INTERNATIONAL DENTAL JOURNAL 75 (2025) 59–74

Concise review

Anterior Endocrowns as An Alternative to Core Crown restorations: A Systematic Review

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ARTICLE INFO

Article history:
Received 24 May 2024
Received in revised form
28 July 2024
Accepted 30 July 2024
Available online 20 September 2024

Key words:
Endodontically treated teeth
Nonvital
Post core-crown restorations
Endocrown
Ferrule effect
Fracture resistance

ABSTRACT

Restoring extensively damaged endodontically treated teeth presents a challenging task due to the state of biomechanical deterioration affecting long-term prognosis. Therefore, the study aims to assess and compare the biomechanical performance of endocrowns and post core-crown restorations in anterior endodontically treated teeth with severe coronal structure loss. Following PRISMA guidelines, a systematic search was conducted using PubMed, Scopus, Web of Science, and Google Scholar for articles published from January 2014 to March 2024. Two independent reviewers screened and selected studies based on the predefined inclusion and exclusion criteria. The included studies were analyzed using the QUIN tool for risk of bias assessment in in-vitro studies. Additionally, the biomechanical outcomes were collected for qualitative comparative analysis. Twelve studies were included in this systematic review. In most studies, Endocrowns demonstrated comparable fatigue resistance under load to failure to post core-crown restorations. Endocrowns without ferrule exhibited a higher rate of debonding but had significantly more repairable failures. Conversely, post core-crown restorations demonstrated higher fracture resistance with the presence of ferrule, but were associated with more catastrophic failure patterns.

List of abbreviations: ETT, endodontically treated teeth; ED, endocrown; PCC, post core-crown; FEA, finite element analysis; PBS, pull out bond strength; LDS, lithium disilicate ceramic; IDS, immediate dentin sealing; RCT, randomised clinical trial; mvM, maximal von mises (Stress); CAD/CAM, computer-aided design/computer-aided manufacturing; QUIN, quality in prognosis studies tool; GC, glass ceramic; GE2, glass ceramic endocrown with 2 mm ferrule; GE0, glass ceramic endocrown without ferrule; N, Newton; CEJ, cementoenamel junction; PBS, pull-out bond strength; MPa, Megapascal; ZrRNC, zirconia post and resin nano ceramic crown; ZrLDS, zirconia post and lithium disilicate ceramic crown; FbRNC, fiber post and resin nano ceramic crown; FbLDS, fiber post and lithium disilicate ceramic crown; EndoRNC, resin nano ceramic endocrown; EndoLDS, lithium disilicate ceramic endocrown; LE, lateral incisor endocrown; CE, central incisor endocrown; LP, lateral incisor post composite core ceramic crown; CP, central incisor post composite core ceramic crown; FNp, nanohybrid composite resin core with ferrule and crown; NfPf, fiber post composite resin core without ferrule and crown; NfNpFR, short-fiber reinforced composite resin core without ferrule and post, and crown; Eld, lithium disilicate endocrown; Erc, resin nanoceramic endocrown; GFPf+, glass fiber post composite core and ceramic crown with ferrule; GFPf-, glass fiber post composite core and ceramic crown without ferrule; Ef+, lithium disilicate endocrown with ferrule; Ef-, lithium disilicate endocrown without ferrule; LPCer, long glass fiber post composite core and ceramic crown; LPCpr, long glass fiber post composite core and crown; SPCer, short glass fiber post composite core and ceramic crown; SPCpr, short glass fiber post composite core and crown; EndoCer, ceramic endocrown; EndoCpr, composite endocrown; FE, finite element; ECIR, no ferrule endocrown; ECER, endocrown with 2 mm circumferential ferrule; PC4, post-core with 2 mm circumferential ferrule; PC3, post-core with 2 mm mesial, palatal, and distal ferrule; PC2, post-core with 2 mm mesial and distal ferrule; PC1, post-core with 2 mm distal ferrule; PC0, post-core without ferrule; LS, lithium disilicate; PICN, polymer-infiltrated ceramic network; Pmax, maximum principal stress; mvM, modified von mises stress; MPCC, metal post-and-core and leucite ceramic crown; LED, leucite ceramic endocrown; LDED, lithium disilicate ceramic endocrown.

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https://doi.org/10.1016/j.identj.2024.07.1216

Additionally, endocrowns generated lower stress levels in both the restorative material and the luting material compared to post core-crown restorations. Among the tested materials, lithium disilicate ceramics provided the best biomechanical properties. Overall, the studies included provided sufficient information for most evaluation criteria of the QUIN risk of bias assessment tool. Endocrowns are a viable and conservative approach for restoring endodontically treated anterior teeth, offering comparable biomechanical performance to traditional post core-crown restorations and less catastrophic failures. The findings of this systematic review suggest that endocrown restorations, especially with lithium disilicate ceramics and proper ferrule design, can improve fracture resistance and longevity of rehabilitated teeth, enhancing patient outcomes for severely damaged anterior endodontically treated teeth.

Introduction

Restoring extensively damaged endodontically treated teeth (ETT) presents a significant challenge due to the biomechanical deterioration that directly affects the long-term prognosis of the tooth.[1,2] Post retained core and crown restorations are still the most commonly practiced method of rehabilitation for ETT.[2-5] Intracanal post insertion was thought to reinforce and strengthen the restorative-dentin complex and enhance its resistance to fracture. Recently the literature provided that the main advantage of post insertion is the retention of the core foundation. Metal posts, due to their high elastic modulus, have a propensity to cause root fractures, whereas fiber posts tend to produce more favorable in vitro failure outcomes. Nonetheless, several studies reported that the invasive nature of intracanal post space preparation weakens the tooth and may also adversely impact the lifespan of endodontically treated teeth (ETT).[6-10] More often limiting the possibility of further intervention.[11]

The advancement of adhesive techniques and widespread adoption of CAD/CAM technology have shifted the clinical approach towards minimally invasive dentistry. Accordingly, indirect adhesive restorations have emerged as a well-established treatment modality for ETT, challenging the conventional post-and-crown concept.[12] Within this context, endocrown restorations have emerged as a practical and economical solution for restoring severely damaged ETT. First introduced by Pissis et al[13] in 1995 and later refined by Bindl and Mormann[14] in 1999, the endocrown concept represents a movement towards adhesive monolithic ceramic restorations that encompasses both the pulp chamber and cavity margins to restore the anatomical crown.[13] Endocrowns gain macro-mechanical anchorage from the internal portion of the pulp cavity and micro-mechanical bonding from its adhesive cementation.[15] Compared to traditional post-retained crowns, where concerns have been raised regarding the efficacy of intracanal bonding procedures and the selection of appropriate post materials, endocrowns offer a conservative simplification, with both the crown and the core buildup being a single unit.[16]

For posterior ETT, the role of the post to retain the core is less critical as they are subjected to predominantly vertical compressive masticatory loads. On the contrary, anterior teeth are obliquely loaded, thus the influence of post placement on the flexural behaviour of a tooth can be pivotal in resistance to fracture.[17-19] However, several studies have associated post placement with no improvement in biomechanical performance as well as high stress concentrations in the root, more often leading to unfavourable root fractures, even among adhesive post-retained buildups.[20-22]

Indeed, due to the lack of consensus on the most suitable treatment approach, especially for anterior dentition, conducting a systematic review was pertinent. Hence, this study aims to assess and compare the biomechanical performance of endocrowns and post, core-crown restorations in rehabilitating anterior endodontically treated teeth with severe coronal structure loss. The hypothesis being tested is that endocrowns are more conservative and exhibit superior biomechanical properties compared to (post-)core-crown restorations.

