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Influence of Cementation Strategies on the Incidence of Fiber Post Debonding in Root Canal Treated Teeth: A Systematic Review and Meta-Analysis

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ABSTRACT

The objective of this systematic review was to investigate the incidence of debonding of fiber posts in root canal-treated teeth with a focus on the cementation strategy employed. This study was registered at PROSPERO (sob number: CRD42022334791). Six databases were searched, in addition to the gray literature. Two independent reviewers performed the selection of the studies as well as data collection. The risk of bias was assessed using the QUIPS (Quality in Prognosis Studies) tool. A meta-analysis was carried out to verify the overall incidence of debonding and the influence of different variables. Random effects were adopted, with a confidence interval (CI) of 95%. Twenty-nine studies met the eligibility criteria. The overall incidence of debonding was 2.7% (CI: 2.1–3.6%). Similar debonding rates were found when using total-etch and self-adhesive systems while a trend towards a higher debonding rate was observed for self-etch systems. Posterior teeth presented a higher incidence of debonding (3.9%) (CI: 2.5-6.0%) than anterior teeth (1.6%) (CI: 1.0-2.5%). A higher debonding incidence was found when 2 or fewer coronal walls were reported at 3.5% (CI:2.0-5.9%). Debondings in fiber posts are multifactorial, with no direct cementation strategy influence.

INTRODUCTION

Teeth that have had root canal therapy typically show loss of coronal structure as a result of trauma or caries.[1] Along with access preparation and root canal preparation, there is an inherent loss of structure with root canal therapy.[2,3] This large reduction especially in the coronal volume of tooth structure can lead to tooth fracture, compromising tooth longevity.[2,4]

In cases where coronal walls are inadequate or absent, fiber posts and cores have been employed extensively in restorative dentistry.[5] Noble alloy cast posts and cores, when designed properly, have long been the most popular intraradicular retention technique.[6] However, because metal has a higher modulus of elasticity than human dentin, it concentrates stress more, particularly in the luting cement, increasing the likelihood of failure and root fracture.[6] On the other hand, fiber-reinforced posts should considerably lower the risk of vertical root fractures because their elasticity modulus is similar to that of natural dentin.[7]

Despite the positive outcomes of this treatment, post-debonding, secondary caries, and restorable cervical fractures are the most frequent reasons for failure related to fiber posts, with post-debonding being the most common cause of failure.[8,9] Thus, it is possible to argue that the kind of cement and the adhesive cementation technique utilized in luting fiber posts is crucial to the long-term success of root canal treatment.[6] Different cementation materials and methods have been proposed and evaluated in *in-vitro* environments to reduce debonding problems.[6] Although total-etch, self-etch, and self-adhesive systems are the primary adhesive techniques that have been investigated, there is still no golden standard for root canal conditioning. These adhesive techniques have been the subject of numerous prospective and retrospective clinical investigations. Yet, only one randomized clinical research has provided a direct comparison.[10] Furthermore, bonding strategies have not been systematically analyzed. Therefore, the objective of this systematic review (SR) was to synthesize the available evidence on the proportion of debonding of fiber post restorations in root canal-treated teeth as a function of the cementation strategy employed.

METHODS

REGISTRATION AND PROTOCOL

Based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA-P),[11] an SR protocol was developed and is registered under the CRD42022334791 number in the Prospective Register of Systematic Reviews (PROSPERO). The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA 2020 Checklist)[12] are followed in the reporting of this SR.

ELIGIBILITY CRITERIA

This is an SR of prognostic factors. The inclusion criteria were based on the PICOTS acronym, in which: P (Population): individuals with compromised teeth in need of root canal treatment and fiber post installation; I (Index prognostic factors): cementing strategies used to cement fiber posts in root canal treated teeth; C (Other prognostic factors that can be considered as comparators): not applicable; O (Outcome): incidence of debonding of fiber posts, T (Time): studies with at least 1 year of follow-up and S: (Setting): Clinical settings or environments where fiber post restorations are carried out, such as dental offices, restorative dentistry clinics or hospitals. The following studies were included: randomized clinical trials (only fiber-post restoration groups), prospective clinical trials and retrospective studies.

Therefore, research related to and assessing the frequency of debonding in people with fiber post restorations in teeth that had undergone root canal therapy, regardless of age, was included. The type of cementation method and materials utilized should be reported in the primary investigations. There were no restrictions on the publishing period used.

Only the patients who completed the study follow-up were included in the descriptive table and the meta-analysis.

The exclusion criteria adopted were the following:

1. Studies that have not reported or with insufficient information on adhesive/cementation systems or failure;
2. Individuals with another type of restoration in root canal treated teeth not including fiber post (i.e. metal, no post, carbon post);
3. Studies with follow-up less than 1 year;
4. Studies published in other languages rather than the Latin (Roman) alphabet;
5. Studies with repeated samples;
6. Studies that did not investigate the outcomes of interest;
7. Reviews, letters, books, conference abstracts, case reports, commentary, opinion articles, technique articles, posters, guidelines, and *in vitro* studies.

The incidence of debonding was derived from the number of debonding frequencies divided by the total number of fiber post-restorations in root canal-treated teeth.

