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SYSTEMATIC REVIEW

Endocrowns: A systematic review

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ABSTRACT

Statement of problem. The restoration of extensively damaged endodontically treated teeth remains a challenge. The use of post-retained restorations has been questioned because of potential tooth weakening.

Purpose. The purpose of this systematic review was to determine whether endocrowns are a reliable alternative to post-retained restorations for extensively damaged endodontically treated teeth and to determine which preparation design is most appropriate and which materials are best adapted for fabricating endocrowns.

Material and methods. The literature that was analyzed covered endocrowns from 1995 to June 2018. A search was conducted for in vitro and clinical studies in English in 3 research databases (PubMed, Cochrane, and Scopus), and this was complemented by a manual search in the bibliographies of the studies found. Case reports were excluded.

Results. A total of 41 publications consisting of 8 clinical studies and 33 in vitro studies were included in this systematic review. Several analysis parameters were identified: for the clinical studies, survival rate, failure modes, and clinical criteria; for the in vitro studies, fracture resistance, stress distribution, preparation criteria, and materials used.

Conclusions. Endocrowns are a reliable alternative to post-retained restorations for molars and seem promising for premolars. A certain preparation design and a rigorous adhesion protocol must be respected. Among the available materials, lithium disilicate glass-ceramic and nanofilled composite resin stand out. (J Prosthet Dent 2019;■:■-■)

The restoration of extensively damaged endodontically treated teeth remains a challenge. Their biomechanical deterioration impacts the tooth's long-term prognosis.[1,2] The most commonly used restoration for these teeth still involves a post-retained foundation restoration and a crown.[2-5] The only advantage of inserting a post is to increase the retention of the core foundation. Conversely, intracanal retention weakens the tooth structure and increases the risk of root fractures.[6-10] In the event of failure, in addition to exposing the tooth to irreversible fractures, the invasive nature of this type of restoration often excludes the possibility of further intervention.[11]

With progress in the development of adhesive techniques, the emergence of minimally invasive dentistry without a post or crown is challenging the post-and-crown concept.[12] First described in 1995 by Pissis,[13] the monoblock technique was the forerunner of the endocrown. The term endocrown was first used by Bindl and Mormann in 1999.[14] They described an adhesive monolithic ceramic restoration anchored in the pulp chamber, exploiting the micromechanical retention properties of the pulp-chamber walls (Fig. 1).

The purpose of this systematic review was to determine whether endocrowns are a reliable alternative to post-retained restorations for extensively damaged endodontically treated teeth and to determine which materials are best for fabricating endocrowns and what preparation criteria should be used.

MATERIAL AND METHODS

The review was established in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. An electronic search in PubMed, Scopus, and the Cochrane Library of articles published from January 1995 to June 2018 was conducted by using combinations of the following search terms: (endocrown OR endocrowns OR endo crown OR endo-crown) AND (computer aided design OR post and

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Clinical Implications

Restoring extensively damaged endodontically treated molars by using an endocrown is a reliable alternative to crowns with post-retained foundations. The preparation design and the choice of material are elements to consider when this technique is used.

core OR fracture strength OR endodontically treated teeth OR ceramic OR monoblock OR CAD-CAM).

The eligibility criteria are listed in Table 1. The titles and abstracts identified through the electronic search were evaluated independently for appropriateness by 2 investigators (N.G., M.C.). Upon identification of an abstract for possible inclusion, the full text of the article was reviewed and subjected to predefined inclusion and exclusion criteria. The electronic search was supplemented by a manual search through the references in the selected articles, and any articles found were reviewed for possible inclusion. Any discrepancies were resolved by discussion between the 2 reviewers.

A reading grid was used for data extraction, after which the information was summarized in a table form. The systematically extracted data included the type of study (in vitro or clinical), number of teeth used, type of teeth used, different prostheses evaluated, and parameters studied.

RESULTS

Using the search criteria, the electronic search produced 110 results. An initial evaluation based simply on the titles resulted in 54 articles being eliminated. After reading the abstracts, 47 articles were retained, and the full text was then studied. From this full reading, 40 articles were included in the study, and to these was added 1 article found during the manual search in the bibliographies of the selected articles (Fig. 2). The 41 selected articles had been published between 1999 and 2018 and are listed in order of publication in Table 2.[14-54] The 15 articles excluded after reading the abstracts or the full text are listed in Table 3. The articles selected for study were divided into clinical and in vitro. For each category, 2 tables were produced by grouping together the materials and methods used (Supplemental Tables 1 and 2, available online) and the results (Supplemental Tables 3 and 4, available online).

A high level of heterogeneity was observed in the methods adopted, the prostheses, the materials used, and the parameters studied. It was decided to group together studies analyzing similar parameters. Eight clinical studies were therefore grouped together, and the parameters they had in common were compared: survival rate, failure modes, and clinical criteria. From the 33 in vitro studies, 4 parameters were extracted: resistance to fracture, stress distribution, available materials, and preparation criteria. Data were collected for molars, premolars, and incisors.

Survival rates were studied in 7 of the clinical studies, differentiating premolars and molars. For molars, survival rates were greater than 90% from 6 months up to 10 years.[14-16,21,27,29,49] In studies that also analyzed the survival rates of traditional crowns, these rates were similar.[15,16,29] Survival rates for endocrowns on premolars varied between 68% and 75% at 55 months and 10 years,[15,16,27,29] while survival rates of 94% and 95% were found for traditional crowns on premolars.[15,16,29] It was not possible to distinguish molars from premolars in 1 study.[44] The grouped molar and premolar survival rate was 99% at 44.7 months.

Failure modes were observed in the different studies and were recorded for crowns and endocrowns. The 3 leading causes of endocrown failure were loss of retention (53% of failures), periodontitis (14%), and fracture of the endocrown (14%). For the traditional crowns, crown fracture was the main reason for failure (53%), followed by vertical root fracture (23%) and irreversible pulpitis (19%).

Four of the clinical studies also looked at a set of clinical parameters, based on modified United States Public Health Service (USPHS) criteria,[14-16,29] which included marginal adaptation, anatomical shape, surface texture, and color. For these criteria, a little significant difference was observed between the crowns and endocrowns.

Among in vitro studies, fracture resistance was evaluated in 3 studies by comparing this parameter for molars restored either by endocrowns or by crowns with or without posts.[23,28,33] The mean values for the endocrowns were higher than those for the crowns with a fiber post.[23] No significant difference was observed between fracture resistance in the endocrowns and that in the crowns with a core foundation without a post.[28,33] For the premolars, 6 studies analyzed fracture resistance according to the restoration provided: endocrowns or crowns with posts (fiber or metal).[17,19,31,40,42,47] In 3 studies, the fracture resistance of endocrowns was similar to that for crowns with posts.[17,40,42] In 2 studies, greater resistance to fracture was reported for the endocrowns,[19,47] and 1 study reported contrary results with lower fracture resistance for the endocrowns.[31] For incisors, 2 studies compared the fracture resistance of teeth restored with endocrowns with that of those restored with posts and crowns.[26,43] No significant difference was reported between the restoration types.