Material and methods

Information sources and search strategy

This systematic review was conducted and reported in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[23] The PICO question framework was used to provide the scope for this investigation and formulate the research question as follows: "In the prosthetic management of patients with endodontically treated anterior teeth (population), how do endocrowns (intervention) compare with post and core restorations (comparison) in terms of mechanical and physical properties, fracture resistance, and failure patterns (outcome)?". Accordingly, the search strategy utilised a combination of Medical Subject Headings (MeSH terms) and keywords in conjunction with Boolean operators (AND, OR, and NOT) to formulate the different search keyword combinations presented in Table 1. An online electronic search of online databases for articles published from January 2014 to March 2024 was conducted and resulted in a total of 1307 articles, 11 from PubMed, 14 from Scopus, 2 from Web of Science and 1280 from Google Scholar.

Table 1 – Search strategies and term adaptation for MEDLINE/PubMed, Google Scholar, Web of Science, and Scopus.

***PubMed:**
("Endo-crown" OR "Endocrowns" OR "no buildup crown" OR "no build-up crown" OR "no-post buildup crown" OR "no-post build-up crown) AND ("Post AND Core AND Restoration" OR "Post and Core Technique" OR "Post-and-core" OR "Post and core" OR "Post core and crown" OR "intrarradicular post core and crown") AND ("Anterior teeth" OR "Front teeth" OR "Incisors" OR "Canines") AND ("failure load" OR "fatigue" OR "cyclic load" OR "laboratory" OR "in vitro" OR "finite element" OR "in silico" OR "biomechanical") AND (2014/01/01[Date - Publication]: 2024/03/31 [Date - Publication])
***Scopus:**
TITLE-ABS-KEY((Endocrown OR "Endo-crown") AND (Post AND Core AND Restoration) AND ("Anterior teeth" OR "Front teeth" OR "Incisors" OR "Canines")) AND PUBYEAR > 2013 AND PUBYEAR < 2025
***Web of Science:**
TS=((Endocrown OR "Endo-crown") AND (Post AND Core AND Restoration) AND ("Anterior teeth" OR "Front teeth" OR "Incisors" OR "Canines")) AND PY=(2014-2024)
***Google Scholar:**
("Endocrown" OR "Endo-crown "endo crowns" OR "endo crown" OR "endodontic crown" OR "endodontic crowns" OR "adhesive endodontic crown" OR "adhesive endodontic crowns") AND ("Post and core" AND Restoration OR "Dowel core and crown" OR "post-retained crown" OR "Core-and-crown" OR "core and crown" OR "buildup and crown" OR "build-up and crown") AND ("Anterior teeth" OR "Front teeth" OR "Incisors" OR "Canines") AND follow up" OR "survival" OR "post-fatigue fracture" OR "failure rate" OR "failure resistance" OR "fracture resistance" OR "von mises stress" OR "failure mode" OR "fractography" OR "load to failure) AND (2014..2024)

Table 2 – Inclusion and exclusion criteria.

- **Inclusion Criteria:**
  -Studies published between 2014 and 2024.
  -Studies published in English Language.
  -In vitro studies or finite element studies.
  -Studies involving only human Anterior teeth (Central, Lateral or Canine).
  -Studies examining the biomechanical outcomes of endocrown restorations.
  -Studies including a control group, such as a sound tooth or post, core and crown restorations.
  -Studies assessing the failure patterns, fatigue life and fracture resistance of endodontically treated anterior teeth, expressed as the mean $\pm$ the standard deviation (SD) measured in Newtons (N) or MPa.
  - Biomechanical comparative Studies including both a study group and a control group, comparing properties of endocrowns with post, core and crown restorations.
- **Exclusion Criteria:**
  -Studies published outside the set timeframe (2014-2024).
  -Studies in languages other than English.
  -Studies involving endodontically treated bovine or resin teeth.
  -Studies involving human Posterior teeth (Molar or Premolar).
  -Studies examining restorative modalities other than endocrowns.
  -Reviews, case reports, pilot studies, case series, editorials, and clinical trials.
  -Studies that does not include direct comparative groups between endocrowns and post and core with crowns.
  -Unpublished studies, conference proceedings and manufacturer reports.
  -Studies involving human posterior teeth (molars or premolars).

Eligibility criteria and selection process

Studies were screened and selected by two reviewers (AA and MH) in accordance with the set inclusion and exclusion criteria listed in Table 2. Initially the two reviewers independently screened the titles and abstracts of the acquired studies and labeled them as included, excluded or uncertain. Selected studies were then checked in full text for eligibility and inclusion. Any discrepancies or uncertainty between reviewers was resolved through discussion and/or introduction of a third reviewer (GN) to reach a consensus. After a collective agreement has been reached on selected studies, the list of studies meeting the inclusion criteria was made. The entire screening and selection process was documented in the PRISMA flow diagram (Figure 1).

Risk of bias assessment

The quality assessment tool for in-vitro studies, the QUIN was used to evaluate the risk of bias in the included studies. The tool developed by Seth et al,[24] is designed to assess the risk of bias specifically in in-vitro dental research and addresses the lack of standardised protocols in this area. it critically examines a range of twelve factors in each study: clarity of the aims and objectives, detailed sample size calculation, sampling technique, comparison group information, a thorough description of the methodology, details about the operators, information on randomisation, the outcome measurement process, specifics on the outcome assessor, blinding practices, and the approach to statistical analysis. Each study was assessed and given an overall quality rating based how well each criterion was specified, in relation to the provided scoring system (adequately specified = 2 points, inadequately specified =1 point, not specified = 0 point, and not applicable). The scores obtained were used to grade the study as either low risk of bias (>70%), medium risk of bias (50% to 70%) and high risk of bias (<50%) as demonstrated in Table 3.

Data collection process

After removing duplicates, the two reviewers (AA and MH) screened and evaluated titles and abstracts of the selected studies to determine their eligibility for full text screening, using Excel software (Microsoft Corporation). The included studies were further evaluated against the set inclusion and exclusion criteria by the reviewers. In the presence of any disagreement between the reviewers, it was resolved by discussion or by consulting a third reviewer. Final registries were then read in full text and obtained data classified as follows:

- **Author and publication year**: The name of the study's primary author and the year of publication.