INFORMATION SOURCES AND SEARCH STRATEGY

An electronic literature search was performed on August 2nd, 2022 in six databases (Cochrane, Embase, Latin American, and Caribbean Health Sciences, PubMed/Medline, Scopus, and Web of Science). Additionally, the gray literature was also consulted through Google Scholar, and Open Grey (Grey Literature in Europe). Reference lists of included articles were also manually searched and experts on the subject were contacted to recommend possible additional studies.

The search strategy was developed under the guidance of a librarian experienced in health research. Each search was adapted for each database in a specific way, using free terms, synonyms, and MeSH Terms. The complete search strategy for each database can be found in Appendix 1. The searches were imported into the EndNote X9 reference manager (Thomson Reuters), where duplicate articles were excluded.

SELECTION PROCESS

Two independent reviewers (P.P. and E.R.C.) screened the articles using an online software program (Rayyan, Qatar Computing Research Institute). The selection of included studies was done in two phases. First, in phase 1, the two reviewers independently read titles and abstracts while applying the eligibility criteria. Second, in phase 2, the same two reviewers (P.P. and E.R.C.) performed a full-text reading while applying the election criteria. Cohen's Kappa statistic was used to assess the level of agreement between reviewers; the values between reviewers ranged from 0.8 (substantial) to 1.0 (almost perfect) for phases 1 and 2, respectively. In both phases, all retrieved information was crosschecked by the third reviewer (M.Ö.). The final selection was based on the full text of the publication.

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DATA COLLECTION PROCESS AND DATA ITEMS

Two independent reviewers (P.P. and E.R.C.) collected data from the included articles in a previously prepared spreadsheet (Microsoft Office® 2019, Microsoft, Redmond, United States). Any disagreement in this step was discussed among the reviewers.

The data items included study characteristics (name of authors, year of publication, study design, country, follow-up study); populational characteristics (number of patients, sex, age), methodological characteristics (post type, tooth region – posterior or anterior, type of definitive restoration, number of residual coronal walls, adhesive system/resin cement, results (number of debonding events, incidence, follow-up) and other information (sources of funding and conflict of interest).

STUDY RISK OF BIAS ASSESSMENT

The risk of bias assessment was performed by two reviewers (P.P and E.R.C) independently. Any disagreement was discussed in a consensus meeting and the third reviewer (M.Ö.) was consulted when necessary. The tool used was the QUIPS (Quality In Prognosis Studies) tool.[13] The tool presents 6 domains (study participation, study attrition, prognostic factor measurement, outcome measurement, study confounding, statistical analysis, and reporting). Each domain can be rated as having a high, moderate, or low risk of bias. The result of the risk of bias assessment was carried out narratively, presenting the main risk of bias of the included studies, in addition to a graphical demonstration created in the online software Robvis (Risk-of-bias VISualization) was generated.[14]

EFFECT MEASURES AND SYNTHESIS METHODS

A proportion meta-analysis was performed using Comprehensive Meta-Analysis software, version 3.0 (CMA 3.0) (Biostat Inc., Englewood, NJ). The incidence of fiber post-retained debonding was calculated. Effect sizes with a 95% confidence interval were calculated using random-effects models for the overall and subgroup meta-analysis.[15] Heterogeneity was assessed using the I^2 statistics. The I^2 gives an estimate of the percentage of variability in results across studies that is due to real differences and not due to chance. An I^2 of 0 to 40%: might not be important; 30 to 60%: may represent moderate heterogeneity; 50 to 90%: may represent substantial heterogeneity; 75 to 100%: considerable heterogeneity. A low P value provides evidence of heterogeneity of intervention effects.[16]

An overall meta-analysis considering debonding events was performed with all 29 included studies (37 study groups). In addition, data regarding follow-up (up to 2 years; 2 to 4 years; 4 to 6 years; more than 6 years) were meta-analyzed. Additional subgroup analyses were performed separately concerning the adhesive protocol employed (total-etch; self-etch/self-adhesive), tooth region (anterior; posterior), number of residual coronal walls (2 or fewer; 3 or more), and post type (fiberglass post; quartz fiber post).

RESULTS

STUDY SELECTION

The selection steps for the included studies is presented in Figure 1. From a total of 5,891 studies identified by the searches of the databases, 2,160 remained after the removal of duplicated records. After the first selection phase of reading titles and abstracts, 67 full-text studies were read in the second phase. Next, 29 studies were finally included for qualitative and quantitative synthesis. No studies were included based on the manual search and the indications of the experts since all of them were already on the list for the second phase. A list of excluded studies and reasons is presented in Appendix 2.

