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SYSTEMATIC REVIEW

Factors influencing success rate of ceramic veneers on endodontically treated anterior teeth: A systematic review

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ABSTRACT

Statement of problem. More conservative restorative approaches have been advocated for nonvital anterior teeth as an alternative to complete coverage crowns to maximize the preservation of tooth structure. Systematic reviews that investigated factors influencing the success rate of porcelain veneers on endodontically treated anterior teeth are lacking.

Purpose. The purpose of this systematic review was to investigate factors influencing the success rate of porcelain veneers on endodontically treated anterior teeth.

Material and methods. Searches were performed across Medline/PubMed, Google Scholar, Scopus, and Web of Science electronic databases. In addition, articles were hand searched from references of systematic reviews concerning porcelain veneers and endodontically treated teeth.

Results. After screening and applying the eligibility, inclusion, and exclusion criteria, 7 articles met the inclusion criteria. Factors that could positively influence the success rate of endodontically treated anterior veneered teeth were immediate dentin sealing, labially positioning of the endodontic access cavity, and incorporating fiber posts.

Conclusions. The use of fiber posts and labial positioning of the endodontic access cavity could positively influence the success rate of porcelain veneers on endodontically treated teeth. The effect of immediate dentin sealing on the survival rate of endodontically treated veneered teeth is still unclear and further research is needed. (J Prosthet Dent xxxx;xxx:xxx-xxx)

Since their introduction in the early 1980s, porcelain veneers have been popular because of their esthetics, conservative nature, and clinical performance.[1] They are a successful treatment option for discolored, malformed, worn, and fractured teeth where direct application of composite resin is not appropriate.[2] When a tooth loses its vitality from caries, trauma, fracture, or bacterial invasion, histological and structural alterations can occur which can affect the longevity of the subsequent restoration.[3] The medicaments and irrigants used during the endodontic treatment have been associated with alterations in the physical properties of dentin, altering the bonding of the dentin-enamel complex to the restoration.[3] The proprioception of the tooth provided by the surrounding periodontal ligaments is modified or diminished in endodontically treated teeth.[3] Moreover, the dentin becomes more sclerotic subsequent to the desiccation of the remaining tooth tissues, and discoloration and staining can occur because of pulp necrosis and endodontic materials. Endodontically treated teeth have been reported more prone to fracture, possibly because of the loss of marginal ridges and reduced cusps or cuspal stiffness.[3–5] The restoration of endodontically treated teeth has undergone considerable changes in the last 20 years, mostly related to the preservation of tooth structure.[3] Complete coverage crowns and post-and-cores were traditionally recommended after endodontic treatment of extensively damaged teeth.[6,7] More recently, the focus has shifted toward partial direct or indirect restorations to preserve tooth

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Clinical Implications

This systematic review will help clinicians with decision-making when performing porcelain veneers on endodontically treated anterior teeth for improved treatment outcomes.

tissue.[3] In addition, studies have investigated the performance of porcelain veneers on endodontically treated maxillary or mandibular incisors as an alternative to crowns or direct composite resin restorations.[8–10]

A post-and-core may be necessary to increase the retention and resistance of the coronal restoration. Fiber posts have a modulus of elasticity of approximately 25 to 57 GPa compared with dentin, which has an elastic modulus of 18 GPa.[11–15] Fiber posts also have a similar flexural strength compared with dentin and can provide more uniform stress distribution to the remaining root structure, protecting the root from fracture.[16] The similarity in flexural strength is important because occlusal load may result in flexure, resulting in a micro-environment that can lead to coronal leakage, caries, and restoration loss.[16] Therefore, fiber posts have been preferred over other post systems because they are safer, conserve tooth structure, provide improved fracture resistance, and are more esthetic.[16] The porcelain veneer technique includes bonding to the tooth surface using adhesive techniques and a luting composite resin. Peumans et al reported that the success of the ceramic veneer is influenced by the durability and strength of the formed bond between the 3 components of the adhesion complex. Magne and Douglas[17] reported in an in vitro study that ceramic veneers bonded to teeth had demonstrated biomimetic behavior, restoring the mechanical behavior and microstructure of the intact tooth using dentin adhesives even if they are bonded to a large area of the dentin surface.[17] Studies have focused on the success rate of porcelain veneers and the esthetic and functional aspects of restoring endodontically treated teeth; most focused on the post, core, and complete coverage.[18,19] However, clear data on the survival rates of endodontically treated teeth with veneers are lacking. Dioguardi et al[20] investigated the success rate of indirect posterior partial restorations on vital and nonvital teeth, concluding that indirect partial posterior restorations have a better survival rate on vital teeth than nonvital teeth. However, the mechanical properties of ceramic partial coverage in the anterior and posterior regions are different. Ferrari et al[21] was unable to conduct a systematic review because of the insufficient availability of studies on the survival rates of endodontically treated posterior teeth restored with ceramic partial coverage crowns.

