Does Ferrule's Presence Affect the Success Rate of Bonded Restorations? A Systematic Review

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ABSTRACT

Aim and objective: Ferrules can reinforce the endodontically treated teeth by encircling the remaining coronal structure. The adhesive connection of bonded restorations to dental dentine *via* resin bonds on one hand and the importance of conservative tooth structure removal during crown preparations present the question "is ferrule necessary for bonded restorations?". This systematic review aimed to study the available literature on the effect of the ferrule on resin-bonded restored teeth.

Materials and methods: A search of the literature in PubMed and PMC's databases, without any date restriction, was carried out. The keywords were based on the PICO question "Does ferrule's presence affect the success rate of bonded restorations?". The full title and abstract of each article were screened by two independent authors using predetermined inclusion and exclusion criteria.

Results: Ten articles were included in this review. All teeth were endodontically treated and received lithium disilicate ceramic crowns bonded adhesively. Ferrules designs ranged from no ferrule to 3 mm and/or different ferrule circumferences. Three studies reported a lack of a significant difference in fracture resistance and/or stress levels and/or cyclic fatigue between different ferrule designs. Six studies reported higher fracture resistance, lower stress levels on root dentin and fiberglass post, higher count of fatigue cycles, less fracture count, less tooth strain value for ferrule groups.

Conclusion: In the limits of this systematic review, a ferrule is still necessary for resin-bonded restorations, and more ferrule in terms of height or/and circumference presents better results than no ferrule at all or interrupted or less ferrule.

Keywords: Bonded restoration, Ferrule, Systematic review.

International Journal of Prosthodontics and Restorative Dentistry (2021): 10.5005/jp-journals-10019-1332

INTRODUCTION

Endodontically treated teeth with severe loss of coronal structure propose a challenge for restorative dentistry and there is still a controversy over the choice of ideal treatment for such teeth.¹ Endodontically treated teeth may face severe tooth structure loss due to caries, preexisting restorations, or the endodontic treatment procedure itself, which leads to an increased chance of fracture in function.^{2,3}

Root-filled teeth restoration success requires an effective coronal seal, remaining tooth protection, functional restoration, and esthetics.⁴ Such teeth restoration may be achieved using direct and indirect restorations. The indirect full coverage method is the preferred one among clinicians.⁵ A post retained crown may be used to restore such teeth which could fail due to root fracture. Crown and post preparation designs aiming at the reduction of this phenomenon's chance are advantageous. Post insertion does not strengthen the endodontically treated tooth but it provides proper retention for the core material.^{6,7} If the coronal hard tissue has been lost severely, a post and core procedure may be required, which can increase the root perforation risk and may increase tooth fracture risk due to the additional dentine removal required for the preparation.^{1,8}

The band of metal encircling the coronal surface of the tooth is called a dental ferrule, which is proposed to be effective in the reinforcement of root-filled teeth. The ferrule effect is the strengthening of the tooth due to the ferrule's resistance to stresses such as functional lever forces, the wedging effect of tapered posts, and the lateral forces exerted after post insertion.⁹ The ferrule can reinforce the endodontically treated tooth by encircling the remaining coronal structure leading to resistance against the functional lever forces during mastication.¹⁰

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How to cite this article: Jalalian B, Abbasi E, Jafarian Z. Does Ferrule's Presence Affect the Success Rate of Bonded Restorations? A Systematic Review. *Int J Prosthodont Restor Dent* 2021;11(3):125–131.

Source of support: Nil

Conflict of interest: None

The endocrown is an indirect treatment option described as a full-coverage restoration with a circumferential butt-joint margin and a central retentive feature that extends into the pulp chamber space.¹¹ Computer-aided design/computer-assisted manufacturing (CAD/CAM) has suggested that the endocrown restoration's adhesive technology is more conservative than post and core procedures.¹²

The resin-bonded restoration was introduced in the 1970s.¹³ Their retention is based on the wrap-around design and the bond to etched enamel.¹⁴ The main advantages of resin-bonded restoration are preserving tooth structure, reduction of pulpal morbidity, and better esthetics. This is especially true when no more aggressive treatment modalities can be born, because of age, medical

condition, or finances.¹⁵ One of the materials used in bonded restorations is lithium disilicate. It has excellent biocompatibility, mechanical strength, and very good esthetic features.¹⁶ Moreover, it has a high strength of adhesion to the substrate due to both micromechanical and chemical bonding mechanisms.¹⁷

Magne et al.¹ studied teeth with no ferrule restored with resin-bonded restorations and reported a high survival rate under fatigue tests. In another study, molars without ferrule were restored using bonded glass-ceramic crowns and showed that such teeth withstood high counts of cyclic loads.¹⁸ The resin bond quality of resin-bonded restoration poses the question “whether classic ferrule concepts still are necessary for these restorations or not?”. Although fracture resistance increasing due to the ferrule has been previously studied.¹⁹ But the effects of ferrule features on resin-bonded restoration have not been systematically reviewed before. Therefore, this systematic review aimed to study the available literature on the effect of the ferrule on resin-bonded restored teeth.