STUDY CHARACTERISTICS

All 29 studies included in the systematic review are presented in Table 1. The included studies were published between 2003[17,18] and 2022[19] and accounted for 4,204 fiber post restorations in root canal-treated teeth. Eleven studies are randomized clinical trials,[10,20-29] ten prospective clinical trials,[17-19,30-36] and eight retrospective studies.[8,37-43] The studies were conducted in Belgium,[29] Brazil,[10,24,27,37] Czech Republic,[38] Egypt,[21] Germany,[19,20,23,25,26,36,44] India,[32] Italy,[8,17,18,22,30,33-35,41-43] Spain,[31] Switzerland,[39] United Kingdom.[40]

RISK OF BIAS IN STUDIES

Out of the 29 included studies, 14 were rated at low risk of bias,[10,23-25,27-29,30,31,34,36,39,42,43] 11 at moderate,[8,17-21,26,33,35,38,41] and 4 at high risk of bias.[22,32,37,40] Among the six domains, the study attrition and statistical analysis and reporting were the most frequent sources of bias *(Figure 2)*

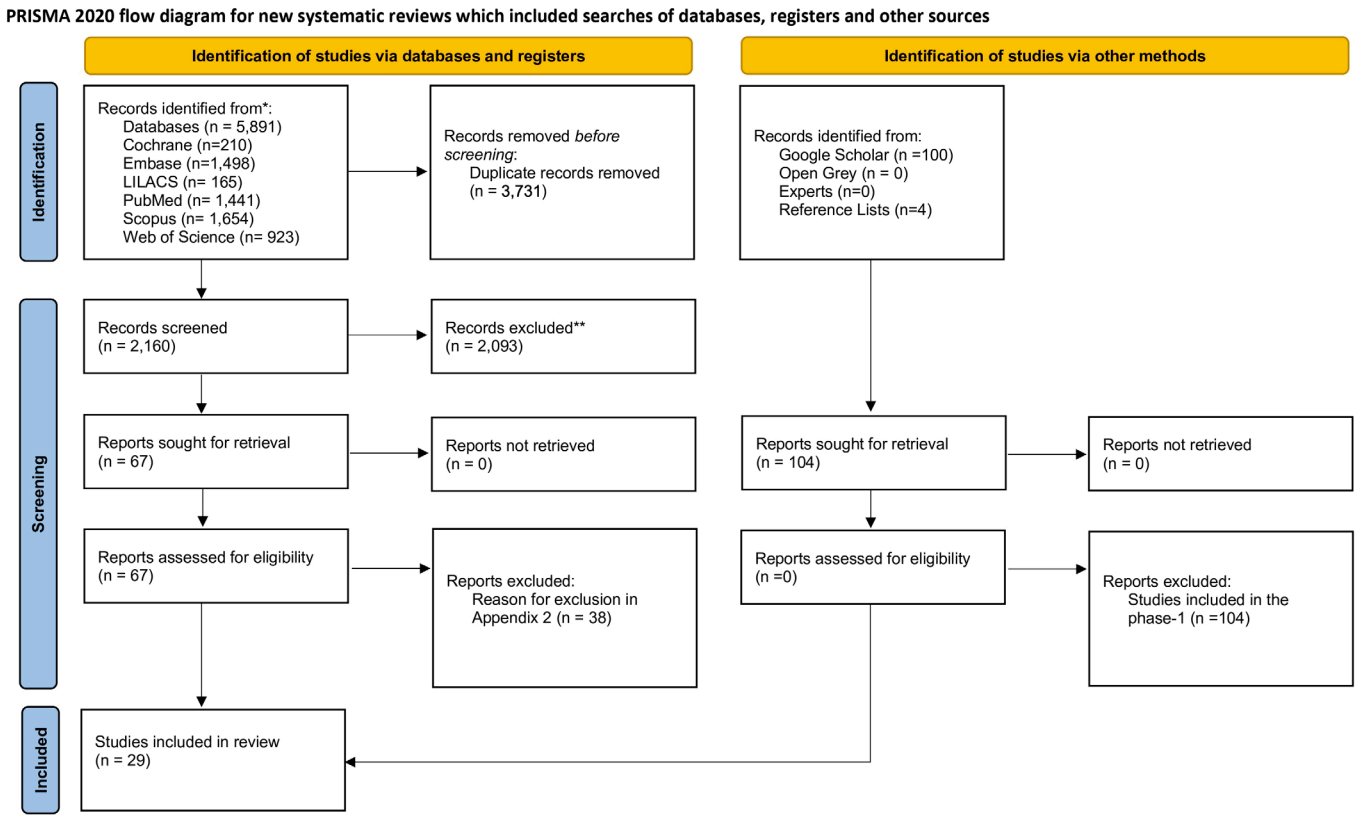
RESULTS OF SYNTHESES

INCIDENCE OF DEBONDING OVERALL AND FOR FOLLOW-UP

The overall incidence of debonding of fiber post-retained restorations in endodontically treated teeth was 2.7% (CI:2.1–3.6%; I^2:52%; p=0.000). The incidence varied according to the follow-up time. The incidence of debonding was 3.6% (CI:1.9–6.8%; I^2:0%; p=0.000) up 2 years, 2.8% (CI:1.7–4.4%; I^2:44%; p=0.000) for a follow-up of 2 to 4 years, 3.4% (CI:1.3–8.5%; I^2:77%; p=0.000) for 4 to 6 years and 2.4% (CI:1.6–3.5%; I^2:13%; p=0.000) for a follow-up of more than 6 years *(Figure 3)*.