The authors are unaware of systematic reviews that investigated factors influencing the success rate of porcelain veneers on endodontically treated anterior teeth.[22,23] Therefore, this systematic review aimed to investigate whether factors such as the technique used and the presence of a post would significantly influence the success rate of porcelain veneers on endodontically treated anterior teeth. The null hypothesis was that no difference would be found in the factors influencing the success rate of ceramic veneers on nonvital anterior teeth.

MATERIAL AND METHODS

A comprehensive search of the Medline/PubMed, Scopus, Google Scholar, and Web of Science electronic databases was conducted. The keywords and combinations used for all the electronic database searches are provided in Supplemental Data 1 (available online). References from the identified studies were manually searched to discover additional relevant studies. Search filters included English and publication date (April 2002 to April 2023). The authors focused on the last 20 years since investigating studies beyond 20 years would have increased heterogeneity with materials and protocols that are no longer current. The titles and abstracts were screened to determine eligibility using inclusion and exclusion criteria (Table 1).

After an initial screening, duplicates were removed, and potentially eligible studies were subjected to full-text analysis to determine eligibility for inclusion in qualitative and quantitative analyses. In addition, 2 independent reviewers (V.B., J.A.) evaluated the full-text articles, and studies that satisfied the eligibility and inclusion criteria were selected for assessment. The systematic review was conducted following the preferred reporting items for

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Papers published in English	Studies in languages other than English
Studies published in last 20 years	Case reports, systematic reviews, meta-analyses, clinical reports, questionnaires, interviews, unpublished literatures, clinical and cohort studies with limited number of specimens
Studies reporting data on porcelain veneers' success and failure rate on vital and endodontically treated teeth	Studies published before 2002
Studies that include details of techniques and use of posts	Studies report composite resin veneers, reporting data on posterior dentitions or non-vital teeth only
In vivo, in vitro, randomized clinical controlled trials, prospective, retrospective, comparative, and cross-sectional studies	Multiple studies on same patient cohorts