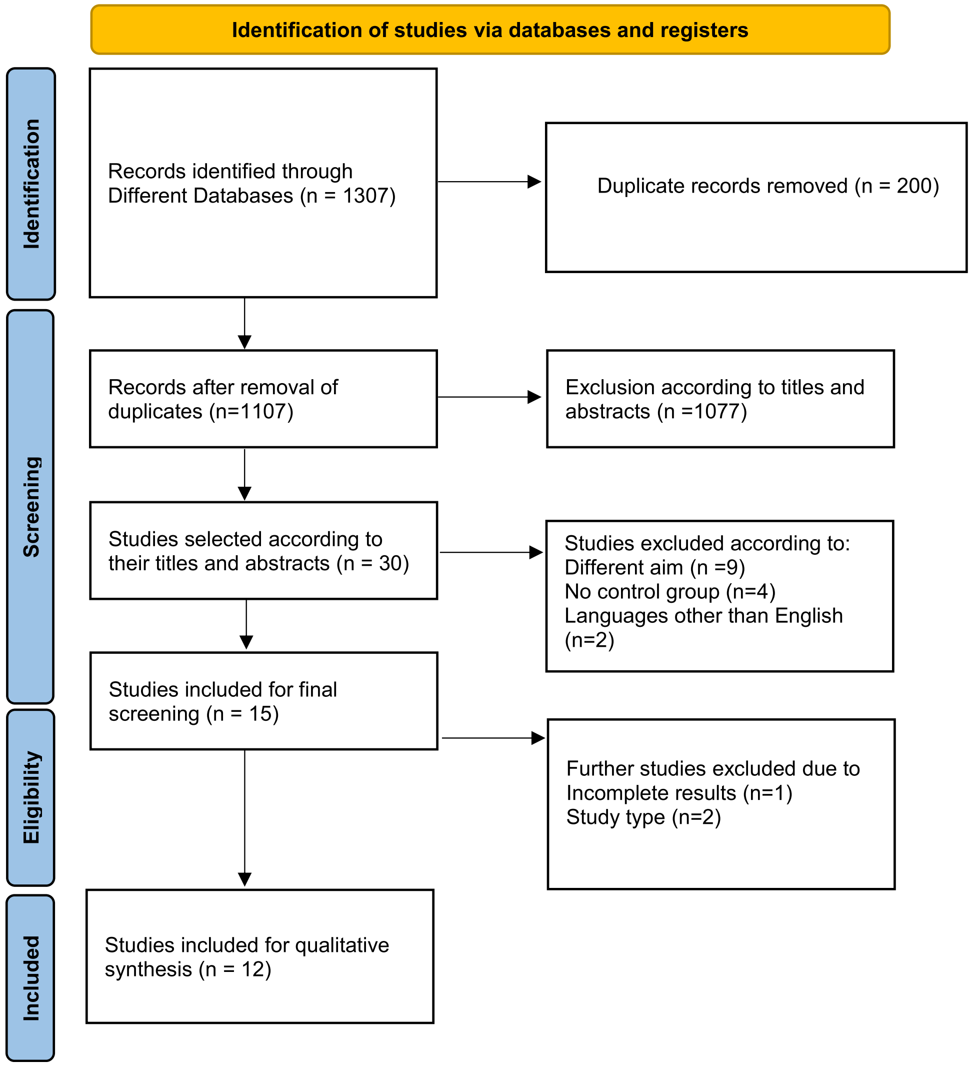

Fig. 1 – PRISMA flow diagram of study selection and decision tree.

- **Study type/Sample tooth:** In-vitro or finite element analysis and Identification of the type of tooth used,
- **Study groups/Sample size:** Description of the study groups, such as core and crown (CC), post, core and crown (PCC), and Endocrowns (ED), remaining tooth structure/ferrule, intracanal depth and crown material composition.
- **Parameters assessed:** The specific parameters examined in each study, including survival rate under fatigue, load to failure, fracture resistance, failure pattern, and the finite element analysis (von Mises stress and estimated fatigue life).
- **Methods:** Description of the experimental techniques used, such as thermocycling technique, load to failure process, Magnitude of load/force, direction and area of applied load.
- **Results:** The key outcomes from the studies, including fracture resistance values in Newtons, Failure mode (Adhesive, cohesive, repairable, or non-repairable fracture), Maximum Von Mises stress and mean and standard deviation values with their associated statistical analysis.
- **Conclusion (outcomes):** Main final remarks regarding validity and predictable longevity of proposed treatments for anterior endodontically treated teeth. (Endocrown vs post, core and crown).

Synthesis methods

The study results were visually displayed in Table 4. A meta-analysis of the included studies could not be conducted, and a narrative approach was selected due to the heterogeneity in study designs, testing methodologies and outcome measurements. As a result, the extracted data were qualitatively presented, allowing for comparative analyses among the studies.

Results

Records were initially identified through different databases, yielding a total of 1307 records. After removing duplicates, 1107 unique records remained. Following exclusion based on titles and abstracts, 30 studies were selected for full-text review. Upon full-text assessment, 9 studies were excluded

Table 3 – Risk of bias assessment (The Quin).

Study	Aims & objectives	Sample size calculation	Sampling technique	Comparison group	Methodology	Operator details	Randomisation	Outcomes measurements	Outcomes assesor details	Blinding	Statistical analysis	Results	Overall quality
De Souza et al.	Adequately specified	Not specified	not specified	Adequately specified	Adequately specified	Not specified	Inadequately specified	Adequately specified	Not specified	Not specified	Adequately specified	Adequately specified	Medium
Bozkurt et al.	Adequately specified	Adequately specified	Inadequately specified	Adequately specified	Adequately specified	Not specified	Inadequately specified	Adequately specified	Not specified	Not specified	Adequately specified	Adequately specified	Medium
Güngör et al.	Adequately specified	Not specified	Not specified	Adequately specified	Adequately specified	Not specified	Inadequately specified	Adequately specified	Not specified	Not specified	Adequately specified	Adequately specified	Medium
Hofsteenge and Gresnigt.	Adequately specified	Adequately specified	Not specified	Adequately specified	Adequately specified	Not specified	Inadequately specified	Adequately specified	Not specified	Not specified	Adequately specified	Adequately specified	Medium
Carvalho et al.	Adequately specified	Not specified	Not Specified	Adequately specified	Adequately specified	Not specified	Inadequately specified	Adequately specified	Not specified	Not specified	Adequately specified	Adequately specified	Medium
Alghalayini et al.	Adequately specified	Not specified	Not Specified	Adequately specified	Adequately specified	Adequately specified	Inadequately specified	Adequately specified	Not specified	Not specified	Adequately specified	Adequately specified	Medium
Silva-Souza et al.	Adequately specified	Not specified	Not specified	Adequately specified	Adequately specified	Adequately specified	Inadequately specified	Adequately specified	Not specified	Not specified	Adequately specified	Adequately specified	Medium
Ramírez-Sebastià et al.	Adequately specified	Not specified	Inadequately specified	Adequately specified	Adequately specified	Not specified	Inadequately specified	Adequately specified	Not specified	Not specified	Adequately specified	Adequately specified	Medium

for various reasons, including lack of a control group, different aim and being written in languages other than English. Consequently, 15 studies were included for final screening. Further exclusions were made based on differences study type and incomplete results, resulting in 12 studies being included for qualitative synthesis Figure 1.

The included studies varied in terms of sample size, testing methodologies and restoration design. Several studies used central incisors, while others incorporated lateral incisors or canines. Randomisation was employed in some studies, but details were often lacking. A range of materials were used, including monolithic zirconia, lithium disilicate, and resin nano-ceramic.

The extracted data of different restorative approaches for endodontically treated anterior teeth are presented in Table 4.

The risk of bias assessment was done through the Quin, a quality assessment tool for in-vitro studies. The included studies underwent the 12 point of assessment and scored an overall quality of medium risk of bias (50%-70%), where most studies had an average score of 59% to 63%.[17] In 8 studies,[25–32] specimens underwent fatigue testing and eventually load to failure. The reported results revealed a range of differences in terms of fracture resistance, failure patterns, pull-out bond strength, and repairability. Two studies[30,32] observed minimal differences in tested parameters between ED and PCC. Another study[28] had the same findings but noted that ED had significantly more repairable failures. Other authors[25,31] revealed higher fracture resistance for PCC restorations compared to ED restorations, especially in the presence of ferrule. Furthermore, lithium disilicate ceramic ED exhibited higher fracture resistance compared to PCC in one study,[27] while ED without ferrule had superior fracture resistance compared to PCC without ferrule in another.[29] Finally, ED with deeper extension (5 mm) demonstrated significantly greater pull-out bond strength compared to PCC.[26]

Most studies suggested that ED often experience more repairable failures compared to PCC,[28–30,32] On the other hand, some studies[27,31] were in favour of PCC in terms of failure pattern analysis. The authors of one study revealed that although PCC showed the superior resistance to fracture to ED groups, both with and without ferrule, ED without ferrule showed less catastrophic failures, mainly debonding of the glass ceramic crown.[25]

Four FEA studies demonstrated contrasting results for the stresses caused by ED and PCC in dentin, adhesive layer, and prosthetic material.[33–36] In absence of dentin ferrule, EDs with 3 mm intracanal extension presented the best stress distribution profile and optimal choice of treatment.[34,35] While 2 analyses revealed PCC groups had lower Von Mises stresses and recommended them as an ideal treatment modality for endodontically anterior teeth in presence of at least 2 intact walls of dentin ferrule.[33,36]

Discussion

This systematic review investigated the biomechanical properties in various studies comparing endocrowns (ED) with post, core, and crown restorations (PCC) in endodontically

Table 4 – Data extracted from included studies.