INCIDENCE OF DEBONDING CONCERNING THE ADHESIVE SYSTEM

Twenty-two groups reporting the use of total-etch adhesive systems were included; the meta-analysis reported an incidence of debonding of 2.7% (CI:1.8–4.1%; I^2:58%; p=0.000). For self-adhesive, 8 groups were included in the meta-analysis and the incidence of debonding was 2.9 (CI:1.1–7.3%; I^2:53%; p=0.034). Three groups were included for the self-etch adhesive system, reporting 4.6% incidence of debonding (CI:2.1–9.7%; I^2:1%; p=0.0362) *(Figure 4)*.



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).
**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/

Figure 1: Flow diagram of literature search and selection criteria.

INCIDENCE OF DEBONDING CONCERNING THE TOOTH REGION

The incidence of debonding in anterior teeth was 1.6% (CI:1.0–2.5%; I^2:0%; p=0.974) in 14 study groups. On the other hand, the incidence of debonding in posterior teeth was 3.9% (CI:2.5–6.0%; I^2:43%; p=0.027) in 18 study groups *(Figure 5)*.

INCIDENCE OF DEBONDING CONCERNING THE RESIDUAL CORONAL WALLS

The incidence of debonding when 2 or fewer coronal walls were reported was 3.5% (CI:2.0–5.9%; I^2:47%; p=0.021). When 3 or more coronal walls were reported, the incidence of debonding was 1.9% (CI:0.8–4.3%; I^2:0%; p=0.711) *(Figure 6)*.

INCIDENCE OF DEBONDING CONCERNING POST TYPE

The incidence of debonding considering the study groups that reported the use of fiberglass posts was 2.7%. (CI:1.8–4.0%; I^2:38%; p=0.028). In the case of quartz fiber posts, the incidence of debonding was 3.1% (CI:1.9–5.1%; I^2:69%; p=0.000) *(Figure 7)*.

DISCUSSION

The present systematic review aimed to synthesize the available evidence on the proportion of debonding of fiber post restorations in root-canal treated teeth as a function of the cementation strategy employed. The overall incidence of debonding was 2.7%. Posterior teeth, 2 or fewer coronal walls presented a higher incidence of debonding. Similar debonding rates were found when different adhesive systems and post types were used.

Several studies have reported that debonding is one of the main causes of fiber post failures,[8,9,38] however, the influence of cementing strategies has not yet been clarified.

The most commonly used adhesive systems were total-etch, self-etch and self-adhesive systems. Although several *in-vitro* studies have evaluated different fiber post cementation strategies, the literature is still inconclusive and it is not possible to define a gold standard protocol for this purpose.[46,47] Furthermore, some clinical studies have described the efficiency of fiber post-cementation, but instead of analyzing the cementation strategies, they have mainly focused on analyzing different types of posts.[18,19,45] The most appropriate type of studies to clarify this question are randomized clinical trials comparing different cementation strategies, however the literature is still scarce. A recent randomized clinical trial assessed the impact of several cementation techniques, including self-adhesive

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Table 1. Summary of descriptive characteristics of included study groups.