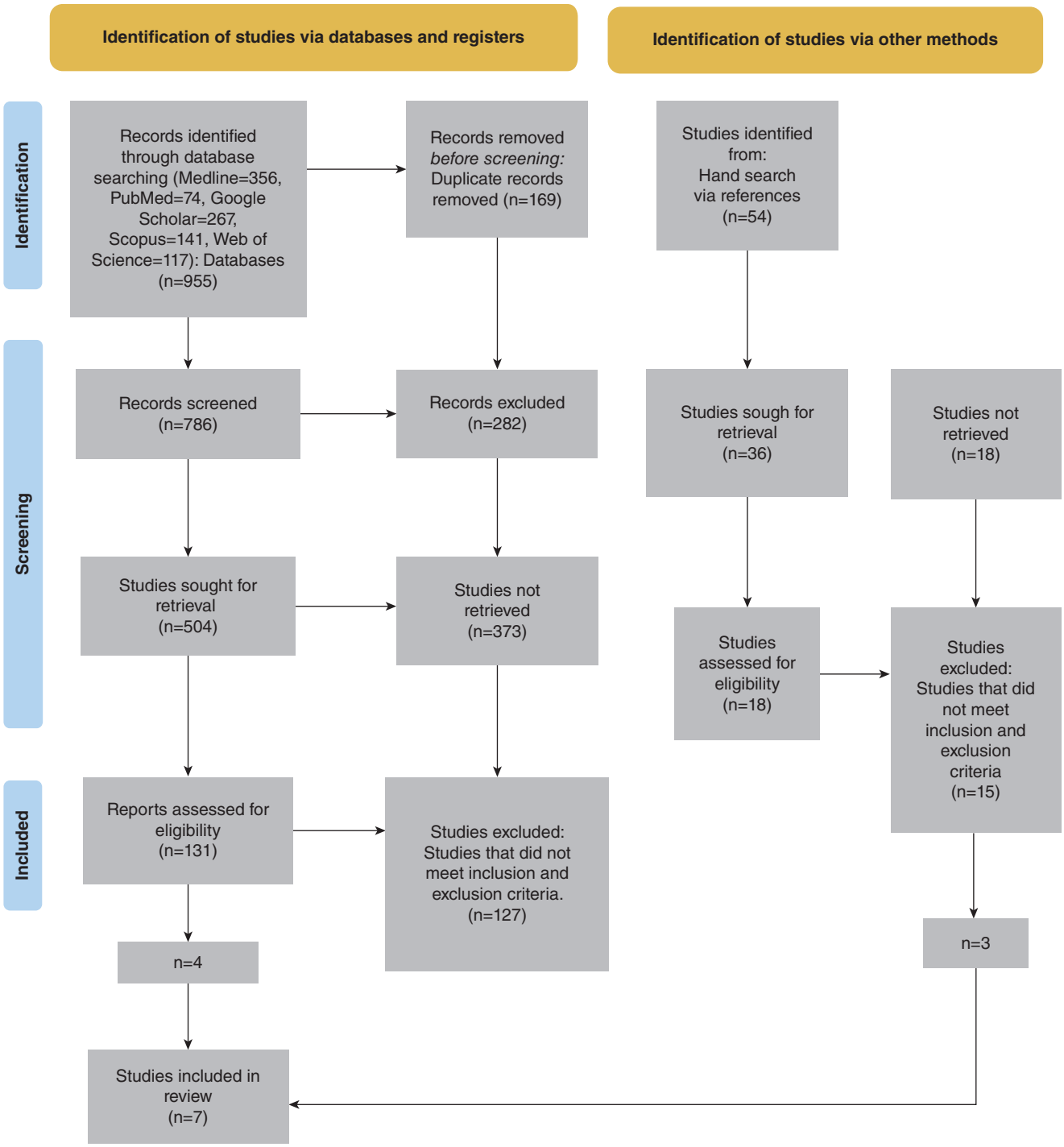

Figure 1. PRISMA Data flow of literature search.

systematic reviews and meta-analyses (PRISMA) guidelines (Fig. 1).[24] Attempts were made to communicate with the corresponding authors of the included studies via email and telephone to supply missing data. The data collected from the selected articles were extracted and imported into a spreadsheet (Microsoft Office Excel 2019; Microsoft Corp). The grading recommendations of assessments, development, and evaluation (GRADE) system[25] was used for the quality assessment of the clinical studies, and the consolidated standards of reporting trials (CONSORT) checklist[26] was used for the quality assessment of the in vitro studies.

Table 2. Summarized results of Group A

Author, Year	Overall Failure Rate	Overall SURVIVAL Rate	Repairable	Statistically Significant (Between Vital and Nonvital)	Factors Positively Affecting Success Rate of Porcelain Veneers in Non-vital Teeth
Gresnigt et al, 2019[28]	N=0.05%, Vital: 0.04% ETT: 0.05% (2 failures out of 43 in ETT) ETT + IDS: 0% Vital + IDS: 0%	95% / 11 years 96%: Vital 88.3%: ETT	– 4%: internal cracks repaired by resin infiltration – 0.007%: Chipping on palatal side repaired with direct composite resin – 0.007%: Chipping on palatal side repaired with direct composite resin	NO (*P*>.05) "Cumulative proportion of absolute failure at time of laminates bonded to teeth without (95%) and with endodontic treatment (88.1%) did not show significant differences (*P*>.05) [Kaplan-Mier Log Rank (Mantel-Cox) (CI=95%)].	IDS
Beier et al, 2012[1]	N=29 Absolute: 82.76% Relative: 17.24% Fracture: 44.83% Cracks: 27.59% Chipping: 10% Debonding: 10%	94.4% / 5 years 94.1% / 8 years 93.5% / 10 years 85.74% / 15 years 82.93% / 20 years	NS	YES (*P*<.001)	NS
Cotert et al, 2009[27]	N=0.06%	99.5% / 8 weeks 99% / 9 weeks 97.5% / 11 weeks 94.9% / weeks 94.4% / weeks 93.8% / 34 weeks 94.8%: Vital 93.3% Non-vital	– 16.77%: made with different preparation designs. – 75%: re-bonded	NO (*P*>.05)	NS