Stress distribution in dental tissue and materials was also analyzed by using 3-dimensional finite element models for teeth restored with endocrowns or traditional

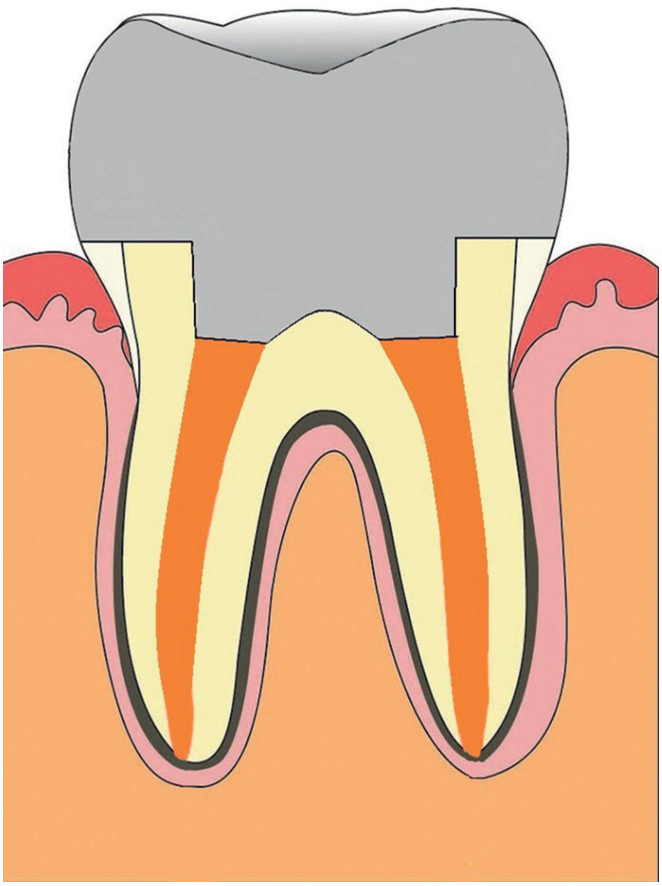

Figure 1. Schematic representation of endocrown.

Table 1. Eligibility criteria

Inclusion Criteria	Exclusion Criteria
Studies evaluating endocrowns	Animal teeth
Studies in English	Case reports
Clinical and in vitro studies	Literature reviews
Molar, premolar, and incisor restorations	Full text not available in English
Materials used: ceramic and composite resin	Nonmonolithic endocrowns

crowns with post-retained foundation restorations. No study evaluated molars. For premolars, 4 studies showed lower stresses in the dentin and cement for teeth restored with endocrowns than for those restored with other prostheses (cast metal post-and-core, fiber posts, metal posts).[18,20,22,24] One study reported that the maximum stresses for endocrowns were almost 3 times greater than those with fiber posts.[31] Another study evaluated stress distribution as a function of endocrown thickness with varying amounts of residual tissue.[39] Increased conserved dental tissue led to increased stresses around the cement and decreased stresses within the dental tissue. Only 1 study used finite element analysis to test incisors restored with endocrowns and with a cast metal post-and-core and a ceramic crown. It reported that stresses were less in the dentin, cement, and crown of teeth restored by cast metal post-and-core and crowns than in the endocrowns.[45]

The preparation criteria for endocrowns have also been analyzed. No significant differences in fracture resistance were reported between endocrowns with pulp-chamber extensions measuring 2.5 or 5 mm.[42] Two other studies showed no difference in fracture resistance for molar endocrowns with a pulp-chamber depth of 2 or 4 mm; however, the occurrence of catastrophic fracture rates increased with increased depth.[46,50] Only 1 study displayed better fracture resistance for endocrowns where the pulp-chamber extension was greater.[54] Concerning the creation of a pulp-chamber floor, putting a fiber composite on the pulp-chamber floor did not affect fracture resistance[30] or endocrown marginal adaptation.[35] Concerning the finish line configuration, 2 studies showed that applying a 1-mm ferrule increased endocrown fracture resistance[48,51] and limited the number of irreparable fractures.[48] Finally, using immediate dentin sealing[55] just after preparation did not improve fracture resistance.[41]

Several studies compared the different materials available for making endocrowns.[32,34] The materials tested, all used via machining, are listed in Table 4. The fracture resistance values for teeth restored using endocrowns with the different materials were high (up to 2675 N), with little difference among them.[38] Some authors identified the potential advantage of using machinable composite resins to produce endocrowns as their elastic modulus is similar to that of dentin.[29] One study showed a better fracture resistance for teeth restored by using nanoceramic resins (Lava Ultimate; 3M) than by using lithium disilicate (e.max; Ivoclar Vivadent AG) and feldspathic porcelain (VITA Mark II; VITA Zahnfabrik).[32] In another study, however, comparing nanoceramic resin and lithium disilicate, no significant difference was found in the fracture resistance of endocrowns restored with these materials and subjected to an axial force.[34] When subjected to a lateral force, better results were obtained with the lithium disilicate. In another study, no difference was observed in fracture resistance for endocrowns made of feldspathic ceramic (VITA Mark II; VITA Zahnfabrik), polymer-infiltrated ceramic network (PICN) (Enamic; VITA Zahnfabrik), and zirconia-reinforced lithium silicate glass ceramics (SUPRINITY; VITA Zahnfabrik).[38] The main distinctions between these materials can be seen in the proportion of critical failures occurring in the failure modes as the rate of irreparable fractures increased with the elasticity modulus of the material. Thus, the nanocomposite (Lava Ultimate; 3M) had the lowest critical failure rate, ahead of the lithium disilicate–reinforced glass-ceramic (e.max; Ivoclar Vivadent AG).[32,34] The zirconia-reinforced lithium silicate glass-ceramic (SUPRINITY; VITA Zahnfabrik) and the zirconia (inCoris TZI; Dentsply Sirona) had the highest irreversible fracture rates.[38,52]