MATERIALS AND METHODS

Focused Question

The present study is a systematic review that was performed following the “Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols” (PRISMA-P, 2015).²⁰ The search was performed using “MeSH” terms and keywords based on the elements of the PICOS question which are presented in Table 1.

Inclusion and Exclusion Criteria

Inclusion Criteria

- *In vitro* studies.
- Without date restriction until February 15, 2021.
- Bonded restoration of any type of studies including but not limited to onlays, overlays, and endocrowns.
- With full-text availability.
- Written in English.
- Published in PubMed or PMC cited scientific journals.

Exclusion Criteria

- Articles about bonded restorations without any comparison between different ferrule heights.
- Review, *in vivo*, human, and animal studies.
- Written in a language other than English.

Search Strategy

An exhaustive search of the literature available in PubMed and PMC's electronic databases, without any date restriction until

February 15, 2021, was carried out. The following keywords were used in the search strategy: (((((((Onlay) OR overlay) OR coverage) OR endocrown) OR coverage) OR crown) OR bridge) AND (((glass ceramic) OR Emax) OR e.max) OR bonded ceramic)) AND ((ferrule) AND ferrule effect) AND (((((((clinical evaluation) OR clinical trial) OR longevity) OR success) OR failure) OR survival rate). The database search resulted in a total of 203 studies, 3 duplicates were found. The full title and abstract of each article were screened by two independent authors using predetermined inclusion and exclusion criteria.

Study Selection

Fourteen articles were chosen for full-text assessment from which eight were selected to compose this systematic review. The articles' initial screening was carried out using the Rayyan QCRI13 systematic review web app.²¹ All the references were selected from the Endnote program (Thomson Reuters, Philadelphia, PA, USA). To ascertain whether any relevant studies have been neglected in the initial search, references from the selected studies were also checked. Two more studies were included based on this hand search. Any differences in the selection of eligible studies were resolved by discussion with a third reviewer.

Data Extraction

β Data were extracted from the included articles by two independent authors. A third author resolved any disagreements in the extracted data. Microsoft Office Excel software (Microsoft Corporation, Redmond, WA, USA) was used for the standardization and organization of the extracted data. The following information was collected:

- General characteristics of the selected studies: title of the article, first author, year, type of study, the title of the journal in which it was published.
- Tooth source and type and quantity.
- Root canal therapy information.
- Ferrule design and height.
- Crown, bond, and post and core material if present.
- Discoveries include fracture, failure, fatigue analysis (Table 2).

Risk of Bias and Quality Assessment

The risk of bias assessment method for the included articles was adapted from previous systematic reviews on *in vitro* studies.^{22,23} The following criteria were used to rate the articles:

- Selection of study groups: sample size calculation, description of clear inclusion/exclusion criteria, a detailed protocol of data collection.
- Detail of treatments on each group including post and core, buildup, ferrule design, bonding.
- Comparability: comparability of patients based on the study design or analysis and management of potential confounders.
- Outcomes: evaluation of results, assessment of accuracy outcomes.
- Statistical analysis: appropriateness/validity of statistical analysis and unit of the analysis reported in the statistical model.

Twenty points could be given to each study; 15–20 points indicated high methodological quality, 10–15 points indicated medium-level, and others were considered as studies with low methodological quality. Two independent authors implemented this assessment.