ETT, endodontically treated teeth; IDS, immediate dentin sealing; NA, Not applicable; NS, Not specified.

RESULTS

After screening and applying the eligibility, inclusion, and exclusion criteria, 7 articles were selected as part of the final review; 3 were clinical, and 4 were in vitro studies. A total of 882 teeth were assessed in the 7 studies, mostly maxillary or mandibular incisors, with 69 endodontically treated teeth being assessed. The overall failure and survival rate of the vital and endodontically treated teeth, their statistical significance, and the specific treatment factors for group A are summarized in Tables 2[1,27,28] and 3.[1,27,28]

Of the clinical studies, 2 were prospective[27,28] and 1 was retrospective.[1] Gresnigt et al[29] assessed 341 vital and 35 nonvital teeth, of which 9 were treated with immediate dentin sealing (IDS). None of the porcelain veneers on nonvital teeth treated with IDS failed. The overall survival rate for endodontically treated teeth was 88.3% and 96% for vital teeth. Nevertheless, the cumulative proportion of the absolute failure of porcelain veneer bonded to teeth with and without endodontic treatment showed no statistically significant difference (*P*>.05). Furthermore, Beier et al[1] reported that the endodontically treated veneered teeth without IDS showed a statistically significantly higher failure rate (*P*<.001). Cotert et al[30] did not specify treatment before placing the veneers for the vital and nonvital groups, reporting that the effect of vitality on the overall survival rate was not statistically significant (*P*>.05). Unfortunately, the amount of remaining tooth structure and the preservation of the marginal ridges on the endodontically treated abutment were not mentioned in the studies conducted by Cotert et al,[30] Beier et al,[1] and Gresnigt et al.[28] Gresnigt et al[29] specified the position and size of the endodontic access cavity but did not provide clear information about the dental tissue remaining before veneer placement.

Four in vitro studies were included in the present study (Group B),[30–33] 130 teeth were vital, and 145 teeth had been endodontically treated. The overall failure and survival rate of the vital and nonvital teeth, their statistical significance, and the specific treatment factors for group B are summarized in Table 4[30–33] and 5.[30–33] The loading technique, angulation, position, location, and load rate were similar in the studies.[30–33] Three of the studies positioned the access cavity on the palatal side of the tooth. Cotert et al[30] investigated different endodontic access locations and their effect on the fracture resistance of porcelain veneers with specimens divided into nonvital teeth with palatal access and labial access. The access cavity was made on the coronal side at the level of the cingulum. In the clinical studies,[30–33] the exact amount of remaining tooth structure was not recorded, but the presence of existing composite resin was specified, which improved the representation of the overall remaining coronal tooth structure. Cotert et al[30] reported that vital teeth had a fracture resistance of 3122.6 N, endodontically treated teeth with palatal access had a fracture resistance of 1867.0 N, and endodontically treated teeth with labial access had a fracture resistance of 2805.6 N. Endodontically treated

Table 3. Summary of factors considered in in vivo studies (Group A)