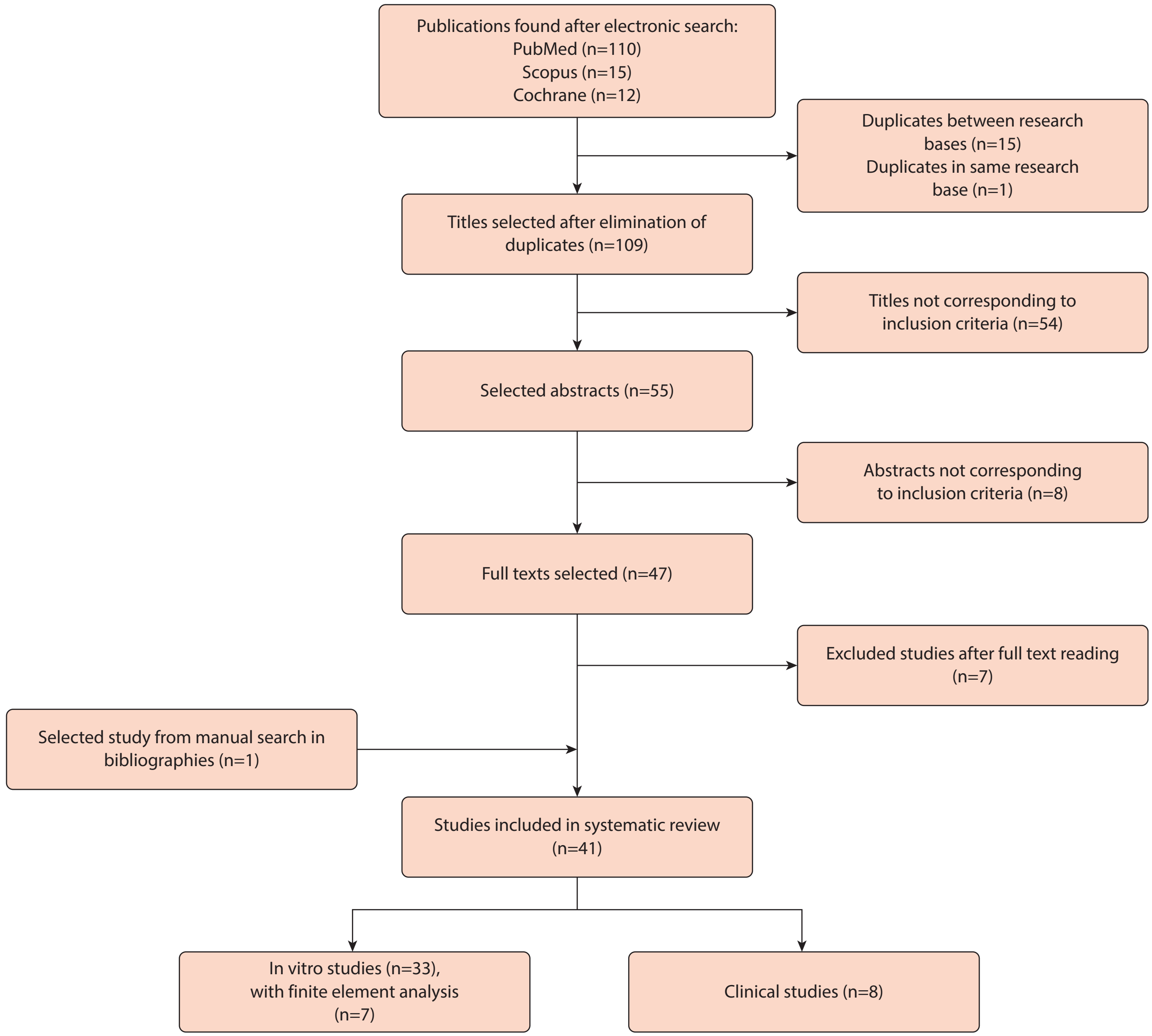

Figure 2. Decision tree of systematic literature review.

Another study revealed a higher degree of marginal leakage for nanoceramic resin restorations (Lava Ultimate; 3M).[32] This could be explained by the coefficient of thermal expansion of these resins, which is higher than that for ceramics and dentin because of their composition (80% nanoceramic particles and 20% resin matrix). Therefore, this thermal expansion would exaggerate the effects of thermocycling on the quality of the marginal limit.

DISCUSSION

For the restoration of extensively damaged endodontically treated molars, the results of clinical and in vitro studies agree that endocrowns are an excellent treatment solution. Excellent survival rates have been reported in the short, medium, and long term for molars restored in this way. Clinical performance is also satisfactory and comparable with that observed for molars restored by using crowns. In addition, endocrowns had fewer catastrophic failures than crowns (with or without post-retained restoration), with 6% of root fractures for endocrowns and 29% for crowns. Most failures found in endocrowns were due to loosening (71%). The importance of respecting the adhesion protocol, thus ensuring the sustainability of the restoration, was stressed in several of the studies. The adhesive technique prevents marginal leakage and reduces the penetration of

Table 2. Selected studies

Year	Authors	Study Type	Number of Teeth Used	Types of Teeth Used	Types of Restorations Studied	Analyzed Parameters
1999	Bindl and Mörmann[14]	Clinical	19	Molars (15), premolars (4)	Endocrowns (19)	Survival rate, clinical criteria evaluation
2004	Otto[15]	Clinical	20	Molars (14), premolars (6)	Endocrowns (10), crowns (10)	Survival rate, clinical criteria evaluation
2005	Bindl et al[16]	Clinical	208	Molars (145), premolars (63)	Endocrowns (86), crowns (122)	Survival rate, clinical criteria evaluation
2008	Forberger and Göhring[17]	In vitro	48	Mandibular premolars (48)	Sound teeth (8), access cavity (8), endocrowns (8), fiber posts-crowns (24)	Fracture strength, marginal continuity
2009	Lin et al[18]	In vitro	FE model	Maxillary premolars	Endocrowns, onlays, cast posts-crowns	Failure risks, stress distribution
2009	Chang et al[19]	In vitro	20	Maxillary premolars	Endocrowns (10), fiber post-crowns	Fracture strength, failure mode
2010	Lin et al[20]	In vitro	FE model and 20 teeth	Maxillary premolars (20)	Endocrowns (10), fiber posts-crowns (10)	Failure risks, fracture strength, stress distribution
2010	Bernhart et al[21]	Clinical	20	Molars (20)	Endocrowns	Survival rate, failure mode, clinical criteria
2011	Lin et al[22]	In vitro	FE model and 15 teeth	Maxillary premolars (15)	Endocrowns (5), inlays (5), cast posts-crowns (5)	Failure risks, fracture strength, stress distribution
2012	Biacchi and Basting[23]	In vitro	20	Mandibular molars (20)	Endocrowns (10), fiber posts-crowns (10)	Fracture strength
2013	Lin et al[24]	In vitro	FE model	Maxillary premolars	Endocrowns, metal posts-crowns, onlays	Failure risks
2013	Ramirez-Sebastia et al[25]	In vitro	48	Incisors	Fiber posts-crowns (32), endocrowns (16)	Marginal adaptation
2014	Ramirez-Sebastia et al[26]	In vitro	48	Incisors	Fiber posts-crowns (32), endocrowns (16)	Fracture strength, failure mode
2014	Decerle et al[27]	Clinical	16	Molars (11), premolars (5)	Endocrowns (17)	Clinical criteria evaluation
2014	Magne et al[28]	In vitro	45	Molars (45)	Endocrowns (15), crowns (30)	Fatigue strength, failure mode
2015	Otto and Mörmann[29]	Clinical	65	molars (41), premolars (24)	Endocrowns (25), crowns (45)	Survival rate, clinical criteria evaluation
2015	Rocca et al[30]	In vitro	40	Molars (40)	Endocrowns	Fracture strength, failure mode
2015	Schmidlin et al[31]	In vitro	FE model and 40 teeth	Maxillary premolars (40)	Endocrowns (10), fiber posts-crowns (10), H posts (20)	Stress distribution, fracture strength, failure mode
2015	El-Damanhoury et al[32]	In vitro	30	Maxillary molars (30)	Endocrowns (30)	Fracture strength, marginal leakage
2016	Carvalho et al[33]	In vitro	45	Molars (45)	Endocrowns (15), no post buildups-crowns	Fracture strength, failure mode
2016	Gresnigt et al[34]	In vitro	60	Molars (60)	Endocrowns (40), sound teeth (20)	Fracture strength, failure mode
2016	Rocca et al[35]	In vitro	32	Molars (32)	Endocrowns (32)	Influence of FRCs' reinforcement on marginal adaptation
2016	Gaintantzopoulou and El-Damanhoury[36]	In vitro	36	Mandibular molars (36)	Endocrowns (36)	Effect of preparation depth on the marginal and internal adaptation
2016	Shin et al[37]	In vitro	48	Mandibular molars (48)	Endocrowns (48)	Effect of preparation depth on the marginal and internal adaptation
2016	Aktas et al[38]	In vitro	36	Mandibular molars (36)	Endocrowns (36)	Influence of diverse ceramics on fracture strength and failure mode
2016	Zhu et al[39]	In vitro	FE model	Premolars	Endocrowns	Stress distribution
2016	Guo et al[40]	In vitro	30	Mandibular premolars (30)	Endocrowns (10), fiber posts-crowns (10), sound teeth (10)	Fracture strength, failure mode
2016	El-Damanhoury and Gaintantzopoulou[41]	In vitro	60	Maxillary premolars	Endocrowns	Fracture strength
2017	Pedrollo Lise et al[42]	In vitro	48	Premolars (38)	Endocrowns (2.5 mm) (16), endocrowns (5 mm) (16), fiber posts-crowns (16)	Influence of different preparation and materials on fracture strength
2017	BankogluGungor et al[43]	In vitro	60	Incisors (60)	Endocrowns (20), cast posts-crowns (20), fiber posts-crowns (20)	Fracture strength, failure mode
2017	Belleflamme et al[44]	Clinical	99	Molars (56), premolars (41), canines (2)	Endocrowns	Survival rate, failure mode, clinical criteria
2017	Dejak and Mlotowski[45]	In vitro	FE model	Incisors	Cast posts-crowns, endocrown	Stress distribution
2017	Hayes et al[46]	In vitro	36	Mandibular molars (36)	Endocrown (36)	Fracture strength