Study/ Author	Study type/ Sample tooth	Study groups/ Sample size	Parameters assessed	Methods	Results	Conclusions
De Souza et al.[18]	In-vitro/Central incisors	-GC: 3D printed glass ceramic resin conventional crown with intra-radicular post (n=10). -GE2: 3D printed glass ceramic resin endocrown with 2 mm ferrule (n=10). -GE0: 3D printed glass ceramic resin endocrown without a ferrule (n=10). -No randomisation reported.	Fracture resistance & Failure mode/ pattern.	-Samples were subjected to a compressive load at 45° on their lingual surface in a universal testing machine at a speed of 1.0mm/ min until failure. -The amount of force required to cause failure was recorded in Newton (N).	*Fracture resistance: -GC: 284.50±201.05N (Highest FR) -GE2: 274.54±199.43N -GE0: 263.81±80.05N *Failure mode: Type I: Catastrophic fracture of the crown and/or remnant (below CEJ). Type II: Fracture of the crown with remnant above or at CEJ. Type III: Debonding of the glass-ceramic crown. -GC: 50% Type II, 40% Type I. -GE2: 60% Type I, 30% Type II. -GE0: 50% Type III, 30% Type I, 20% Type II.	-GE0: No ferrule Endocrown group exhibited a higher rate of debonding. -GE2: 2mm of ferrule Endocrown group, showed lower rates of fracture resistance, and the worst results when assessing the failure pattern (60% Type I). -GC: The control group has shown a higher fracture rate (50%) of the glass-ceramic crown piece without compromising the fiber post or the remaining tooth structure (Type II). -The amount force required for fracturing the central incisors is higher than the normal reported values of oblique loads described in the literature. -No statistically significant difference was found in fracture resistance and failure mode between groups. -Endodontically treated anterior teeth could be restored with endocrown, which could be considered a conservative and viable treatment option.
Bozkurt et al.[19]	In-vitro/ Central incisors	-Group I: Glass fiber post-and-core, monolithic zirconia crown (n=12). -Group II: Mono-lithic zirconia endocrown with 3-mm extension depth (n=12). - Group III: Mono-lithic zirconia endocrown with 5-mm extension depth (n=12). -Teeth were randomly assigned (n = 36)	pull-out bond strength (PBS) and Failure mode/ pattern.	-Samples were aged in a chewing simulator (50 N load at 45° × 6,000 cycles, 2.1 Hz frequency) with a thermal cycle feature (5-55°C). -PBS values (MPa) were calculated using an electromechanical servo universal testing machine. -pull-out was performed at a speed of 1 mm/min until the restoration material was removed.	*Pullout Bond Strength: -Group III (Mono-lithic zirconia endocrown with 5-mm extension depth) demonstrated significantly greater PBS values (P = 0.001) than Groups I (Glass fiber post-and-core, monolithic zirconia crown) and II (Mono-lithic zirconia endocrown with 3-mm extension depth). No significant difference was found between Groups I and II (P = .072). *Failure modes (adhesive, cohesive, mixed): Adhesive luting agent/post luting agent dentin failure: separation of the crown restoration or post from the tooth or root with its luting agent. Cohesive failure: separation of the luting agent material within itself. -Group I demonstrated adhesive post-luting agent failure at the post-dentin interface. -Group II and Group III, demonstrated adhesive luting agent-dentin failures.	-Monolithic zirconia endocrowns with a 5-mm extension depth had the maximum pull-out bond strength value. -Increasing the endocrown extension depth influences the pull-out bond strength of endodontically treated anterior teeth restored with monolithic zirconia endocrowns. -All restorations survived the thermal cycling and chewing simulation. -Most failure modes were adhesive luting agent-dentin (47.22%). -The bond strength at the glass-fiber post-dentin interface was lower than that of core-crown bond strength.

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Table 4. (*Continued*)

Study/ Author	Study type/ Sample tooth	Study groups/ Sample size	Parameters assessed	Methods	Results	Conclusions
Güngör et al.[20]	In-vitro/Central incisors	-ZrRNC: zirconia post and resin nano ceramic crown (n = 10). - ZrLDS: zirconia post and lithium disilicate ceramic crown (n = 10). - FbRNC: fiber post and resin nano ceramic crown (n=10). -FbLDS: fiber post and lithium disilicate ceramic crowns (n = 10). -EndoRNC: resin nano ceramic endocrown (n = 10). - EndoLDS: lithium disilicate ceramic endocrown (n = 10). -Teeth were randomly assigned (n = 60).	Fracture resistance & Failure mode/ pattern.	- Samples were subjected to a compressive load at 45° palatally at a speed of 1 mm/min until fracture occurred. The maximum load at which the specimens fractured was recorded in Newtons (N).	*Fracture resistance: -ZrRNC: 893.43N. - ZrLDS: 764.63N. - FbRNC: 580.02N. -FbLDS: 646.78N. -EndoRNC: 869.04N. - EndoLDS: 915.91N. *Failure mode: Type I: fracture of the restoration. Type II: post fracture with or without the fracture of the restoration. Type III: dislodgement without fracture. Type IV: fracture of the tooth. -ZrRNC: (Type I: 7), (Type II: 3). - ZrLDS: (Type I: 3), (Type II: 6), (Type III: 1). - FbRNC: (Type I: 3), (Type III: 7). -FbLDS: (Type I: 8), (Type III: 2). -EndoRNC: (Type IV: 10). -EndoLDS: (Type I: 3), (Type IV: 7).	- Endocrowns showed higher fracture resistance values compared to fiber post, core and crown groups. The lithium disilicate Endocrown (EndoLDS) had the highest fracture strength. - Resin nano-ceramic (RNC) crowns showed higher fracture resistance when zirconia posts were used compared with lithium disilicate crowns (LDS). -Failure modes in fiber posts groups showed the fracture of the restoration without post fracture or dislodgement from the root canal. - Failure modes in zirconia post groups showed the fracture of the restoration with or without post. -Failure modes in endocrowns showed tooth fractures (unfavorable failure) while post-core restorations caused no tooth fracture. - Resin nano-ceramic crowns showed higher fracture resistance when zirconia posts were used compared with lithium disilicate crowns.
Hofsteenge and Gresnigt.[21]	In-vitro/Central & Lateral incisors	-LE: Lateral incisor, 6-mm deep endocrowns (n = 12). -CE: Central incisor, 6-mm deep ceramic endocrowns (n = 12). -LP: Lateral incisor, 11-mm post, composite core, ceramic crown (n = 12). -CP: Central incisor, 11-mm post, composite core, ceramic crown (n = 12). -Teeth were randomly assigned (n = 48, Central= 24, Lateral-24).	Fracture resistance & Failure mode/ pattern.	-Samples were aged using thermocycling: 10,000 times in baths of 5°C and 55°C, with a dwell time of 30 seconds. -Fracture load was performed in a universal testing machine where specimens subjected to a compressive load at 45° on their incisal edge in a universal testing machine at a speed of 1.0mm/min until failure. The maximum load at which the specimens fractured was recorded in Newtons (N).	*Fracture resistance:(mean) -LE: 240.9N -CE: 258.3N -LP: 267.8N -CP: 319.8N *Failure modes: (1) cohesive failure in the material of the indirect restoration. (2) Adhesive failure between the indirect restoration material and the dentin: (CE: 8.33%). (3) Adhesive failure between the build-up and the crown. (4) Loosening of the post and core crown. (5) Cohesive failure in dentin: (LE: 8.33%), (CE: 16.66%). (6) Fracture extending to the root: (LP and CP: 100%), (CE: 75%), (LE: 91.67%). (7) Repairability: CE (42% repairable) and LE (8% repairable) while CP and LP (0% repairable.	-Endocrowns and post and core crowns on central and lateral incisors had no statistically different fracture strengths. -The endocrown restorations had significantly more repairable failures than the post and core crowns in the central incisor groups. -Fractures observed in the endocrown groups were more horizontally oriented (Figure 6A), whereas the post and core crowns had more vertical root fractures.