Author, Year	Type of Study	Observation Period (n=Years)	Sample Size and Distribution	Mean Age of Patients (Years)	Number of Patients (Men/ Women)	Type of Operator	Use of Post	Type of Teeth	Type of Occlusion	Position of Access Cavity, Presence of Marginal Ridges and Amount of Remaining Tooth Structure	IDS Used	Smoker	Bruxist/ Parafunctional Activity	Occlual Splint Received
Gresnigt et al, 2019[28]	Prospective clinical study	11	N=384 N1: 43 (ETT) N2: 341 (Vital)	42.1	N=104 (NS)	- Vital teeth: Restorative dentist, - ETT: Endodontist	No	-Maxillary central incisors: 156. - Lateral incisors:125. Canine: 103	NS	– Cavity made as small as possible. Incisal edge and cingulum remained intact, but opening toward incisal edge. – No posts used. No mention of how endodontic treatment done or size of prepared root canal or GP point – Extent of composite resin restoration not mentioned. – Exact amount of tooth structure – left not mentioned. – Presence of marginal ridges not mentioned.	– Total IDS used: 60 – IDS Vital:51 (15%) (IDS vital/vital). – IDS ETT: 9 (2.6%) (IDS non-vital/non-vital)	NS	17.3%	17.3%
Beier et al, 2012[1]	Retrospective study	15 ±5.25	N=298 N1:287 (Vital) N2: 11 (ETT))	NS	N=84 (38/46)	Dentists in University setting	NS	Anterior maxillary and mandibular teeth	NS	– Exact amount of remaining tooth structure not mentioned. – Presence of marginal ridges not mentioned.	– No dentin bonding (12%). – No IDS	27.38%	50%	50%
Cotert et al, 2009[27]	Clinical study	1.4	N=200 N1: 185 (Vital) N2: 15 (ETT)	33	N=40 (14/26)	Dentists in university setting	NS	Maxillary or mandibular teeth	NS	– Presence of marginal ridges not mentioned. – Exact amount of tooth structure left not mentioned.	No IDS	NS	NS	NS

ETT, endodontically treated teeth; IDS, immediate dentin sealing; NA, Not applicable; NS, Not specified;

Table 4. Summarized results of Group B

Author, Year	Fracture Resistance (Newtons)	Statistically Significant (Between Vital and Nonvital) in Fracture Resistance	Factors Positively Affecting Success Rate Of Porcelain Veneers In Non-vital Teeth
Cotert et al, 2021[30]	Vital: 3122.6 ETT with P access: 1867 ETT with L access: 2805.6	Vital versus ETT with P access: YES (P<.05) Vital versus ETT with L access: NO	ETT teeth with labial access
D'Arcangelo et al, 2010[32]	ETT + porcelain veneer (E-PV): 921.5 ETT + Fiber post+ porcelain veneer (E-FP-PV): 1110.5 Vital ceramic veneer (PV): 1168.4	Veneer versus Endo + post + veneer: NO Veneer versus Endo + veneer: YES Endo + post + veneer versus Endo + veneer: YES	Fiber post added in ETT
D'Arcangelo et al, 2008[30]	Endo + veneer + fiber post> veneer/veneer + endo Control: 778.31 Porcelain veneer only: 753.77 Endo Only: 774.08 Endo+ porcelain veneer: 671.07 Endo + porcelain veneer + fiber post: 918.23	Veneer versus veneer + endo group: YES Control versus Veneer + endo group + fiber post: NO Endo + veneer + fiber post versus veneer + endo: YES (endo+ veneer+ post higher) Endo + veneer + fiber post versus veneer: YES (endo + veneer + post higher)	Fiber post added in ETT
Ho et al, 2001[33]	Non vital + porcelain veneer: 448 ±156 Vital + porcelain veneer: 420 ±128	Veneer versus veneer + endo: NO	NS

ETT, Endodontically treated teeth; NA, Not applicable; NS, Not specified;

teeth with labial access had significantly better fracture resistance than those with palatal access (P<.05) and their fracture resistance was statistically similar to vital teeth.

A fiber post was incorporated for 2 studies by D'Arcangelo et al.[31,32] They concluded that incorporating a fiber post in an endodontically treated tooth restored with a porcelain veneer could positively influence its success rate. The authors reported that the endodontically treated teeth with fiber post and porcelain veneer showed higher fracture resistance than the nonvital group[31] and had a statistically similar value to the vital tooth group.[32]

