ferracane JL (2008) Buonocore Lecture. Placing dental composites—a stressful experience. Oper Dent 33(3):247–257. https://doi.org/10.2341/07-BL2

Jung MK, Jeon MJ, Kim JH, Son SA, Park JK, Seo DG (2024) Comparison of the stress distribution in base materials and thicknesses in composite resin restorations. Heliyon 10(3):e25040. https://doi.org/10.1016/j.heliyon.2024.e25040

Limkangwalmongkol S, Burtscher P, Abbott PV, Sandler AB, Bishop BM (1991) A comparative study of the apical leakage of four root canal sealers and laterally condensed gutta-percha. J Endod 17(10):495–499. https://doi.org/10.1016/S0099-2399(06)81797-8

Lin GS, Ghani NR, Ismail NH, Singbal K, Murugeshappa DG, Mamat N (2020) Fracture strength of endodontically treated lateral incisors restored with new zirconia reinforced rice husk nanohybrid composite. J Clin Exp Dent 12(8):e762–e770. https://doi.org/10.4317/jced.56864

Lopes-Olhê FC, de Assis HC, Creazzo G, Macedo AP, Carvalho MA, Torres-Carrillo AJS, Altube LG, Jacob G, Alves Dos Santos GN, Mazzi-Chaves JF, Sousa-Neto MD (2025) Biomechanical behavior of maxillary premolars with non-carious cervical lesions: Influence of minimally invasive endodontic access and restoration protocols. J Endod 51(12):1783–1792. https://doi.org/10.1016/j.joen.2025.07.019

Mincik J, Urban D, Timkova S, Urban R (2016) Fracture resistance of endodontically treated maxillary premolars restored by various direct filling materials: an in vitro study. Int J Biomater 2016:9138945. https://doi.org/10.1155/2016/9138945.

Mohd Mutalabisin FF, Fauzi FA, Ahmad N, Daud S (2025) Fracture resistance of direct composite and composite onlay on endo-treated upper premolar with MOD cavity. IJOHS 6(1):26–32. https://doi.org/10.31436/ijohs.v6i1.316

Patel SR, Youngson C, Jarad F (2025) Principles guiding the restoration of the root-filled tooth. Br Dent J 238:508–516. https://doi.org/10.1038/s41415-025-8401-4

Ray HA, Trope M (1995) Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J 28(1):12–18. https://doi.org/10.1111/j.1365-2591.1995.tb00150.x

Schwartz RS, Robbins JW (2004) Post placement and restoration of endodontically treated teeth: a literature review. J Endod 30(5):289–301. https://doi.org/10.1097/00004770-200405000-00001

Soares CJ, Pizi ECG, Fonseca RB, Martins LRM (2005) Influence of root embedment material and periodontal ligament simulation on fracture resistance tests. Braz Oral Res 19:11–16. https://doi.org/10.1590/s1806-83242005000100003

Soares CJ, de Paula Rodrigues M, Faria-E-Silva AL, Santos-Filho PCF, Veríssimo C, Kim HC, Versluis A (2018) How biomechanics can affect the endodontic treated teeth and their restorative procedures? Braz Oral Res 32:e76. https://doi.org/10.1590/1807-3107bor-2018.vol32.0076

Suksaphar W, Banomyong D, Jirathanyanatt T, Ngoenwiwatkul Y (2017) Survival rates against fracture of endodontically treated posterior teeth restored with full-coverage crowns or resin composite restorations: a systematic review. Restor Dent Endod 42(3):157–167. https://doi.org/10.5395/rde.2017.42.3.157

Taheri AT, Ikhar A, Nikhade PP, Tawani G, Patel A, Ali Z (2021) Comparative evaluation of fracture resistance of endodontically treated premolars with one remaining cavity wall restored using different techniques and materials: An in vitro study. Saudi Endod J 11(1):36–41. https://doi.org/10.4103/sej.sej_6_20

Tronstad L, Asbjørnsen K, Døving L, Pedersen I, Eriksen HM (2000) Influence of coronal restorations on the periapical health of endodontically treated teeth. Endod Dent Traumatol 16:218–221. https://doi.org/10.1034/j.1600-9657.2000.016005218.x

Ulusoy N, Alagoz LG (2021) Evaluation of two CAD/CAM materials for Nayyar core and post-retained restorations: Three-dimensional stress analysis. J Mech Behav Biomed Mater 117:104381. https://doi.org/10.1016/j.jmbbm.2021.104381