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Table 4. (*Continued*)

Study/ Author	Study type/ Sample tooth	Study groups/ Sample size	Parameters assessed	Methods	Results	Conclusions
Carvalho et al.[22]	In-vitro/ Incisors	-FNp: nanohybrid composite resin core with 2 mm ferrule, and a crown (n = 15). -NfPf: fiber post, composite resin core without ferrule, and a crown (n = 15). -NfNpFR: short-fiber reinforced composite resin core without ferrule, without post, and a crown (n = 15). -Eld: lithium disilicate endocrown (n = 15). -Erc: resin nanoceramic endocrown (n = 15).	Fracture resistance & Failure mode/pattern.	-Samples were subjected to accelerated fatigue testing. Cyclic isometric loading was applied to the incisal edge at a 30-degree angle at a frequency of 5 Hz, beginning with a load of 100 N (5,000 cycles). A subsequent increase of 100 N of load was applied every 15,000 cycles. Specimens were loaded until failure or to a maximum of 140,000 cycles.	*Load to failure: - All specimens failed before 140,000 load cycles. FNp > Eld > Erc > NfNpFR > NfPf. -FNp: 73,244 mean endured cycles. -Eld: 53,448 mean endured cycles. -Erc: 52,397 mean endured cycles. -NfNpFR: 45,557 mean endured cycles. -NfPf: 35,025 mean endured cycles. *Fracture resistance: -FNp: 633.33N. -NfPf: 380N. -NfNpFR: 492N. -Eld: 541N. -Erc: 512N. *Percentage of catastrophic failure: -FNp: 53% -NfPf: 100% -NfNpFR: 33% -Eld: 27% -Erc: 20%	-Endocrowns resulted in mostly non-catastrophic failures (with an advantage for Erc group), while post and core, crown group showed 100% catastrophic failures. -Anterior endocrowns without ferrule had superior fracture resistance and failure patterns compared with adhesive post-and-core and no-post buildups. -Nanohybrid composite resin core and crown with 2 mm of ferrule outperformed Endocrown groups without ferrule.
Alghalayini et al.[23]	In-vitro/ Central incisors	-Group A: post, core and nano ceramic crown restoration with 0.5 mm remaining tooth structure above CEJ (n = 10). -Group B: post, core and nano ceramic crown restoration with 2 mm remaining tooth structure above CEJ (n = 10). -Group C: post, core and lithium disilicate crown restoration with 0.5 mm remaining tooth structure above CEJ (n = 10). -Group D: post, core and lithium disilicate crown restoration with 2 mm remaining tooth structure above CEJ (n = 10). -Group E: nano ceramic composite endocrown restoration with 0.5 mm remaining tooth structure above CEJ (n = 10). -Group F: nano ceramic composite endocrown restoration with 2 mm remaining tooth structure above CEJ (n = 10). -Group G: lithium disilicate endocrown restoration with 0.5 mm remaining tooth structure above CEJ (n = 10). -Group H: lithium disilicate endocrown restoration with 2 mm remaining tooth structure above CEJ (n = 10). -Teeth were randomly assigned (n = 80)	-Fracture resistance. -Failure mode/pattern -Crack formation & propagation.	- Samples underwent cyclic loading (100,000 cyles) in the form of sine wave at the rate (frequency) of 10,000 Hz. Alternating between 100N to 20N of load applied at inclined 130 degrees angle just above the cingulum on the palatal surface. - Samples were examined under 10X magnification in a stereomicroscope to detect any cracks and surface flaws. After which constant compressive load was applied at a crosshead speed of 1 mm / min until failure occurred. - CEJ was considered the reference line to evaluate mode of failure.	*Rate of cracks per unit at 100,000 cycles: -A: 0.0 -B: 0.0 -C: 5.2 -D: 5.4 -E: 0.2 -F: 0.0 -G: 6.6 -H: 6.6 *Post-fatigue load to failure: (Fracture resistance) -A: 1130.8N -B: 1119.1N -C: 667.2N -D: 421.7N -E: 1073.8N -F: 1019.6N -G: 627.9N -H: 449.1N *Percentage of restorable samples: -A: 40% -B: 80% -C: 60% -D: 100% -E: 60% -F: 0% -G: 80% -H: 40%	-Endocrown and core, post crown restorations showed insignificant differences in terms of fracture resistance, independent of material and remaining ferrule. -The endocrowns were more restorable after load to failure than post-core-crowns, due to less interfaces and better failure patterns. - Nano ceramic composite (Lava Ultimate) materials tend to have higher or equal fracture resistance compared to CAD/CAM ceramic specimens (lithium disilicate). - Lava Ultimate specimens had more catastrophic failure patterns, hence less restorable than the IPS e.max specimens.

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Table 4. (*Continued*)