DISCUSSION

The null hypothesis that no difference would be found in the factors influencing the success rate of ceramic veneers on nonvital anterior teeth was rejected, as a difference was found in the factors influencing the success rate of ceramic veneers on nonvital anterior teeth. The present review aimed to investigate the techniques used and the presence of a post on the success rate of porcelain veneers on endodontically treated anterior teeth. Data from the past 20 years were investigated, since including earlier studies would have increased heterogeneity with materials and protocols that are no longer current. Both in vivo and in vitro study designs were evaluated with a total of 214 endodontically treated teeth and 941 vital teeth included. Among the in vivo studies (Group A), all 3 studies provided high-quality evidence according to the GRADE system. Beier et al[1] and Cotert et al[30] concluded that no factors significantly affected the success rate of porcelain veneers in endodontically treated teeth. However, Gresnigt et al[29] reported that using IDS on nonvital teeth positively impacted the success rate of porcelain veneers. However, the number of nonvital teeth treated with IDS before cementation of the veneers (9) was only 2.6% of the overall teeth tested.

Of the 4 in vitro studies (group B), the Modified CONSORT quality assessment determined that 3 had 100% and 1 had 91%.[24] Cotert et al[30] concluded that positioning the access cavity on the labial surface positively influenced the success rate of porcelain veneers. D'Arcangelo et al in 2008[31] and 2010[32] studies reported that incorporating fiber posts in endodontically treated teeth with porcelain veneers positively influenced the success rate. Ho et al[33] reported no statistically significant differences among the forces required to fracture the specimens in the endodontically treated ceramic group with the control group and the group of vital teeth with a porcelain veneer.

From the present study, the validity of the findings could not be determined because of the many variables in the studies evaluated and their heterogeneity. The follow-up periods were different, with Gresnigt et al[29] and Beier et al[1] having follow-up periods of 11–15 years and Cotert et al[27] of 1.5 years. Gresnigt et al[29] described the survival rate of endodontically treated veneered teeth versus vital veneered teeth (respectively 88.3% and 96%), while Beier et al[1] reported only the overall survival rate of veneered teeth without specifying whether the abutment had been endodontically treated. Cotert et al[27] reported a survival rate for nonvital teeth with porcelain veneers and for vital teeth but with a follow-up period of only 1.5 years, making comparison difficult.

The amount of remaining tooth structure is not mentioned in the in vitro studies[12–14] and this could have altered the results. Gresnigt et al[29] completed 159 restorations on teeth with preexisting composite resin

Table 5. Summary of factors considered in in vitro studies (Group B)

Author, Year	Type of Study	Observation Period	Sample Size and Distribution	Type of Operator	Type of Teeth	Type of Occlusion	Position of Access Cavity + Amount of Remaining Tooth Structure	IDS Used	Loading Technique: Angulation, Position, Location and Rate of Load
Cotert et al, 2021[30]	In vitro study	NS	N=30 N1: 10 (Control, vital teeth) N2: 10 (ETT)with labial access) N3:10 (ETT)with palatal access)	Dentists in university setting	Maxillary central incisors	NA	– Root canal: Prepared to Pro-Taper rotary size F5. – Palatal: Initial entrance through center of palatal surface and cingulum. – Labial: bur positioned parallel to long axis of tooth to reach pulp in straight line and applied to center of labial surface of tooth. – Both P and L: access cavities performed on coronal side at level of cingulum, and pulp horns removed M-D direction. – No existing composite resin restorations present in ETT, indicating marginal ridges most likely intact. – - Exact amount of tooth structure left not mentioned.	No IDS	45°, Palatal side 1 mm from incisive edge, 0.02 mm/min
D'Arcangelo et al, 2010[32]	In vitro study	NS	N=120 N1: 15 (Control) N2: 15 (Veneer preparation) N3: 15 (Resin composite veneer N4: 15 (Endodontic + resin comp veneer) N5: 15 (Endodontic + fiber post + resin comp veneer) N6: 15 (Porcelain veneer) N7: 15 (Endodontic + ceramic veneer) N8: 15 (Endodontic+ fiber post + Porcelain veneer)	Dentists in University setting	Maxillary central incisors	NA	– Root canal: Palatal access prepared to size 25 apically. – No existing composite resin restorations present in ETT, indicating marginal ridges most likely intact. – - Exact amount of tooth structure left not mentioned.	No IDS	45°, Between middle and cervical thirds of crown palatal aspect, 0.5 mm/min
D'Arcangelo et al, 2008[31]	In vitro study	NS	N=75 N1: 15 (Control group) N2: 15 (Porcelain veneer) N3:15 (Endodontic therapy) N4: 15(Endo + Porcelain veneer) N5: 15 (Endo + Porcelain veneer + fiber post)	Dentists in university setting	Maxillary central incisors	NA	– Root canal: Palatal access prepared to size 25 apically. – No existing composite resin restorations present in ETT, indicating marginal ridges most likely intact. – - Exact amount of tooth structure left not mentioned.	NS	45°, On enamel between middle and cervical third of crown palatal aspect, 0.5 mm/min
		NS				NA		No IDS	