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Table 2. (*Continued*) Selected studies

Year	Authors	Study Type	Number of Teeth Used	Types of Teeth Used	Types of Restorations Studied	Analyzed Parameters
2017	Atash et al[47]	In vitro	30	Premolars (30)	Cast posts-crowns (10), fiber posts-crowns (10), endocrowns (10)	Fracture strength, failure mode
2017	Einhorn et al[48]	In vitro	36	Mandibular molars (36)	Endocrowns (36)	Influence of ferrule on fracture strength
2017	Fages et al[49]	Clinical	447	Molars (447)	Endocrowns (235), crowns (212)	Survival rate, failure mode
2017	Rocca et al[50]	In vitro	48	Maxillary premolars (48)	Overlay (12), endocrowns (2 mm) (12), endocrowns (4 mm) (12), fiber posts-crowns (12)	Fatigue strength, marginal integrity
2017	Taha et al[51]	In vitro	32	Mandibular molars (32)	Endocrowns (32)	Influence of ferrule on fracture strength
2017	Kanat-Ertürk et al[52]	In vitro	100	Maxillary incisors (100)	Endocrowns (100)	Influence of preparation depth and materials on fracture strength and failure mode
2018	Zimmermann et al[53]	In vitro	1	Maxillary molar	Endocrowns	Influence of materials on marginal adaptation
2018	Dartora et al[54]	In vitro	30	Mandibular molars	Endocrowns	Influence of preparation depth on fracture strength

H post, H-shaped intracanal extension; FE Model, finite element analysis; FRC, fiber-reinforced composite.

Table 3. Exclusions

Excluded Studies	Reasons for Exclusion
Zarone et al (2006)	Nonmonolithic endocrown. Intracanal extensions are as deep as the posts and longer than two-third of the canal
Hasan et al (2012)	Nonmonolithic endocrown
Dejak and Mlotkowski (2013)	Endocrowns are compared with multiple post restorations
Rocca et al (2016)	Nonmonolithic endocrown
Helal and Wang (2017)	Endocrowns are compared with multiple post restorations
Gulec and Ulusoy	Noncompliant representation of the endocrown
Skalskyi et al (2018)	Fracture strength studied for materials and not teeth

Table 4. Commercial designation and structures of different materials used

Commercial Designation	Structure
VITA mark II; VITA Zahnfabrik	Feldspathic ceramic
e.max CAD; Ivoclar Vivadent AG	Lithium disilicate–reinforced glass-ceramic
Lava Ultimate; 3M	Nanofill composite
CERASMART, GC	Nanofill composite
ENAMIC; VITA Zahnfabrik	Polymer-infiltrated ceramic network (PICN)
SUPRINITY, VITA Zahnfabrik	Zirconia-reinforced lithium silicate glass-ceramic
Celtra Duo; Dentsply Sirona	Zirconia-reinforced lithium silicate glass-ceramic
InCoris TZI; Dentsply Sirona	Zirconia

microorganisms from the crown toward the apex, thus contributing to the clinical success of the endodontic treatment.[14] During clinical studies, the bonding system was retained on the intaglio surface of loosened endocrowns and failed at the dentin interface.[14,29] Several phenomena can account for this situation. First, the presence of sclerotic dentin in the pulp chamber can result in poorer adhesion than with sound dentin.[16] Then, the high elastic modulus of some materials, such as ceramic, may transmit undamped stresses at the tooth-to-material bonded interface.[29] Finally, when the residual height of the walls is low (less than 2 mm), this could also have a negative impact.[29] The results of in vitro studies are consistent with those of clinical studies and show fracture resistance and excellent stress distribution.

For premolars, clinical studies reported a higher failure rate than for molars. Survival rates were also considerably lower than those obtained for molars or for premolars restored with crowns.[16,29] One clinical study of premolars was halted after failures rapidly occurred.[29] However, all failures in clinical studies on premolars were due to loss of adhesion and hence were repairable. These disappointing clinical results regarding recommending endocrowns on premolars are in contrast with the in vitro study results. Survival rates, fracture resistance, and stress distribution of the premolar endocrowns were comparable with those observed for peripheral crowns with post-retained restorations. Most clinical studies used feldspathic ceramic endocrowns, whereas new materials with better properties have been introduced.

For incisors, the few studies available and the conflicting results observed made it impossible to draw any conclusions regarding the use of endocrowns as an alternative treatment for this type of tooth. Overall, the number of clinical studies that focused on endocrowns remains low, and only 4 of them exceeded 3 years. More long-term prospective studies are necessary to validate the findings.

Concerning pulp-chamber extension, only 1 study showed an increase in fracture resistance in premolars restored with endocrowns when the pulp-chamber extension increased in length.[54] The pulp chamber should not be extended at the expense of the pulpal floor. It is therefore necessary to make maximum use of the depth of pulp chamber available to maximize the available bonding surface and thus limit the risks of displacement. The preparation of intracanal extensions should be avoided as it results in a decrease in the marginal and internal adaptation of the endocrowns,[36] important factors in retention, and the clinical performance of the restorations.

Regarding the finish line configuration, in most studies, endocrowns were placed in teeth that lacked a ferrule. However, a ferrule gives greater fracture resistance to teeth restored by endocrowns[48,51] and to teeth restored with conventional crowns.[4,56] Attempts to add a ferrule should not be for the detriment of the enamel in teeth where the margins are close to the cementoenamel junction (CEJ). In the absence of a ferrule, a concave bevel on the peripheral enamel can increase the enamel bonding surface area and hence improve the biomechanical behavior of the endocrowns.[57] Placement of supragingival margins also remains an essential parameter. The prepared tooth must be able to be isolated so that optimal bonding protocols can be implemented under a rubber dam.

Basing the pulp chamber floor improves neither fracture resistance nor marginal adaptation. However, by using this technique, undercuts of the pulp chamber can be blocked out, hence saving tissue.

Regarding the choice of materials used, nanofill composite resins have some interesting characteristics for endocrown fabrication, thanks to their modulus of elasticity, which is similar to that of dentin and thus limits irreparable fractures, while retaining a high fracture resistance. However, a decrease in elastic modulus reduces stress in the dentin while increasing it at the interface, thus leading to risks of debonding and detachment of the prosthesis.[39] In addition, the fracture resistance observed for the different materials considered was mainly greater than the masticatory forces. As the risk of debonding has been shown to be greater than the risk of fracture, materials with the greatest adhesion values, such as lithium disilicate, are the best choice. The esthetic properties of this material are unrivaled by composite resin, which can be an advantage for some patients. Ceramics also age better and have a lower plaque retention than composite resins.[58]

CONCLUSIONS

Based on the findings of this systematic review, the following conclusions were drawn:

1. Endocrowns appear to be a promising alternative for restoring molars treated endodontically and with extensive loss of tooth structure.
2. The recommended use of endocrowns for premolars requires further study, especially clinical trials, to corroborate the results reported in the in vitro studies.
3. The lack of data on endocrowns on incisors and the varied results obtained mean that a clinical indication for restoring anterior teeth with endocrowns cannot yet be stated.
4. As observed in the clinical studies, a successful endocrown restoration requires a good preparation design and good mastery of bonding techniques to limit failures due to displacement.
5. The new nanocomposite resins and lithium disilicate seem to have advantages in the fabrication of endocrowns.