Study/ Author	Study type/ Sample tooth	Study groups/ Sample size	Parameters assessed	Methods	Results	Conclusions
Silva-Souza et al.[24]	In-vitro/ Canines	-Sound tooth (n = 10) -GFPf+: glass fiber post, composite core and ceramic crown with ferrule (n = 10). -GFPf-: glass fiber post, composite core and ceramic crown without ferrule (n = 10). -Ef+: lithium disilicate endocrown with ferrule (n=10). -Ef-: lithium disilicate endocrown without ferrule (n=10). -Teeth were randomly assigned (n=50)	-Fracture resistance. -Failure mode/ pattern.	-Thermomechanical cyclic loading was applied at a frequency of 5 Hz, starting with a load of 80 N, followed by ascending increase in load of 120, 160, 200, 240, 280, and 320 N at a maximum of 20,000 cycles. - A total of 16 thermal cycles with a water bath between 5 °C and 55 °C and dwell time of 40 s in each bath. - Samples were then loaded at a 45° in relation to its long axis, simulating incisal oblique loading to a maximum of 140,000 cycles or until failure.	*Fracture resistance: -S: 1364.3N. -GFPf+: 1550.9N. -GFPf: 1817.0N. -Ef+: 950.8N. -Ef-: all samples fractured during fatigue test. *Failure modes/patterns: -S: 100% non-repairable tooth fracture with a survival margin of 20% with load of up to 240 N. -GFPf+: showed higher restoration failure associated with repairable tooth fracture with a survival margin of 60% with load of up to 320 N. -Ef+: showed higher restoration failure associated with repairable tooth fracture with a survival margin of 80% with load of up to 320 N. -GFPf-: survival margin of 30% with load of up to 320 N. -Ef-: all samples failed with load of up to 280 N.	- Presence of ferrule was vital for the longevity and fracture resistance of endodontically treated teeth. - Glass fiber post showed superior performance in fatigue testing in no ferrule groups. -Fracture resistance values were higher in groups containing glass fiber posts. -Specimens which failed fatigue test resulted mostly in irreparable fractures for endocrowns, regardless the presence of ferrule. -Repairable fractures occurred more frequently in preparations with ferrule, irrespective of treatment modality (GFP and ED).
Ramírez-Sebastià et al.[25]	In-vitro/ Central incisors	-LPCer: 10-mm glass fiber post (long), composite core and ceramic crown (n = 8). -LPCpr: 10-mm glass fiber post (long), composite core and crown (n = 8). -SPCer: 5-mm glass fiber post (short), composite core and ceramic crown (n = 8). -SPCpr: 5-mm glass fiber post (short), composite core and crown (n = 8). -EndoCer: ceramic endo-crown (n = 8). -EndoCpr: composite endo-crown (n = 8). -Teeth were randomly assigned (n = 48)	-Fracture resistance. -Failure mode/ pattern	- Thermomechanical cyclic loading was applied via a chewing machine with 600,000 mechanical cycles at 49 N and 1,500 thermal cycles between 5 and 55°C. -Samples were placed in a fixing device, and a controlled load at a crosshead speed of 1 mm/min was applied using a stainless steel rod at a 45° on their palatal surface, 3 mm below the incisal edge with respect to the longitudinal axis of the root. -The samples were loaded until fracture, and the maximum breaking loads were recorded in Newtons (N).	*Fracture resistance: -SP: 470.9 ± 55.2N. -Endocrown: 552.4 ± 54.4N. -LP: 432.6 ± 55.3N. -Ceramic: 483.1 ± 46.2N. -Composite: 487.5 ± 42.4N. *Failure modes/patterns: -LP: 4 repairable and 12 non-repairable fractures. -SP + Endo C: 19 repairable and 13 non-repairable fractures.	-Most groups showed similar rate of survival under fatigue and fracture testing. -The long post group (10mm) had the highest number of non-repairable fractures. -Endocrowns and short posts were associated with repairable fractures. -Either endocrowns or a short glass fiber post with an adhesive crown can be used for the restoration of largely destroyed anterior teeth with at least 2mm of ferrule. -Crowns fabricated from machinable composite resin blocks are a viable alternative to all-ceramic crowns

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Table 4. (*Continued*)

Study/ Author	Study type/ Sample tooth	Study groups/ Sample size	Parameters assessed	Methods	Results	Conclusions
Demirel et al.[26]	In-vitro / FE Model of Central Incisors	FE 3D Models: -ECIR: no ferrule, endocrown. -ECER: 2 mm circumferential ferrule, endocrown. -PC4: 2 mm circumferential ferrule, post −core. -PC3: 2 mm mesial palatal, and distal ferrule, post−core. -PC2: 2 mm mesial and distal ferrule, post−core. -PC1: 2 mm distal ferrule, post−core. -PC0: no ferrule, post−core. -Both lithium disilicate (LS) and a polymer-infiltrated ceramic network (PICN) crowns were used for all groups.	-Fatigue performance -Fatigue life.	-150 N force (on the palatal incisal edge at a 45° angle) was applied to each group for 1000 cycles. The data were obtained as maximum principal stress values (Pmax).	*Pmax values found in the restoration: ECIR > ECER > PC0 > PC1 > PC2 > PC3 > PC4. *Pmax values found in resin cement: ECER > ECIR > PC0 > PC1 > PC2 > PC3 > PC4. *Pmax values found in dentin: ECIR > PC0 > PC1 > PC2 > PC3 > ECER > PC4. -PC4 group was identified as the most successful group. *Pmax values found in resin composite core & fiber post: PC4> ECER > PC3 > PC2 > PC1 > PC0 > ECIR. -Pmax values of the PICN material were higher than in the LS material groups, except those found in the restoration, LS recorded higher Pmax values. *Estimated Fatigue performance: -ECER showed the most unsuccessful fatigue performance in relation to dentin. - ECIR group with internal retention showed a result close to PC1, while PC2 and PC3 had better fatigue performance. -PC4 group with a 4 wall ferrule showed the best fatigue performance.	- post−core groups generally showed successful results than endocrowns. -The presence of even one coronal wall (PC1) is critical for fatigue performance. -In configurations where the ferrule effect cannot be created, debonding will occur faster. -At least two intact walls should be present to ensure ideal distribution of load in post, core and crown restorations. − When the remaining number of walls is 1 or none, an endocrown with internal retention may be indicated. -Endocrowns for anterior teeth are not a good treatment alternative. - The use of more rigid restorative materials, such as LS, may be recommended for endodontically treated teeth with excessive coronal tissue loss.
Li et al.[27]	In-vitro / FE Model of Central Incisors	FE 3D Models: -A: Glass fiber post-composite resin core- lithium disilicate crown. -B: Cast post core-lithium disilicate crown. -C: 3 mm deep lithium disilicate endocrown. -D: 4 mm deep lithium disilicate endocrown. -E: 5 mm deep lithium disilicate endocrown. -The five groups were simulated with both 1 and 2 mm of remaining ferrule.	-Von Mises equivalent stress. -Maximum principal stress distribution.	-A simulated static loading force of 100 N in a 45° direction from the long axis of the tooth was applied at the middle 1/3 of the lingual surface with a loading area of 2 mm^2.	*Dentin height ferrule of 1mm: -Stresses at dental Prothesis: B > E > D > C > A -Stress at tooth structure: A > D > C > B > E -Stresses at adhesive layer: A > C > D > E > B *Dentin height ferrule of 2mm: -Stresses at dental prothesis: B > E > D > C > A -Stresses at tooth structure: A > C > B > D > E -Stresses at adhesive layer: A > D > C > E > B	-Circumferential dentin ferrule with enough height is crucial (2mm) for repairing heavily defected maxillary central incisor with fiber or cast post-core crown. -In case of insufficient dentin ferrule, the stress distribution of the endocrown is more favorable than post-core-crown. -Endocrown with a depth of 3mm retainer may be the best repair method. -Cast post-core crown provided favorable and uniform stress distribution in residual tooth tissue compared to fiber post-core crown.

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Table 4. (*Continued*)