Authors, Year, Study Design, Country	Number of patients (M/F) Age mean (range)	Post Brand	Post Type	Teeth			Type of definitive restoration		Number of residual coronal walls		Post space Acid Etched Yes/No (Time)	Adhesive System / Resin Cement	Number of debonding events			Incidence			Number of residual coronal walls (failures)		Follow-up: mean (range)	Report on the sources of funding	Conflict of Interest
				Anterior	Posterior	Total	Crowns (material)	Direct resin composite	2 or fewer	3 or more			Anterior	Posterior	Total	Anterior	Posterior	Total	2 or fewer	3 or 4			
Bergoli, CD, Brondani LP, Wandscher VF et al., 2018[28] RCT Brazil	114 (19/95) M: 49.25 F: (47.4)	White Post DC system (FGM; Joinville, Brazil)	Glass fiber	60	75	70 65	135 (metal-ceramic)	0	NR	NR	No Yes (15s)	Self-adhesive resin cement Relyk U100 - U200 (3M ESPE; Maggiewood, MN, USA)	NR	NR	1 3	NR	NR	1.42% 4.61%	4	0	37 months - 3.1 years	This work was not supported by any institutional or department funding. The authors thank CAPES for the MSc Scholarship.	The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.
Bitter K, Noertzel J, Stamm O et al., 2009[29] RCT Germany	NR NR	DT Light Post (VDW GmbH; Munich, Germany)	Quartz fiber	15	45	60	40 (metal-ceramic) 8 (all-ceramic) 2 (gold partial) 2 (metal full) 3 (ceramic partial)	0	NR	NR	Yes (15s)	Clearfil New Bond (Kuraray Noritake; Hattersheim, Germany)	NR	NR	1	NR	NR	1.66%	NR	NR	32.4 (13.7) months	NR	NR
Brunhoe M, Wierichs RJ, von Stein-Lausnitz M et al., 2022[30] Prospective Clinical Trial Germany	41 (22/19) 49.4 ± 14.6 41 (25/16). 54.5 ± 15.4	Fiberpoints Root Pins Glass (Schuetz Dental Group; Rosbach, Germany) Relyk Fiber Post (3M ESPE; Maggiewood, MN)	Glass fiber Glass fiber	19 14	22 27	41 41	NR NR	0	41 41	0 0	No	Self-adhesive Relyk Universal 2 (3M ESPE; Maggiewood, MN, USA)	NR NR	NR NR	0 0	NR NR	NR NR	0 0	0 0	NE NE	191 (24 - 148) months 64 (12 - 178) months	Supported by 3M ESPE, Seefeld, Germany.	The authors deny any conflicts of interest related to this study.
Cagidiaco MC, Radovic I, Simonetti M et al., 2007[31] Prospective Clinical Trial Italy	150 56 (18-75)	DT Light Post (RTD; St Egrève, France)	Quartz fiber	57	105	162	121 (all ceramic)	41	93	69	Yes (15s)	Prime&Bond NT dual cure adhesive (Dentsply Sirona; Charlotte, NC, USA) Dual Cure resin cement Calibra (Dentsply Sirona; Charlotte, NC, USA)	2	5	7	3.5 %	4.8 %	4.3 %	7	0	2 years	NR	NR
Calabro DE, Kojima AN, Pecorari VGA et al., 2019[32] Retrospective Clinical Trial Brazil	NR NR	White Post DC system (FGM; Joinville, Brazil)	Glass fiber	23	22	45	45 (zirconia)	0	45	NE	Yes (30s)	NR / U100 (3M ESPE; Maggiewood, MN) Panavia F (Kuraray Noritake; Hattersheim, Germany)	0	0	0	0	0	0	0	NE	4.8 years	NR	The authors report no conflicts of interest.
Cerny D, Eckert S & Mounajjed R 2019[33] Retrospective Clinical Trial Czech Republic	133 (41/92) 47.5 (11.5-82.1)	NR	Quartz fiber	301	NE	301	Metal ceramic crowns All ceramic crowns	NR	NR	NR	Yes (30s)	Ena Bond (Micerium ; Avegno, Italy) / Ena Cem HF	3	NE	3	0.99 %	NE	0.99 %	NR	NR	9 years	NR	The authors report no conflicts of interest.
El-Enein YA, Elgendy J & Zaki AA, 2021[34] RCT Egypt	12 (NR) NR	FibreKleer Post (Pentron; Wallingford, CT, USA)	Glass fiber	12	NE	12	12 (all ceramic - IPS e-max)	0	NR	NR	No	Biscem self-adhesive resin cement (Bisco; Schaumburg, IL, USA)	0	NE	0	0	NE	0	NR	NR	1 year	NR	NR
Ferrari M, Cagidiaco MC, Goracci C et al., 2007[35] Retrospective Clinical Trial Italy	1168 (NR) 53 (20-84)	C-Post (RTD; St Egrève, France) Aitsheni Post (RTD; St Egrève, France) Aitsheni Post Plus (RTD; St Egrève, France)	Quartz fiber Quartz fiber Quartz fiber	335 47 122	270 37 106	605 84 228	56% metal-ceramic 30% all ceramic.	14%	NR	NR	NR	All Bond 2 and One-Step (Bisco; Schaumburg, IL, USA) / C&B resin cement (Pentron; Wallingford, CT, USA). Scotchbond Multi-purpose (3M ESPE; Maggiewood, MN, USA) / Opal luting composite (Ultradent; South Jordan, UT, USA) / Scotchbond 1 (3M ESPE; Maggiewood, MN, USA) / Unity A-Cem (3M ESPE; Maggiewood, MN, USA).	NR	NR	NR 5 5	NR	NR	NR 2.14 % 3.57 % 2.19 %	13 3 5	0 0 0	10.2 (8 - 11) years 7.5 (7 - 7.9) years 7.2 (7 - 7.5) years	NR	NR