Table 1: PICOS question elements

PICOS question	
Participants (P)	Teeth in need of restorations
Intervention (I)	Restoration using bonded restorations
Comparison or control (C)	Presence or lack of ferrule
Outcome measures (O)	Laboratory evaluations of fracture resistance, failure stress, failure modes, fracture counts, fatigue cycles, etc.
Types of studies included (S)	<i>In vitro</i> studies

Table 2: Data extracted from the articles

Article	Species	Teeth type	RCT	Number of teeth	Ferrule design	Crown	Bond	Post and core	Result
Valdivia, 2018	Bovine	Incisor	Yes	20	2 mm (10)/0 (10)	LDC	SAC	CRC	Significantly higher fracture resistance was observed for the ferrule group. The NFe group revealed a lower fracture resistance: root strain ratio than did the Fe group. The stress levels on root dentin and fiberglass post were lower for the Fe group. Calculated failure stress found no difference in failure resistance among the three groups. The endocrown preparations without ferrule had significantly lower fracture load resistance. Failure mode analysis identified that all preparations demonstrated a high number of catastrophic failures. The fracture strength was not statistically significant between the ferrule and no ferrule groups. A slight trend toward less irreparable fractures was recorded for all ceramic restorations and teeth prepared with ferrule the percentage (%) of repairable fractures was slightly higher in ETC with ferrule than in ETC without ferrule respectively of the type of crown restoration. Statistically significant difference was not detected.
Einhorn, 2017	Human	Molar	Yes	36	1 mm (12)/2 mm (12)/0 (12)	LDC	SAC	Endocrown	Specimens with a 0.0-mm ferrule survived few fatigue cycles despite the fact that both the post and crown were bonded with resin cement. Teeth with a 0.5-mm ferrule showed a significant increase in the number of fatigue cycles over the 0.0-mm group, whereas teeth with the 1.0-mm ferrule exhibited a significantly higher fatigue cycle count over the 0.0-mm but not the 0.5-mm group. The ferrule effect significantly enhanced the fracture resistance of the restored teeth, regardless the use of a post the ferrule effect has been found to significantly affect the fracture resistance of endodontically treated teeth. That the groups without/ferrule effect, regardless of the type of restoration used (GFP without ferrules and endocrowns without ferrules), presented a higher number of fractured samples.
Evangelinaki, 2013	Human	Canine	Yes	20	2 mm (10)/0 (10)	LDC	SAC	CRC	
Fragou, 2012	Human	Canine	Yes	20	3 mm (10)/0 (10)	LDC	SAC	CRC	
Ma, 2009	Human	Incisor	Yes	15	1 mm (5)/0.5 mm (5)/0 (5)	LDC	SAC	CRC	
Zicari, 2012	Human	Premolar	Yes	40	2 mm (20)/0 (20)	LDC	SAC	CRC (20)/EC (20)	
Silva-Sousa, 2020	Human	Canine	Yes	40	1 mm + post (10) 0 + post (10) 2 mm + EC (10) 0 + EC (10)	LDC	SAC	CRC (20)/EC (20)	

Contd...

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Article	Species	Teeth type	RCT	Number of teeth	Ferrule design	Crown	Bond	Post and core	Result
Sherfudhin, 2011	Human	Premolar	Yes	40	1 mm + no post (10)	LDC	SAC	CRC	No difference was reported.
					1 mm + post (10)				
					2 mm buccal + 1 mm lingual + post (10)				
					3 mm buccal + 2 mm lingual + post (10)				
Roscoe, 2013	Human	Canine	Yes	20	2 mm + CRC (5)	LDC	SAC	CRC/MC	The absence of a ferrule significantly increased the buccal and proximal strain values.
					0 mm + MC (5)				
					2 mm + CRC (5)				
					0 mm + mc (5)				
Naumann, 2006	Human	Incisor	Yes	40	2 mm facial (10)	LDC	SAC	CRC	An incomplete crown ferrule is associated with greater variation in load capacity and, despite high fracture values, inclines to fracture.
					2 mm palatal (10)				
					2 mm 360° (10)				
					2 mm interrupted (10)				

RCT, root canal therapy; LDC, lithium disilicate ceramic; SAC, self-adhesive composite; CRC, composite resin core; MC, metal core; EC, endocrown

RESULTS

Literature Search

A total of 203 studies were in the database search. Three were duplicates, and 186 were excluded after reviewing the titles and abstracts; 14 articles were chosen for full-text assessment. Four articles were excluded due to the lack of any comparison between different ferrule designs. Two other studies were excluded because they were review articles. Two studies were added to the review manually by going through the included articles' references thoroughly. In the last step, a total of 10 articles were included in the qualitative assessment (all *in vitro* studies, 9 on human teeth and 1 on bovine teeth) (Flowchart 1). The extracted data from included articles are presented in Table 2.