Study/ Author	Study type/ Sample tooth	Study groups/ Sample size	Parameters assessed	Methods	Results	Conclusions
Cruzado-Oliva et al.[28]	In-vitro / FE Model of Central Incisors	FE 3D Models: -A: Endocrowns without ferrule at 0 mm depth. -B: Endocrowns without ferrule at 1 mm depth. -C: Endocrowns without ferrule at 3 mm depth. -D: Endocrowns without ferrule at 5 mm depth. -E: Endocrowns with ferrule at 0 mm depth. -F: Endocrowns with ferrule at 1 mm depth. -G: Endocrowns with ferrule at 3 mm depth. -H: Endocrowns with ferrule at 5 mm depth. -I: Fiber post, core and crown.	-Von Mises stress distribution.	A simulated static load of 100N in a 45° direction from the long axis of the tooth, in the middle 1/3 of its palatal surface and with a load area of 2 mm^2.	*Endocrown without ferrule: -Stresses in restoration: D > B > C >A -Stresses in dentine: C > A > B > D -Stresses in cement: A > B > C > D * Endocrown with ferrule: -Stresses in restoration: G > E > F > H -Stresses in dentine: F > E > G > H -Stresses in cement: E > F > G > H *Fiber post, core and crown: -Stresses in restoration: 45.53MPa -Stresses in dentine: 29.74MPa -Stresses in cement: 34.84MPa	-Endocrowns with ferrules showed similar biomechanical behavior as fiber post, core and crowns. - Endocrowns without ferrules showed better stress distribution than endocrowns with ferrules. -Endocrowns without ferrule and 3mm intracanal depth (Group C) was the most optimal, presented lower Von Mises stresses and greater mechanical resistance.
Dejak et al.[29]	In-vitro / FE Model of Central Incisors	FE 3D Models: -MPCC: metal post-and-core and leucite ceramic crown. -LED: leucite ceramic endocrown. -LDED: lithium disilicate ceramic Endocrown.	-Modified Von Mises stresses (mvM). -Contact Stresses; shear, tensile and compressive	The models were fixed in nodes in the outer surface of the periodontium and were loaded with simulated clenching forces of 100N in centric occlusion. The load was applied under the lingual cusp, in a distance of 5 mm from the incisal edge, at a 45° angle in relation to the long axis of the tooth.	* Maximal Von Mises stress (MPa): At restoration: LDED>LED>MPCC. At dentin: LDED>LED>MPCC. At cement: LDED>LED>MPCC. *Contact stresses within the adhesive interface: Shear stress: LDED = LED>MPCC. Tensile stress: LDED>LED>MPCC. Compressive stress: LDED>LED>MPCC.	-Incisors with endocrowns showed Significantly higher mvM stresses (LDED, LED) compared to the teeth with metal post and cores (MPCC). - The mvM stresses in the leucite endocrown were near the material's tensile strength. - Endocrowns should be made of materials with higher strength than leucite ceramics to avoid fracture during function as a result of critical stresses at the area of crown-anchor element (CEJ). - mvM stresses present in lithium disilicate ceramic endocrown were 4 times lower than the tensile strength of the material. -Recorded contact stresses around lithium disilicate ceramic endocrown were significantly lower than the bond strength between the resin cement and tooth dentin. - Low mvM stresses occurred in anterior teeth restored with post and cores than those restored with endocrowns. - post-core and crown are still more recommended than endocrowns for anterior teeth.

treated anterior teeth. The research question was addressed by analyzing results from in vitro and Finite element analysis (FEA) studies, encompassing survival rates under fatigue, resistance to fracture, failure patterns, pull out bond strength (PBS) stress distribution across anterior teeth.

Drawing from the included studies, De Souza et al,[25] found that EDs provided similar biomechanical performance compared to traditional core-crown restorations, with no statistically significant difference observed between groups. However, ED groups without ferrule exhibited a higher rate of debonding, while ED groups with ferrule had the highest percentage of irreparable fractures. Silva-Souza et al,[31] noted that although PCC groups showed higher fracture resistance values, the presence of ferrule was pivotal for the longevity and clinical success of endodontically treated teeth. Specimens with ferrules exhibited superior mechanical stability irrespective of the treatment modality (ED or PCC). The presence of ferrule was documented in the literature to enhance resistance against lever loads and strengthens the overall structural integrity of the dentin-restorative complex by promoting even distribution of stresses.[37–39] Additionally, a concave bevel along the peripheral enamel in the preparation design can increase the bonding surface area of enamel, especially in absence of ferrule.[40] Güngör et al,[27] demonstrated that EDs generally exhibited higher fracture resistance compared to PCC groups, with the lithium disilicate EDs showing the highest fracture strength. Nevertheless, PCC groups resulted in more forgiving failure patterns that did not cause tooth fracture. With high fracture toughness (3.3 MPa m1/2) and flexural strength (400 MPa), lithium disilicate ceramic restorations (LDS) exhibit a notable ability to absorb incoming loads while minimizing the transmission of these forces to surrounding structures. This is achieved through the tight interlocking matrix-like structure facilitated by its crystalline phase, which aids in preventing the initiation of microcracks and may be crucial in preventing catastrophic failures.[41–43] Another major advantage of LDS ceramics is their superior bondability to dental structures.[36]

The load to failure in the majority of the studies supported the use of EDs for endodontically treated anterior teeth. Hofsteenge and Gresnigt[28] found no significant difference in fracture strengths between EDs and traditional PCCs on central and lateral incisors. However, ED restorations had significantly more repairable failure patterns than PCC restorations in the central incisor groups. The PCC groups were accompanied by irreparable vertical root fractures, in contrast to ED groups that demonstrated horizontally oriented restorable fractures. This was explained by Kishen et al,[44] describing it as an adhesive failure that is associated with the initiation of a slow propagating crack that causes a gap between the crown margin and tooth, which widens overtime and ends up in microbial infiltration, periodontal affection, caries and bone loss, eventually leading to catastrophic failures. It is Also known as the initial failure phenomenon, an important factor that contributes to several mechanical and microbiological complications in PCC restorations, that is often overlooked or undiagnosed. Ramírez-Sebastià et al,[32] also suggested that both EDs and short posts PCC (5mm) with adhesive crowns can be viable options for restoring largely destroyed anterior teeth with sufficient ferrule height. In addition, their study advised against the use of long posts PCC (10 mm) as it recorded the highest number of non-repairable fractures.

Carvalho et al,[29] further emphasised the failure patterns associated with different restorative techniques, showcasing that ED restorations made of resin-nano ceramic had 7% lower catastrophic failures than lithium disilicate EDs, underscoring the lower modulus of elasticity of resin nano-ceramic materials and its tendency to generate less stresses on the root.[45,46] Regardless of the material, ED restorations resulted in higher resistance to fracture values and mostly non-catastrophic failures, while PCC groups showed lower fracture resistance values and predominantly catastrophic failures. Moreover, the authors concluded that remaining dentin ferrule was the dominant factor in fatigue resistance regardless of material or technique. This underlines the importance of considering not only fatigue resistance but also failure mode when selecting a restorative approach. Alghalayini et al,[30] reported insignificant differences in fracture resistance between EDs and PCC restorations, suggesting that both techniques offer comparable mechanical performance. However, EDs resulted in more restorable fractures independent of material or remaining dentin ferrule. Sudden debonding or failure of no postrestorations can be considered a favorable clinical scenario as repair can be immediately initiated.[47,48]

Bozkurt et al,[26] highlighted the significance of extension depth in monolithic zirconia EDs, with deeper extensions (5mm) demonstrating higher pull-out bond strength. This suggests that the design of EDs, particularly the depth of insertion, plays a crucial role in their mechanical stability. Accordingly, Kanat-Erturk et al,[49] explored the effect of different ED restorations depths (short intracanal depth: 3 mm and long intracanal depth: 6mm) in one hundred maxillary central incisors teeth samples using various materials. They concluded that zirconia ED groups had the highest fracture resistance irrespective of the intracanal extension depth. Nevertheless, zirconia's rigid nature and high modulus of elasticity (210 GPa) in comparison to dentin (18.6 GPa) caused stress accumulation within the root leading to catastrophic failures.[50–53] Intracanal extension depth was only significant for fracture toughness when feldspathic ceramics was used for ED restorations. It has been reported that EDs with increased intracanal extension depth tend to suffer from increased marginal and internal gap.[54] On the contrary, EDs with shallow extension depth revealed minimal marginal gap and better seating.[55]