Ferrari M, Vichi A, Fadda GM et al., 2012[36] RCT Italy	NR NR	Aitsheni Post (RTD; St Egrève, France)	Quartz fiber	NE	120	120	120 (metal ceramic)	0	80	40	Yes (15s)	Prime&Bond NT dual cure adhesive (Dentsply Sirona; Charlotte, NC, USA) Dual Cure resin cement Calibra (Dentsply Sirona; Charlotte, NC, USA)	NE	12	12	NE	10%	10%	11	1	6 years	The authors received no financial support.	The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.
Ferrari M, Sorrentino R, Juloski J et al 2013[37] Prospective Clinical Trial Italy	60 (37/23) NR	GC Fiber post (GC Corporation; Tokyo, Japan)	Glass fiber	0	60	60	60 (metal ceramic)	0	NR	NR	No	Self-Etching Bond (GC Corporation; Tokyo, Japan)	NE	4	4	NE	6.7 %	6.7 %	NR	NR	7 years	The authors received no financial support.	The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.
Grandini S, Goracci C, Tay F et al 2005[38] Prospective Clinical Trial Italy	81 (45/36) 35.17 (15-56)	DT Light Post (RTD; St Egrève, France)	Quartz fiber	38	62	100	0	100	NR	NR	Yes (15s)	One-Step (Bisco; Schaumburg, IL, USA) / Duo-Link (Bisco; Schaumburg, IL, USA)	0	0	0	0	0%	0%	0	0	30 months	NR	NR
Goldner K, Lanares C, Guldener B et al 2011[39] Retrospective Clinical Trial Switzerland	NR NR	EasyPost (Mailefer Instruments Holding Sàrl; Ballaigues, Switzerland)	Glass fiber	27	79	106	41 (metal ceramic)	65	106	0	Yes (30s)	Syntac Primer (Ivoclar Vivadent AG; Schaan, Liechtenstein) / Heliobond (Ivoclar Vivadent AG; Schaan, Liechtenstein)	0	0	0	0	0%	0%	0	0	8.8 ± 2.3 years	NR	The authors deny any conflicts of interest related to this study.
Juloski J, Fadda GM, Monticelli F et al 2014[40] Prospective Clinical Trial Italy	120 (55/65) (18-72)	GC Fiber post (GC Corporation; Tokyo, Japan) GC Fiber post (GC Corporation; Tokyo, Japan)	Glass fiber Glass fiber	0 0	60 60	60 60	60 (metal ceramic) 60 (metal ceramic)	0 0	NR NR	NR NR	No No	GC Fuji Bond (GC Corporation; Tokyo, Japan) / Grada Core (GC Corporation; Tokyo, Japan) G-Cem dual-cure self-adhesive universal resin cement (GC Corporation; Tokyo, Japan)	NE NE	2 8	2 8	NE NE	3.3% 13.3%	3.3% 13.3%	NR NR	NR NR	48 months	The authors received no financial support.	The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.
Malferrari S, Monaco C, Scotti R 2003[41] Prospective Clinical Trial Italy	132 (NR) (18-63)	Aitsheni Post Plus (RTD; St Egrève, France)	Quartz fiber	124	56	180	180 (metal-ceramic and all-ceramic)	0	NR	NR	Yes (15s)	All Bond 2 and One-Step (Bisco; Schaumburg, IL, USA) / C&B resin cement (Bisco; Schaumburg, IL, USA).	2	0	2	1.61%	0%	1.1%	NR	NR	30 months	NR	NR
Mancebo JC, Jiménez-Castellanos E & Cañadas, 2010[42] Prospective Clinical Trial Spain	87 (32/55) (23-79)	Snowpost (Carbotech, Ganges, France)	Glass fiber	46	41	87	97 (metal-ceramic and all ceramic)	0	45	42	Yes (15s)	Relyit Unicem (3M Espe, St. Paul, MN, USA)	1	0	1	2.17%	0%	1.15%	NR	NR	3 years	NR	Authors have no conflict of interest.
Mehra SB, Millar BJ, 2008[43] Retrospective Clinical Trial United Kingdom	NR 52.8 (14-78)	Fibre-White Paraposts (Coltene Whaledent)	Glass fiber	34 29	45 21	79 50	129 (precious metal and metal-ceramic)	0	NE	129	Yes (15s) No	Caulk's Prime&Bond (Dentsply; Caulk, USA) / Calibra Aesthetic Dental Resin Cement (Dentsply; Caulk, USA) ED Primer II (Kuraray Noritake; Hattersheim, Germany) / Panavia F 2.0 (Kuraray Noritake; Hattersheim, Germany)	NR NR	NR NR	3 0	NR NR	NR NR	3.8% 0%	NE NE	3 0	38 - 54 months 28 - 50 months	NR NR	NR NR
Monticelli F, Grandini S, Goracci C, Ferrari M, 2003[44] Prospective Clinical Trial Italy	225 51 (18-78)	Aitsheni Post Plus (RTD; St Egrève, France) DT Light Post (RTD; St Egrève, France) FRC Postec (Ivoclar Vivadent AG; Schaan, Liechtenstein)	Quartz fiber Quartz fiber Glass fiber	0 0 0	75 75 75	75 75 75	225 (all-ceramic)	0	75 75 75	NE	Yes (15s) Yes (15s) Yes (NR)	One-Step (Bisco; Schaumburg, IL, USA) / Duo-Link (Bisco; Schaumburg, IL, USA). Excite DSC (Ivoclar Vivadent AG; Schaan, Liechtenstein) / MultiLink Automix (Ivoclar Vivadent AG; Schaan, Liechtenstein)	NE	3 2 3	3 2 3	NE	4% 2.66% 4%	4% 2.66% 4%	3 2 3	NE	3 years	NR	NR