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Supplemental Table 1. Material and methods of clinical studies

Study	Type of Study	Number of Patients	Type of Teeth	Prosthetic Restorations Studied	Preparation Criteria for Endocrowns	Materials Used for Endocrowns	Endocrown Fabrication	Adhesive Pretreatment	Bonding	Evaluation Criteria
Bindl and Mörmann (1999)[14]	Retrospective clinical trial	13	4 premolars, 15 molars	Endocrowns	Butt margin Preparation depth: 4 mm Angle of cavity walls: 90 ±4 degrees	VITA mark 2; VITA Zahnfabrik. VITA In-Ceram Alumina/ Spinell; VITA Zahnfabrik	CEREC 2 unit; Dentsply Sirona	VITA Mark II: - Hydrofluoric acid 4.9% (VITA ceramics etch; VITA Zahnfabrik) - Silane (Monobond S; Ivoclar Vivadent AG), - Adhesive (Heliobond; Ivoclar Vivadent AG) In-Ceram: - Air abrasion alumina 50 μm at 3-4 bar 30 sec Tooth: - Phosphoric acid 37% (Ultra-etch; Ultradent) - Primer (Syntac; Ivoclar Vivadent AG) - Adhesive (Syntac; Ivoclar Vivadent AG) - Heliobond, Ivoclar Vivadent AG	VITA Mark II: Tetric; Ivoclar Vivadent AG In-Ceram: Panavia 21 TC; Kuraray Noritake	Modified USPHS criteria
Otto (2004)[15]	Prospective clinical trial	20	6 premolars, 14 molars	Endocrowns: -9 molars -1 premolar Reduced preparation crowns: -5 premolars -5 molars		VITA mark 2; VITA Zahnfabrik	CEREC 3 unit; Dentsply Sirona	VITA Mark II: - Hydrofluoric acid 5% (VITA ceramics etch; VITA Zahnfabrik) - Silane (VITAsil; VITA Zahnfabrik) Tooth: - Phosphoric acid 35% (Ultra-etch; Ultradent) - Adhesive (A.R.T. Bond; Coltène)	Duo Cement Plus; Coltène	Modified USPHS criteria
Bindl et al (2005)[16]	Prospective clinical trial	136	63 premolars, 145 molars	Endocrowns: -16 premolars -70 molars Classic crowns: -33 premolars -37 molars Reduced preparation crowns: -14 premolars -38 molars		VITA mark 2; VITA Zahnfabrik	CEREC 2 unit; Dentsply Sirona	VITA Mark II: - Hydrofluoric acid 5% (VITA ceramic etch; VITA Zahnfabrik) - Silane (Monibond S; Ivoclar Vivadent AG) Tooth: - Primer and adhesive auto etch (Syntac classic; Ivoclar Vivadent AG) - Adhesive (Heliobond; Ivoclar Vivadent AG)	Tetric; Ivoclar Vivadent AG	Modified USPHS criteria ,
Bernhart et al (2010)[21]	Prospective clinical trial	18	20 molars	Endocrowns	Butt margin	VITA mark 2; VITA Zahnfabrik	CEREC; Dentsply Sirona	VITAblocs Mk II: - Hydrofluoric acid 5% (VITA ceramic etch; VITA Zahnfabrik) - Silane (Clearfil porcelain bond activator and Clearfil SE Bond Primer; Kuraray Noritake)	Panavia F2.0; Kuraray Noritake	Modified USPHS criteria
Decerle et al (2014)[27]	Prospective clinical trial	16	5 premolars, 11 molars	Endocrowns	Butt margin	VITA mark 2; VITA Zahnfabrik	CEREC AC; Dentsply Sirona		RelyX Unicem; 3M	Modified FDI criteria
Otto and Mörmann (2015)[29]	Prospective clinical trial	15	24 premolars, 41 molars	Endocrowns: -20 molars -5 premolars Crowns: -21 molars -19 premolars		VITA mark 2; VITA Zahnfabrik	CEREC 3 unit; Dentsply Sirona	VITAblocs Mk II: - Hydrofluoric acid 5% (VITA Ceramics Etch; VITA Zahnfabrik) - Silane (VITAsil; VITA Zahnfabrik) Tooth: - Phosphoric acid 35% (Ultra-etch; Ultradent) - Adhesive (A.R.T. Bond; Coltène)	Duo Cement Plus; Coltène	Modified USPHS criteria Plaque and bleeding index Patient satisfaction Sensitivity (CO_2 test)

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Supplemental Table 1. (*Continued*) Material and methods of clinical studies

Study	Type of Study	Number of Patients	Type of Teeth	Prosthetic Restorations Studied	Preparation Criteria for Endocrowns	Materials Used for Endocrowns	Endocrown Fabrication	Adhesive Pretreatment	Bonding	Evaluation Criteria
Belleflamme et al (2017)[44]	Retrospective clinical trial	64	56 molars, 41 premolars, 2 canines	Endocrowns	Classification of the endocrowns into 3 categories depending on residual tissues: Class 1 (n=16): at least 2 walls conserving at least half of their original height Class 2 (n=8): 1 wall conserving at least half of its original height Class 3 (n=76): all walls have less than half of their original height	IPS Empress 2 or IPS e.max Press; Ivoclar Vivadent AG (n=84) Enamic, VITA Zahnfabrik (n=12) Indirect composite (n=3)	Hot pressing CAD/CAM Artisanal	Ceramic: - Hydrofluoric acid 9% 20 sec (Ultradent) - Silane (Monobond S; Ivoclar Vivadent AG) Enamic: - Hydrofluoric acid 9% 60 sec (Porcelain etch; Ultradent) - Silane (Monobond S; Ivoclar Vivadent AG) Artisanal composite: - Sandblasting (CoJet; 3M) - Silane (Monobond S; Ivoclar Vivadent AG) Teeth: - IDS (Immediate Dentin Sealing) OptiBond FL; Kerr - Air abrasion of the IDS with CoJet; 3M - Excite DSC; Ivoclar Vivadent AG	Variolink 2; Ivoclar Vivadent AG	FDI criteria
Fages et al (2017)[49]	Prospective clinical trial	323	447 molars	Endocrowns (235), crowns (212)	Butt margin	VITA mark 2; VITA Zahnfabrik	CEREC 3 unit; Dentsply Sirona	Ceramic: - Hydrofluoric acid 5% (VITA Ceramics Etch; VITA Zahnfabrik) Teeth: - Phosphoric acid	Relyx Unicem; 3M	Survival rate, failure mode

FDI, World Dental Federation; USPHS, United States Public Health Service.