Quality Assessment

All but one of the studies included in this review received 15–20 points out of the possible 20 points, which is of high-level methodological quality (Fig. 1).

Study Description

Two hundred and ninety-one teeth were studied among the studies. Incisors (75), canines (100), premolars (80), and molars (36) were studied. All teeth were endodontically treated and received lithium disilicate ceramic crowns bonded adhesively. Two hundred and five of the teeth received composite resin posts and cores, 76 teeth received endocrowns without any posts, and 10 teeth received metal cast cores.

Different ferrules were designed in the included studies ranging from no ferrule to 3 mm ferrules. Two studies compared different ferrule circumferences (only buccal, only palatal, interrupted, and 360° ferrules).^{24,25}

Three studies^{25–27} reported a lack of a significant difference in fracture resistance and/or stress levels and/or cyclic fatigue between different ferrule designs. Two of them compared ferrule vs no ferrule,^{26,27} and the other used different ferrule circumferences.²⁵

Six studies reported higher fracture resistance,^{24,28–30} lower stress levels on root dentin and fiberglass post,²⁸ higher count of

Flowchart 1: Flow diagram of literature search and selection criteria adapted from PRISMA

Fig. 1: Validity of studies based on selection criteria, treatment detail, comparability, outcome, and statistics

fatigue cycles,³¹ less fracture count,³² less tooth strain value³³ for ferrule groups. Naumann et al.²⁴ compared ferrules with different circumferences (palatal, facial, 360°, and interrupted), and reported that incomplete crown ferrule is associated with greater variation in load capacity and inclination to fracture.

DISCUSSION

The adhesive connection of bonded restorations to dental dentine *via* resin bonds on one hand and the importance of conservative tooth structure removal during crown preparations present the question "is ferrule necessary for bonded restorations?". Therefore, this systematic review aimed to investigate the effect of different ferrule designs on the success of teeth restored with bonded restorations. A meta-analysis was deemed inappropriate due to many affecting factors leading to incomparable results among studies. Factors such as different tooth sources and types, different experimental methods, different ferrule designs. Some studies have suggested a direct influence of ferrule on the success rate of endodontically treated teeth,³⁴ but some others have found no effect of different ferrule heights for teeth treated with fiber posts and resin cores.^{35,36}

The difference among the species from which the teeth were obtained for the included study could have affected the results of the study but even in the only study which used bovine incisor teeth, the results were similar to other studies, and significantly higher fracture resistance was observed for the ferrule group, the 0 ferrule group revealed a lower fracture resistance: root strain ratio than did the ferrule group, and the stress levels on root dentin and fiberglass post were lower for the ferrule group.²⁸

Different types of teeth were studied in the included articles. Different anatomy of the studied teeth could result in different conclusions which could stem from different thicknesses of dentine or length of the root. Studies with no significant difference between ferrule designs^{25–27} as well as studies with significant differences^{30,32,33} included canine and premolars, therefore no conclusion could be made on the effects of tooth type on how ferrule could affect bonded restorations, can be made from the included studies.

Only one study used metal cast posts,³³ but the results for both metal cast posts and composite resin cores were the same in this study, the absence of a ferrule significantly increased the buccal and proximal strain values.

One study used endocrowns,²⁹ and two studies used both composite resin cores and endocrown (compared different ferrule designs in each group separately).^{30,32} The results for endocrowns remain the same, the endocrown preparations without ferrule had significantly lower fracture load resistance and the ferrule effect was found to significantly affect the fracture resistance of endodontically treated teeth. It can be deducted that ferrule shows better results than no ferrule regardless of post type and presence of a post.

Fragou et al.²⁶ despite reporting a lack of significant difference between 3 mm of the ferrule and no ferrule in the tendency toward the type of failure, reported a slight trend toward less irreparable fractures for all-ceramic restorations and that in teeth prepared with ferrule the percentage of repairable fractures was slightly higher in ferrule groups.

Although both significant and not significant differences in fracture resistance, stress levels on root dentin and fiberglass post, count of fatigue cycles, fracture count, and tooth strain value have

been reported, even in studies that failed to report a significant difference, the ferrule group showed better results.^{25–27} Although different heights of the ferrule and different circumferential designs of ferrule have been studied, taller ferrules and complete circumferential ferrules tend to show better results.

CONCLUSION

In the limits of this systematic review, a ferrule is still necessary for resin-bonded restorations. More ferrule in terms of height or/and circumference presents better results than no ferrule at all or interrupted or less ferrule.

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