Naumann M, Blankenstein F, Dietrich T, 2004[45] Prospective Clinical Trial Germany	83 (37/46) (15 - 98)	Fibrekor Post (Pentron; Wallingford, CT, USA) Lucent Anchors (Dentatus, Sweden)	Glass fiber Glass fiber	19 25	35 26	54 51	NR NR	0 0	NR NR	NR NR	Yes (20s) Yes (20s)	EBSetc Multi (3M ESPE; Maggiewood, MN, USA) / Panavia F (3M ESPE; Maggiewood, MN, USA)	NE NE	NE NE	NR 2 NR	NR 1.9% NR	NR NR	NR NR	NR 24 - 37 months NR	NR	NR
Naumann M, Sterzenbach G, Dietrich T et al., 2013[46] RCT Germany	41 NR	Fiberpoints Root Pins Glass (Schuetz Dental Group; Rosbach, Germany)	Glass fiber	NR	NR	41	41 (metal ceramic)	0	41	NE	No	Relyit Unicem (3M ESPE; Maggiewood, MN, USA)	0	0	0	0	0%	0%	0	NE	101 ± 41 months	NR	The authors deny any conflicts of interest related to this study.
Parisi C, Valandro LF, Ciocca L, et al., 2015[47] Retrospective Clinical Trial Italy	NR NR	DT Light Post (RTD; St Egrève, France)	Quartz fiber	29	70	99	NR	0	NR	NR	Yes (15s)	All Bond 2 and One-Step (Bisco; Schaumburg, IL, USA) / C&B resin cement (Bisco; Schaumburg, IL, USA).	NR	NR	9	NR	NR	9.09%	NR	NR	5.88 ± 1.37 years	NR	NR
Preethi GA, Kalu N, 2008[48] Prospective Clinical Trial India	10 (NR) 31.9 (20-40)	NR	Glass fiber	10	0	10	10 (metal-ceramic)	0	NR	NR	Yes (15s)	Scotch bond multipurpose (3M ESPE; Maggiewood, MN, USA) / Relyx (3M ESPE; Maggiewood, MN, USA)	0	NE	0	0	NE	0%	NR	NE	1 year	No	None declared
Sarkis-Onofre R, Pinheiro RA, Poletto-Neto V et al., 2020[49] RCT Brazil	NR NR	White Post DC (FGM; Joinville, Brazil)	Glass fiber	44	67	111	111 (metal-ceramic)	0	111	NE	No	Relyit ARC or U100/200 (3M ESPE; Maggiewood, MN, USA)	1	2	3	2.27%	2.99%	2.7%	3	NE	9 years	Meridional Foundation (Passo Fundo - Brazil) and National Council for Scientific and Technological Development (CNPq - Brazil).	The authors deny any conflicts of interest related to this study.
Schmitter M, Rammelsberg P, Gabbert O et al., 2007[50] RCT Germany	46 NR	ER-dentin post (Bisco; Schaumburg, GA, USA)	Glass fiber	9	37	46	46 (NR)	0	NR	NR	Yes (NR)	Variolink II (Ivoclar Vivadent AG; Schaan, Liechtenstein)	NR	NR	1	NR	NR	2.17%	NR	NR	13.6 ± 3.3	NR	NR
Schmitter M, Hamadi K & Rammelsberg P, 2011[51] RCT Germany	39 NR	ER-dentin post (Bisco; Schaumburg, GA, USA)	Glass fiber	NR	NR	39	NR	NR	NR	NR	Yes (NR)	Variolink II (Ivoclar Vivadent AG; Schaan, Liechtenstein)	NR	NR	2	NR	NR	5.1%	NR	NR	5 years (61.37 months)	NR	NR
Signore A, Benedicenti S, Kaitsas V et al., 2009[52] Retrospective Clinical Trial Italy	192 (74/118) F: 36.8 (20-66) M: 38.3 (19-65)	Fibrekor Post (Pentron; Wallingford, CT, USA) / Parallel - sided post Fibrekor Post (Pentron; Wallingford, CT, USA) / Tapered post	Glass fiber Glass fiber	249 277	0 0	249 277	249 (all ceramic) 277 (all ceramic)	0 0	NR NR	NR NR	Yes (60s) Yes (60s)	All Bond 2 (Bisco; Schaumburg, IL, USA) / LuxaCore-Dual (DMG Dental-Material GmbH; Germany).	5	0	5	0.95%	NE	0.95%	5	0	5.3 years	NR	NR
Signore A, Kaitsas V, Ravera G et al., 2011[53] Retrospective Clinical Trial Italy	134 (46/78) NR	Oval Translucent Post (Bolzoni; Sarsorno, Italy)	Glass fiber	0	154	154	154 (all ceramic)	0	38	116	Yes (60s)	LuxaBond (DMG Dental-Material GmbH; Germany) / LuxaCore Z (DMG Dental-Material GmbH; Germany)	0	2	2	0	1.3	1.3	2	0	42.3 ± 2.7 months	NR	NR
Skupien JA, Cenci MS, Opdam NJ et al., 2015[54] RCT Brazil	47 42.5±11.5	White Post DC system (FGM, Joinville, Brazil)	Glass fiber	14	43	57	27 (metal ceramic)	30	46	11	Yes (NR)	Adper Single Bond or Scotchbond Multi-Purpose (3M ESPE; Maggiewood, MN, USA) / RelyX ARC (3M ESPE; Maggiewood, MN, USA) / Adper Scotchbond (3M ESPE; Maggiewood, MN, USA)	0	0	0	0	0	0	0	0	2.5 (13 to 59 months)	CAPES financial support (CAPES/ NUFFIC 026/11 and scholarship)	NR
Sterzenbach G, Franke A & Naumann 2012[55] RCT Germany	45 (20/25) 49.2 ± 14.8	Fiberpoints Root Pins Glass (Schuetz Dental Group; Rosbach, Germany)	Glass fiber	22	23	45	45 (metal ceramic)	0	45	NE	No	Relyit Unicem (3M ESPE; Maggiewood, MN, USA)	0	0	0	0	0	0	0	NE	70 (24 - 84) months	NR	The authors deny any conflicts of interest related to this study.
Zicari F, Meerbeek BV, Debels et al., 2011[56] RCT Belgium	NR NR	Parapost FibreLux (Coltene-Whaledent; Cuyahoga Falls, OH, USA)	Glass fiber	16	49	65	65 (all ceramic)	0	65	NE	NR	ED Primer II (Kuraray Noritake; Hattersheim, Germany) / Panavia F 2.0 (Kuraray Noritake; Hattersheim, Germany)	0	0	0	0	0	0	0	NE	21 ± 9 months	NR	NR