Supplemental Table 2. Materials and methods of in vitro studies

Study	Type of Teeth	Model Type	Type of Restorations Studied	Endocrown Preparation Criteria	Materials Used for Endocrowns	Bonding Material	Type of Tests
Forberger and Göhring (2008)[17]	Mandibular premolars	Extracted teeth	Fiber posts-crowns, gold cast posts-crowns, zirconia posts-crowns, endocrowns	Ferrule: 2 mm	Experimental Press; Ivolcar Vivadent AG (lithium disilicate)	Variolink; Ivoclar Vivadent AG	Fatigue test
Lin et al (2009)[18]	Maxillary premolars	3D FE model	Endocrowns, onlays, cast posts (Ni Cr)-crowns		VITA mark 2; VITA Zahnfabrik		Fracture strength
Chang et al (2009)[19]	Maxillary premolars	Extracted teeth	Endocrowns, fiber posts-crowns	Butt margin: 5-mm deep	IPS Impress CAD; Ivoclar Vivadent AG	Variolink II; Ivoclar Vivadent AG	Fatigue strength, fracture strength
Lin et al (2010)[20]	Maxillary premolars	3D FE model	Endocrowns, fiber posts-crowns	Butt margin	VITA mark 2; VITA Zahnfabrik		Fracture strength
Lin et al (2011)[22]	Maxillary premolars	3D FE model and Extracted teeth	Endocrowns, cast posts-crowns (Ni Cr), inlays	Butt margin	VITA mark 2; VITA Zahnfabrik		Fracture strength
Biacchi and Basting (2012)[23]	Mandibular molars	Extracted teeth	Fiber posts-crowns, endocrowns	Butt margin Depth: 3.7 to 5 mm	IPS e.max Press; Ivoclar Vivadent AG	RelyX ARC; 3M	Fracture strength
Lin et al (2013)[24]	Maxillary premolars	3D FE model	Onlays, endocrowns, metal posts-crowns	Butt margin	VITA mark 2; VITA Zahnfabrik		Fracture strength
Ramirez-Sebastia et al (2013)[25]	Maxillary incisors	Extracted teeth	Endocrowns - Ceramic - Composite Ceramic crowns: - Fiber posts 10 mm - Fiber posts 5 mm Composite crowns - Fiber posts 10 mm - Fiber posts 5 mm		MZ100; 3M. IPS Empress CAD; Ivoclar Vivadent AG	Clearfil Esthetic Cement; Kuraray Noritake	Fatigue strength
Ramirez-Sebastia et al (2014)[26]	Maxillary incisors	Extracted teeth	Endocrowns - Ceramic - Composite Ceramic crowns: - Fiber posts 10 mm - Fiber posts 5 mm Composite crowns: - Fiber posts 10 mm - Fiber posts 5 mm		MZ100; 3M. IPS Empress CAD; Ivoclar Vivadent AG	Clearfil Esthetic Cement; Kuraray Noritake	Fracture strength
Magne et al (2014)[28]	Maxillary molars	Extracted teeth	Endocrowns - 2 mm no post buildups-crowns 4 mm no post buildups-crowns	Butt margin	Lava Ultimate blocks; 3M	RelyX Unicem 2 automix; 3M	Fatigue strength, fracture strength
Schmidlin et al (2015)[31]	Maxillary premolars	3D FE model and Extracted teeth	Endocrowns, crowns with intracanal H–shaped posts, fiber posts-crowns	Butt margin	IPS Empress; Ivoclar Vivadent AG. IPS e.max; Ivoclar Vivadent AG	Filtek Supreme; 3M	Fracture strength
Carvalho et al (2016)[33]	Maxillary molars	Extracted teeth	Endocrowns 2 mm no post buildups-crowns 4 mm no post buildups-crowns	Butt margin	IPS e.max; Ivoclar Vivadent AG	RelyX Unicem 2 automix; 3M	Fatigue strength, fracture strength
El Damanhoury et al (2015)[32]	Maxillary molars	Extracted teeth	Endocrowns made of: - Feldspathic ceramic - Lithium disilicate - Nanofill composite	Butt margin Depth: 2 mm	CEREC Blocs; Dentsply Sirona. IPS e.max; Ivoclar Vivadent AG. Lava Ultimate; 3M	Variolink II; Ivoclar Vivadent AG	Fracture strength, microleakage
Rocca et al (2015)[30]	Molars	Extracted teeth	Endocrowns		Lava Ultimate; 3M	G-aenial posterior; GC	Fatigue strength, fracture strength
Rocca et al (2016)[35]	Molars	Extracted teeth	Endocrowns	Butt margin	Lava Ultimate; 3M	G-aenial posterior; GC	Fatigue strength; SEM microscope
Gresnigt et al (2016)[34]	Mandibular molars	Extracted teeth	Sound teeth, endocrowns	Butt margin	IPS e.max; Ivoclar Vivadent AG. Lava Utlimate; 3M	Variolink II; Ivoclar Vivadent AG	Fracture strength
Aktas et al (2016)[38]	Mandibular molars	Extracted teeth	Endocrowns		VITA Mark II; VITA Zahnfabrik. SUPRINITY; VITA Zahnfabrik. Enamic; VITA Zahnfabrik	RelyX Ultimate; 3M	Fracture strength

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Supplemental Table 2. (*Continued*) Materials and methods of in vitro studies

Study	Type of Teeth	Model Type	Type of Restorations Studied	Endocrown Preparation Criteria	Materials Used for Endocrowns	Bonding Material	Type of Tests
Gaintantzopoulou and El-Damanhoury (2016)[36]	Mandibular molars	Acrylic resin teeth	Endocrowns of different preparation depth and intracanal extensions	Depth 2 mm	VITA Enamic; VITA Zahnfabrik	None	Microtomography
Shin et al (2016)[37]	Mandibular molars	Extracted teeth	Endocrowns of different preparation depth (2 and 4 mm)	Depth: 2 to 4 mm	IPS e.max CAD; Ivoclar Vivadent AG	Duo Link; Bisico	Microtomography
Zhu et al (2016)[39]	Maxillary premolars	3D FE model	Endocrowns		IPS e.max CAD; Ivoclar Vivadent AG. MZ100; 3M. IPS Empress; Ivoclar Vivadent AG. In-Ceram Zirconia; VITA Zahnfabrik	Multilink Automix; Ivoclar Vivadent AG	Compression test
Guo et al (2016)[40]	Mandibular premolars	Extracted teeth	Endocrowns, fiber posts-crowns, sound teeth	Butt margin Depth: 5 mm	IPS e.max; Ivoclar Vivadent AG	Variolink II; Ivoclar Vivadent AG	Fracture strength
El-Damanhoury and Gaintantzopoulou (2016)[41]	Maxillary premolars	Extracted teeth	Endocrowns	Butt margin Depth: 2 mm	VITA Mark II; VITA Zahnfabrik	Variolink II; Ivoclar Vivadent AG	Fracture strength
Pedrollo Lise et al (2017)[42]	Premolars	Extracted teeth	Endocrowns of different preparation depth, fiber posts-crowns	Butt margin	IPS e.max CAD; Ivoclar Vivadent AG. CERASMART; GC	Clearfil Esthetic Cement; Kuraray Noritake	Fracture strength
BankogluGungor et al (2017)[43]	Maxillary incisors	Extracted teeth	Endocrowns: - Lithium disilicate - Nanofill composite Zirconia posts associated with: - Nanofill composite crowns - Lithium disilicate crowns Fiber post associated with: - Nanofill composite crowns - Lithium disilicate crowns	2-mm ferrule	IPS e.max CAD; Ivoclar Vivadent AG. Lava Ultimate; 3M	Bifix SE; Voco Cuxhaven	Fracture strength
Dejak and Mlotowski (2017)[45]	Maxillary incisors	FE 3D model	Cast posts-crowns, leucite endocrowns, lithium disilicate endocrowns	Ferrule			Stress distribution
Hayes et al (2017)[46]	Maxillary molars	Extracted teeth	Different depths endocrowns: - 2 mm - 3 mm - 4 mm	Butt margin	IPS e.max CAD; Ivoclar Vivadent AG	RelyX Unicem; 3M	Fracture strength
Atash et al (2017)[47]	Premolars	Extracted teeth	Cast posts-crowns, fiber posts-crowns, endocrowns	Butt margin	IPS e.max CAD; Ivoclar Vivadent AG	Panavia SA cement plus; Kuraray Noritake	Fracture strength
Einhorn et al (2017)[48]	Mandibular molars	Extracted teeth	Endocrowns: - No ferrule - 1-mm ferrule - 2-mm ferrule	Butt margin, ferrule: 1 mm or 2 mm	IPS e.max CAD; Ivoclar Vivadent AG	RelyX Unicem; 3M	Fracture strength
Rocca et al (2017)[50]	Maxillary premolars	Extracted teeth	Different depths endocrowns: - 2 mm - 4 mm Fiber posts-crowns	Butt margin	IPS e.max CAD; Ivoclar Vivadent AG	Multilink Automix; Ivoclar Vivadent AG	Fatigue strength, marginal integrity
Taha et al (2017)[51]	Mandibular molars	Extracted teeth	Endocrowns: - No ferrule - 1-mm ferrule	Butt margin, ferrule: 1 mm	Enamic; VITA Zahnfabrik	RelyX Unicem 2; 3M	Fracture strength
Kanat-Ertürk et al (2017)[52]	Maxillary incisors	Extracted teeth	Different depths endocrowns: - 3 mm - 6 mm	Butt margin	IPS e.max CAD; Ivoclar Vivadent AG. VITA Mark II; VITA Zahnfabrik. Enamic; VITA Zahnfabrik. Lava Ultimate; 3M. InCoris TZI; Dentsply Sirona	RelyX U200; 3M	Fracture strength