Regarding FEA studies, Demirel et al,[33] cautioned that PCC groups generally showed more successful results than EDs, adding that ideal distribution of load in PCC restorations can be achieved with the presence of at least two intact walls and the use of lithium disilicate ceramic crown material. The analysis restricted the use of ED restorations in case of only one remaining dentin wall or absence of any ferrule. Li et al,[34] underlined the importance of circumferential dentin ferrule height (2 mm) for repairing heavily defected anterior teeth, with EDs of 3 mm intracanal extension showing favorable stress distribution in cases of insufficient ferrule. The absence of ferrule inevitably leads to decementation of the restoration, as the amount of remaining dentin ferrule decrease, the loads acting on the restoration-dentin interface rapidly increase.[56] Cruzado-Oliva et al,[35] demonstrated that EDs without ferrules and 3 mm intracanal depth displayed the lowest Von Mises stresses and greatest mechanical resistance, while those with ferrules exhibited similar biomechanical behaviour as PCC restorations. Dejak et al,[36] described the importance of using lithium disilicate ceramic ED restorations, reporting 4 times lower Maximal Von Mises stresses than the tensile strength of the material as well as significantly lower contact stresses than the bond strength between the resin cement and tooth dentin. Nonetheless, the authors recommended metal PCC restorations over EDs for anterior teeth as it recorded the lowest mvM stress values in all test scenarios. In post-core systems, the insertion of the post within the root canal enables the root and restoration material to function as a cohesive unit, providing better stress distribution with increased retention and fatigue resistance.[57,58] However, previous studies elaborated that the presence of a post in endodontically treated incisors does not affect fatigue resistance when a ferrule is present.[48,59] In regard to ED restorations, they are fabricated as a single block, thus eliminating the hybrid post/composite core component and reducing the number of bonding interfaces between restorative materials and tooth substrate. This limits volumetric shrinkage to the cementation gap in the indirect restoration rather than affecting the entire buildup.[60,61] Additionally, indirect adhesive restorations are technique sensitive and require optimisation of bonding and cementation protocols to achieve a superior micromechanical retention with the target substrate. Several studies have demonstrated the paramount role of attaining a strong bond to dentin through immediate dentin sealing (IDS) in the success of such indirect restorations.[62-65]

Furthermore, El-Enein et al[66] performed a double blinded, randomised clinical trial (RCT) with a one-year clinical evaluation of e.max press EDs vs e.max press PCC, in twenty-four patients. No statistical significance was observed in gross fracture throughout the follow-up period, showcasing ED's comparable clinical performance to PCC restorations. However, EDs showed 33% of marginal discrepancy, which was not statistically significant. Marginal fit is widely regarded as one of the most crucial technical factors for ensuring long-term success of any restoration.[67] The ill adaptation of any restoration will lead to stress concentration and eventually debonding and/or fracture. All PCC group participants recorded complete satisfaction with provided treatment. The authors concluded that e.max press EDs provided similar successful performance to e.max PCC, yet PCC are still the recommended restorations for treating anterior endodontically treated teeth. A fairly new approach was introduced by Kasem et al., where the authors used anterior endocrowns as provisional restorations. The study reported enhanced retention and stability of such temporary restorations, especially in teeth with minimal remaining structure. This technique involves fabricating the endocrown from materials like self-polymerizing resin or Bis-Acryl composite resin, utilizing the internal walls of the pulp chamber for added retention. It minimises tooth structure removal, provides a better seal, and reduces the risk of dislodgement compared to traditional temporary crowns. The approach offers a more conservative solution for provisional restorations, protecting endodontically treated teeth during the provisional phase.[68]

The risk of bias assessment tool (The Quin)[24] showed medium level of bias risk for all included in-vitro studies (Table 3). In general, sample selection criteria were mentioned in most studies, with regards to teeth being cracks, caries, or defects free. Also, most studies had significant potential of bias due to inadequate reporting. For example, Bozkurt et al.[26] and Güngör et al.[27] did not provide sufficient information on the randomisation process, which raises concerns about selection bias. Additionally, the lack of blinding in several studies, such as those by Hofsteenge and Gresnigt,[28] could introduce detection bias, potentially affecting the objectivity of outcome assessments. The lack of sample size calculation and sampling technique in studies like those by Carvalho et al.[29] and Silva-Souza et al.[31] further limit the robustness of their conclusions. Finally, the absence of operator and outcome assessor details could lead to performance and detection biases as well. These methodological limitations highlight the need for more rigorously designed studies. Future research should focus on enhancing the methodological quality by ensuring comprehensive reporting of study details to produce well founded and reliable evidence.

The outcomes of this systematic review were categorised according to biomechanical outcomes of endocrown restorations and post retained restorations. Several limitations were present due heterogeneity among included studies in relation to specimen configuration (central, lateral, or canine), different restoration materials (monolithic zirconia, lithium disilicate, resin nano-ceramic), varying intracanal depths (3mm-5mm), distinct load application angles and magnitudes (45° −130° and 49N−320N) and testing methodologies (fracture resistance, failure patterns, pull-out bond strength), which precluded the possibility of performing a meta-analysis. Furthermore, the results of this systematic review necessitate the need for standardizing methodologies in this field of research, given the wide variability in outcomes from similar analyses, particularly when using finite element analysis (FEA) studies. Moreover, the studies included in this review were predominantly in-vitro, which inherently limits their generalisability to clinical practice, as artificial settings lack patient-specific variables.

Last but not least, both EDs and PCCs remain viable options for restoring severely damaged anterior teeth, with each having distinct advantages. Nevertheless, endocrowns offers a minimally invasive and effective alternative to traditional post-and-core restorations. Studies indicate that endocrowns, particularly those made from lithium disilicate, provide comparable or superior fracture resistance and more favourable failure patterns, preserving more tooth structure for potential retreatment. Ideal candidates for endocrowns are those with significant coronal loss but sufficient remaining dentin walls, whereas cases requiring a substantial ferrule effect may benefit more from traditional methods. A 3 to 5 mm intracanal extension along with proper adhesive bonding protocols and resin cements are recommended to enhance retention and stability of endocrowns. The presence of a 1 to 2 mm ferrule further improves biomechanical stability. Regular follow-up and good oral hygiene practices are essential for maintaining the restoration's longevity. Overall, endocrowns are a conservative, esthetically pleasing, and durable option for restoring severely damaged anterior teeth.

Conclusion

Within the limitations of this study, it was concluded:

- Endocrowns (ED) demonstrated comparable biomechanical performance to traditional post, core, and crown restorations (PCC) in endodontically treated anterior teeth.
- Endocrown restorations (ED) offer a minimally invasive approach for endodontically treated anterior teeth.
- The presence of ferrule significantly enhances the mechanical stability and longevity of endodontically treated teeth. In absence of ferrule endocrowns (ED) are superior to traditional post, core, and crown restorations (PCC).
- Lithium disilicate ceramics remain the material of choice, yet new nanocomposite resins are promising for the fabrication of endocrowns (ED).
- Well-designed clinical trials with long term follow-up are needed to corroborate the results reported in in-vitro studies and establish more robust guidelines for the prosthetic management of endodontically treated anterior teeth.
- Mastering preparation design, optimisation of bonding technique and attention to marginal accuracy are essential to limit displacement and achieve long-term success.

Conflict of interest

None disclosed.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used [Chat GPT] in order to [check for any misspelling or grammatical errors]. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Author contributions

Hisham A Mously: Conceptualisation of the research idea and substantial contribution to study design. Ghada Nagiub: Critical and Final Revision of study draft before submission. Author's contributions to the study and guidance on the area of research were instrumental in ensuring the relevance and rigour of our research findings. Ahmed Abougazia: Scientific writing of the research paper and cross communication of study design and findings across authors to reach consensus regarding final draft. Afaf A. Almabadie: Analysis of information and data, Interpretation of results and major findings, Contributed to the flow and order of information and final study framework. Osama A Qutub: Manuscript drafting and editing. The author's vast knowledge in research added value to the study through data acquisition and interpretation regarding the area of research, enhancing its quality or validity. Mohamed T. Hamed: The author provided invaluable guidance and mentorship throughout the course of the research project. Supervised and participated in every step to for quality assurance, underscoring the significance of his contributions to our study. Intervened when appropriate to maintain the novelty of intellectual content.

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