Table 5 (*Continued*)

Author, Year	Type of Study	Observation Period	Sample Size and Distribution	Type of Operator	Type of Teeth	Type of Occlusion	Position of Access Cavity + Amount of Remaining Tooth Structure	IDS Used	Loading Technique: Angulation, Position, Location and Rate of Load
Ho et al, 2001[33]	In vitro study		N=40 N1: 10 (Control) N2: 10 (Endodontically treated) N3: 10 (Porcelain Veneer) N4: 10 (Endo + Porcelain veneer)	Dentists in university setting	Mandibular incisors		– Root canal: Apical stop prepared to size 30, and size 45 prepared at 1.5 mm coronal to apical stop. – No existing composite resin restorations present in ETT, indicating marginal ridges most likely intact, given that minimally invasive preparation of access cavity performed. – Amount of tooth structure left not mentioned.		30°, 1 mm below incisal edge on labial surface, 5 mm/min

ETT, endodontically treated teeth, IDS, immediate dentin sealing; NA, Not applicable; NS, Not specified;

restorations, but the size of the restorations was not specified. Of the teeth without existing restorations, 35 had been endodontically treated. The cavity dimensions were stated to have been made as small as possible and the incisal edge and the cingulum were kept intact, but measurements were not provided.[29] The study did not specify whether the existing restorations were class 3, and flexure of the tooth could have occurred during loading and function. In anterior teeth, the cingulum and the marginal ridges are specific areas that contain thicker enamel,[34] playing a crucial role in stress distribution during function and influencing the flexibility of the teeth.[34]

The use of a fiber-reinforced post was associated with a significant increase in mean maximum load values in endodontically treated teeth restored with porcelain veneers in 2 studies.[31,32] Peroz et al[35] reported that posts should only be used to retain material where there is only a small amount of dental structure left. They should not be used to reinforce the tooth as preparation may further weaken the tooth by removing remaining tooth structure.[35] According to Goracci and Ferrari[13] and Cagidiaco et al,[14] fiber posts are preferred because they are conservative of tooth structure and have a similar modulus of elasticity to dentin. In addition, fiber posts are adhesively luted and increase stress distribution to the surrounding tooth structure.[11–15] In addition, most fiber posts have an irregular surface, which further increases the retention of the composite resin foundation restoration.[3] D'Arcangelo et al[31] reported the highest fracture resistance for the use of a fiber post in nonvital teeth with porcelain veneers, demonstrating that the additional incorporation of fiber posts can positively influence the success rate. Since different load angles result in different fracture strengths, the load was applied at a 45-degree angle to simulate the most severe clinical situation.[19,31,32,36,37] However, cyclic mechanical loading was not considered, which has been reported as the leading cause of failure for restored endodontically treated teeth. The heterogeneity of the included studies and the limitations of the data extracted did not allow for definitive conclusions but did identify possible routes to explore to increase the survival rates of endodontically treated veneered teeth. Further research is needed to clarify the role of each factor in the overall success rate of endodontically treated veneered anterior teeth.

CONCLUSIONS

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

1. The use of fiber posts and labial positioning of the endodontic access cavity could positively influence

the success rate of porcelain veneers on endodontically treated teeth.
2. The effect of immediate dentin sealing on the survival rate of endodontically treated veneered teeth is still unclear and further research is needed.

APPENDIX A. SUPPORTING INFORMATION

Supplemental data associated with this article can be found in the online version at doi:10.1016/j.prosdent.2023.10.031.

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