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Supplemental Table 2. (*Continued*) Materials and methods of in vitro studies

Study	Type of Teeth	Model Type	Type of Restorations Studied	Endocrown Preparation Criteria	Materials Used for Endocrowns	Bonding Material	Type of Tests
Zimmermann et al (2018)[53]	Maxillary molar	Artificial teeth	Endocrowns	Butt margin	Lava Ultimate; 3M. Celtra Duo; Dentsply Sirona. IPS Empress CAD; Ivoclar Vivadent AG	None	Adaptation
Dartora et al (2018)[54]	Mandibular molars	Extracted teeth	Different depths endocrowns: - 1 mm - 3 mm - 5 mm	Butt margin	IPS e.max CAD; Ivoclar Vivadent AG	RelyX ARC; 3M	Fracture strength

Supplemental Table 3. Results of clinical studies

Study	Follow-up	Survival Rate	Failures
Bindl and Mörmann (1999)[14]	14 to 35.5 mo, average 26 mo	95% (PM and M), 93.3% M, 100% PM	1 Debonding for one PM, secondary caries
Otto (2004)[15]	12 to 16 mo, average 15 mo	100% endocrowns, 100% reduced preparation crowns	
Bindl et al (2005)[16]	Average 55 mo	97% PM and 94.6% M for classic crowns; 92.9% PM and 92.1% M for reduced preparation crowns; 68.8% PM and 87.1% M for endocrowns	Classic preparation crowns: - 3 crown fractures (2 M and 1 PM) - 5 irreversible pulpitis (5 M) - 3 vertical radicular fractures (2 M and 1 PM) - 1 new restoration needed (partial denture support teeth) (M). Reduced preparation crowns: - 4 crown fractures (3 M and 1 PM) - 3 vertical radicular fractures (1 M and 2 PM) Endocrowns: - 14 debonding (9 M and 5 PM) - 2 vertical radicular fractures (2 M) - 2 periodontitis (2 M) - 1 interradicular osteitis (1 M)
Bernhart et al (2010)[21]	2 y	90.00%	1 endocrown fracture, 1 tooth/endocrown fracture
Decerle et al (2014)[27]	6 mo	100% PM and 90.9% M	1 secondary caries
Otto and Mörmann (2015)[29]	9 y and 8 mo to 12 y and 2 mo; average 9 y and 8 mo	Crowns: 95% M and 94.7% PM; endocrowns: 90.5% M and 75% PM	Crowns: - 1 ceramic chip (M) - 1 mesiodistal fracture (PM) Endocrowns: - 2 debonding (M) - 1 endocrown fracture (PM)
Belleflamme et al (2017)[44]	Average 44.7 mo	99.00%	Debonding: 2 Minor chipping: 2 Major fractures: 1 Secondary caries: 2 Periodontitis: 3
Fages et al (2017)[49]	Average 55 mo	Success rate: - Endocrowns 99.78% - Crowns 98.66%	Endocrowns: - Ceramic fractures: 1 Crowns: - Ceramic fractures: 5

Supplemental Table 4. Results of in vitro studies

Study	Fracture Strength	Stress Distribution	Failure Mode	Marginal Adaptation	Failure Probability
Forberger and Göhring (2008)[17]	Sound teeth: 849.0 (94) N Endocrowns: 1107.3 (217.1) N Fiber posts-crowns: 1092.4 (307.8) N Zirconia posts-crowns: 1253.7 (226.5) N Gold posts-crowns: 1101.2 (182.9) N		Endocrowns: 3/8 critical failures Fiber post-crowns: 4/6 critical failures Zirconia post-crowns: 5/7 critical failures Gold posts-crowns: 3/7 critical failures	Before TCML: Significant difference between fiber posts and endocrowns - Endocrowns: 72.4 (15.8)% of continuous margins - Fiber posts: 94.8 (3)%. After TCML: - Endocrowns: 44.7 (14.5)% - Fiber posts: 75.5 (8.4)% - Zirconia post: 75.5 (8.4)% - Gold posts: 68.6 (19.8)%	
Lin et al (2009)[18]		Endocrown group shows the lowest stress in enamel, dentin, and cement. Endocrowns: - Dentin 4 MPa - Cement 5.93 MPa Inlay cores-crowns: - Dentin 5.43 MPa - Cement 15.37 MPa Onlays: - Dentin 9.57 MPa - Cement 13.34 MPa			Endocrowns: 1% Inlay cores-crowns: 1% Onlays: 27.5%
Chang et al (2009)[19]	Endocrowns: SD=1446.68 (200.34) N Fiber posts-crowns: SD=1163.30 (163.15) N		Endocrowns: - Critical failures: 7/10 Fiber posts-crowns: - Critical failures: 6/10		
Lin et al (2010)[20]		Endocrown group shows the lowest stress in dentin and cement. Fiber posts-crowns: - Dentin: 5.43 MPa - Cement: 15.36 MPa Endocrowns: - Dentin: 3.65 MPa - Cement: 2 MPa			Failure probability similar for crowns and endocrowns
Lin et al (2011)[22]	Endocrowns: SD=1085 (400) N Inlay cores-crowns: SD=1126 (128) N Inlays: SD=946 (404) N	Endocrown group shows the lowest stress in enamel, dentin, and cement. Endocrowns: - Dentin 3.85 MPa - Cement 5.81 MPa Inlay cores-crowns: - Dentin 6.43 MPa - Cement 15.73 MPa Inlays: - Dentin 10.15 MPa - Cement 74.75 MP			Inlays: 95% Endocrowns: 2% Cast posts-crowns: 2%
Biacchi and Basting (2012)[23]	Endocrowns: 674.75 (158.85) N Fiber post-crowns: 469.90 (129.83) N		Endocrowns: - Restoration fractures: 0 - Tooth fractures: 10 - Fractures with displacement: 90 - Displacement without fracture: 0 Fiber posts-crowns: - Restoration fractures: 10 - Tooth fractures: 0 - Fractures with displacement: 80 - Displacement without fracture: 10		

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Supplemental Table 4. (*Continued*) Results of in vitro studies

Study	Fracture Strength	Stress Distribution	Failure Mode	Marginal Adaptation	Failure Probability
Lin et al (2013)[24]		Endocrown group shows the lowest stress in enamel, dentin, and cement. With crack above bone level: - Endocrowns: - Dentin 3.60 MPa - Cement 6.32 MPa - Onlays: - Dentin 8.09 MPa - Cement 11.29 MPa - Metal posts-crowns: - Dentin 5.02 MPa - Cement 6.12 Mpa With crack below bone level: - Endocrowns: - Dentin 3.84 MPa - Cement 6.44 MPa - Onlays: - Dentin 5.81 MPa - Cement 11.60 MPa - Metal posts-crowns: - Dentin 5.18 MPa - Cement 7.65 MPa			With crack above bone level: - Endocrowns: 2% - Crowns: 1% - Onlays: 27% With crack below bone level: - Endocrowns: 10% - Crowns: 2% - Onlays: 70%
Ramirez-Sebastia et al (2013)[25]				Teeth restored with composite endocrowns or crowns show the most continuous limits after fatigue test.	
Ramirez-Sebastia et al (2014)[26]	No significant differences between groups. Short post (5 mm): 470.9 N Endocrowns: 552.4 N Long posts (10 mm): 432.6 N		Endocrowns group shows the highest proportion of repairable fractures		
Magne et al (2014)[28]	Survival rates show no significant differences: - 4 mm buildup: 53% - 2 mm buildup: 87% - Endocrowns: 87% Fracture resistance shows no significant differences: - 4 mm buildup: 2969 N - 2 mm buildup: 2794 N - Endocrowns: 2606 N		After fatigue test only 4-mm buildup shows critical failures. 2-mm buildup: - 2 cohesive failures at crown Endocrowns: - 1 cohesive failure at crown - 1 cohesive failure at crown and buildup + dentin chip 4-mm buildup: - 1 cohesive failure at crown - 3 cohesive failures at crown and buildup + adhesive failure at dentin margin - 1 adhesive failure at crown and buildup + adhesive failure at dentin margin - 2 critical failures After fracture strength test, 100% of critical failures.		
Schmidlin et al (2015)[31]	H post (glass ceramic): 547 (232) N H post (SiO2): 1044 (501) N Endocrowns: 592.4 (147) N Fiber post: 890 (125) N	Highest stress areas: - H posts: 33 to 35 MPa, junction between palatal limit and core - Endocrowns: 55 to 60 MPa, mesial corners of the radicular slot - Fiber posts: 15 to 20 MPa, mesial aspect	% of repairable failures: - Endocrowns: 100% - H posts (glass-ceramic): 90% - H posts (SiO2): 70% - Fiber posts: 50%		
Carvalho et al (2016)[33]	Survival rates show no significant differences: - 4-mm buildup: 100% - 2-mm buildup: 93% Endocrowns: 100% 2-mm buildup group show higher fracture resistance than 4-mm and endocrown groups. - 4-mm buildup: 3181 N - 2-mm buildup: 3759 N - Endocrown: 3265 N		1 failure after fatigue test: cohesive fracture of the crown in the 2-mm buildup group After fracture strength test, 100% of critical failures.		

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Supplemental Table 4. (*Continued*) Results of in vitro studies

Study	Fracture Strength	Stress Distribution	Failure Mode	Marginal Adaptation	Failure Probability
El-Damanhoury et al (2015)[32]	Resin group shows the highest fracture strength - Resin: 1583.28 N - Feldspathic ceramic: 1340.92 N - Li2Si2O5 : 1368.77 N		Resin group shows the highest number of repairable fractures Type IV fractures: - Resin: 0% - Feldspathic ceramic: 30% - Li2Si2O5 : 70%	Resin shows the lowest leakage. Resins show the highest leakage Dye penetration: - Resin: 2.80 mm - Feldspathic ceramic: 1.11 mm - Li2Si2O5 : 1.91 mm	
Rocca et al (2015)[30]	No significant differences				
Rocca et al (2016)[35]				No significant differences	
Gresnigt et al (2016)[34]	No significant differences under axial forces: - Li2Si2O5: 2428 (566) N - resin: 2675 (588) N - Sound teeth: 2151 (672) N. Under lateral forces, resin group shows lower fracture strength than Li2Si2O5: - Li2Si2O5: 1118 (173) N - Resin: 838 (169) N - Sound teeth: 1499 (418) N		Critical failures (axial): - Li2Si2O5: 30% - Resin: 30% - Sound teeth: 20%. Critical failures (lateral): - Li2Si2O5: 50% - Resin: 20% - Sound teeth: 50%		
Aktas et al (2016)[38]	No significant differences - Alumina silicate: 1035.08 N - Zirconia reinforced: 1058.33 N - Polymer infiltrated: 1025.00 N		Critical failures: - Alumina silicate: 5/12 - Zirconia reinforced: 12/12 - Polymer infiltrated: 3/12		
Gaintantzopoulou et al (2016)[36]				Group of 2-mm depth shows the lowest values for: - Marginal gap - Marginal discrepancies - Internal margin gap	
Shin et al (2016)[37]				4-mm-deep endocrowns show larger marginal and internal volumes than 2-mm endocrowns.	
Zhu et al (2016)[39]		As the quantity of preserved dental tissues increased, the von Mises stress in dentin decreased, and the peak von Mises strain value of the cement layer increased. When the elastic modulus of the endocrown material increased, the von Mises stress in endocrown and dentin increased, and the peak von Mises strain value of the cement layer decreased.			
Guo et al (2016)[40]	No significant differences between fiber post end endocrowns groups. - Sound teeth: 997.1 (166.3) N - Endocrowns: 479.1 (180.6) N - Fiber post-crowns: 510.1 (191) N		Sound teeth: - Noncritical failures: 7:10 - Critical failures: 3/10 Endocrowns: - Noncritical failures 4/10 - Critical failures 6/10 Fiber posts-crowns: - Noncritical failures 4/10 - Critical failures 6/10		
El-Damanhoury and Gaintantzopoulou (2016)[41]	IDS does not improve fracture strength				
Pedrollo Lise et al (2017)[42]	No significant differences between the different configurations				

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Supplemental Table 4. (*Continued*) Results of in vitro studies

Study	Fracture Strength	Stress Distribution	Failure Mode	Marginal Adaptation	Failure Probability
BankogluGungor et al (2017)[43]	No significant differences. Endocrowns show the highest values. Endocrowns - Lithium disilicate: 915.91 N - Nanofill composite: 869.04 N Zirconia posts +: - Nanofill composite crowns: 893.43 N - Lithium disilicate crown: 764.03 N Fiber posts +: - Nanofill composite crowns: 580.02 N - Lithium disilicate crown: 646.78 N		Only the endocrown group shows tooth fractures. Post restorations group only shows fractures of the materials. Tooth fractures for the endocrowns (all materials): 17/20 Tooth fractures for cast posts-crowns (all materials): 0/20 Tooth fractures for fiber post-crowns (all materials): 0/20		
Dejak and Mlotowski (2017)[45]		Cast posts-crown group shows the lowest stress. Cast posts-crowns: - Dentin: 11 MPa - Cement: 10.3 MPa Leucite endocrowns: - Dentin: 13.3 MPa - Cement: 17.2 MPa Lithium disilicate endocrowns: - Dentin: 13.7 MPa - Cement: 18.5 MPa			
Hayes et al (2017)[46]	Endocrowns of 2 and 4 mm depth show the best fracture strength. - 2 mm: 843.4 N - 3 mm: 762.8 N - 4 mm: 943.5 N		Nonrepairable fractures: - 2 mm: 8/12 - 3 mm: 11/12 - 4 mm: 10/12		
Atash et al (2017)[47]	Endocrown group shows the highest fracture strength: endocrowns: 1717.17 N cast posts-crowns: 1068.82 N fiber posts-crowns: 1091,11 N				
Einhorn et al (2017)[48]	Endocrowns with ferrule show better fracture strength. No ferrule: 638.5 N 1 mm: 1101.0 N 2 mm: 956.3				
Rocca et al (2017)[50]	No significant differences			No significant difference	
Taha et al (2017)[51]	Endocrowns with ferrule show better fracture strength. Ferrule: 1270 N Butt margin: 1140 N		No significant difference		
Kanat-Ertürk et al (2017)[52]	Zirconia group shows highest fracture strength Zirconia: 533 N e.max: 244 N Enamic: 172 N Lava Ultimate: 81 N VITA mark II: 47 N		Zirconia group shows the highest number of nonrepairable fractures		
Zimmermann et al (2018)[53]				Lava Ultimate shows better adaptation than Celtra Duo	
Dartora et al (2018)[54]	The deepest endocrowns show the best fracture strength - 1 mm: 1268 N - 2 mm: 1795 N - 3 mm: 2008 N				

Li2Si2O5, lithium disilicate.