Abbreviations: RTC, randomized clinical trial; NR, not reported; NE, not evaluated.

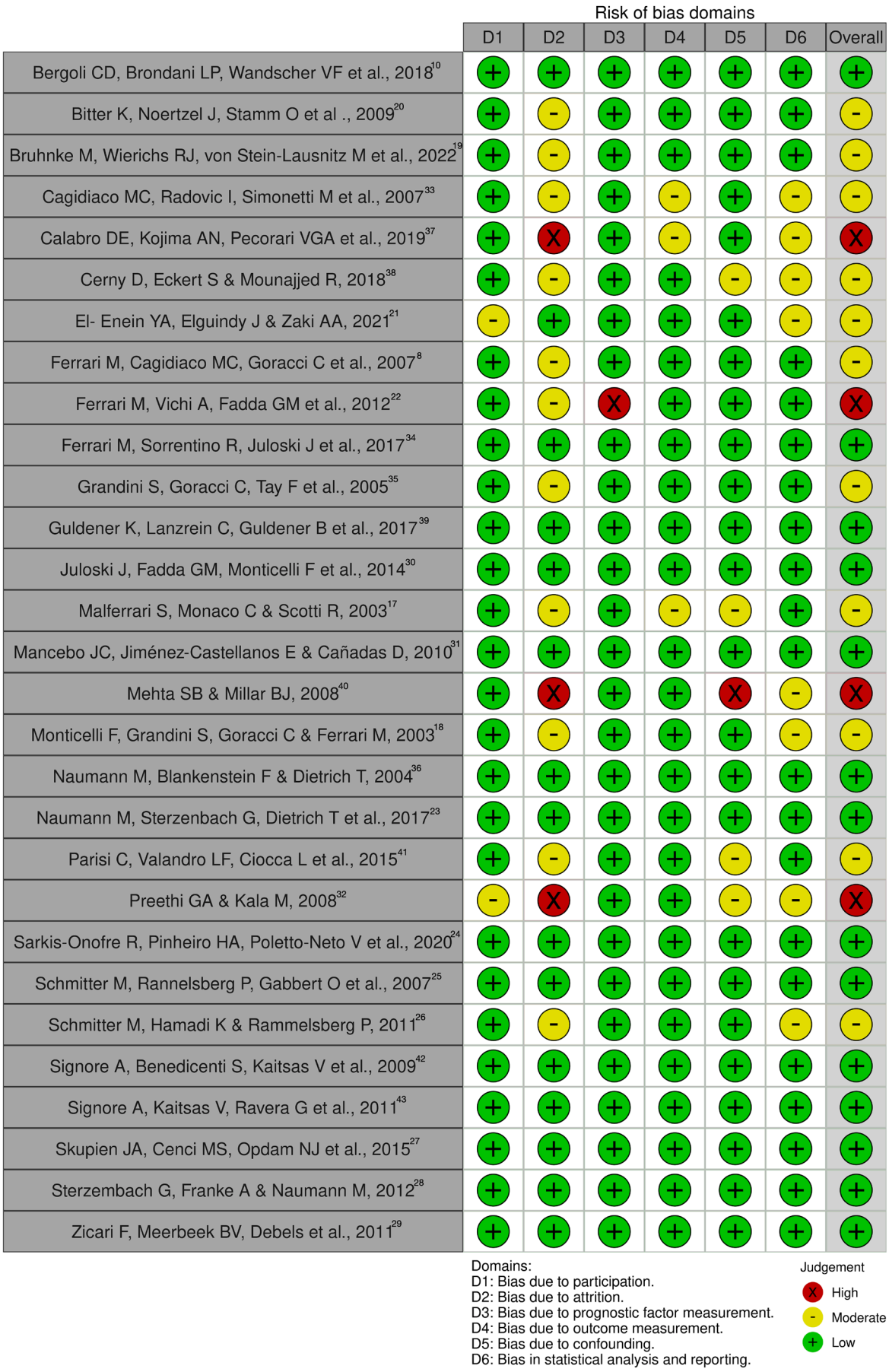

Figure 2: Risk of bias of included studies using the QUIPS (Quality In Prognosis Studies) tool.

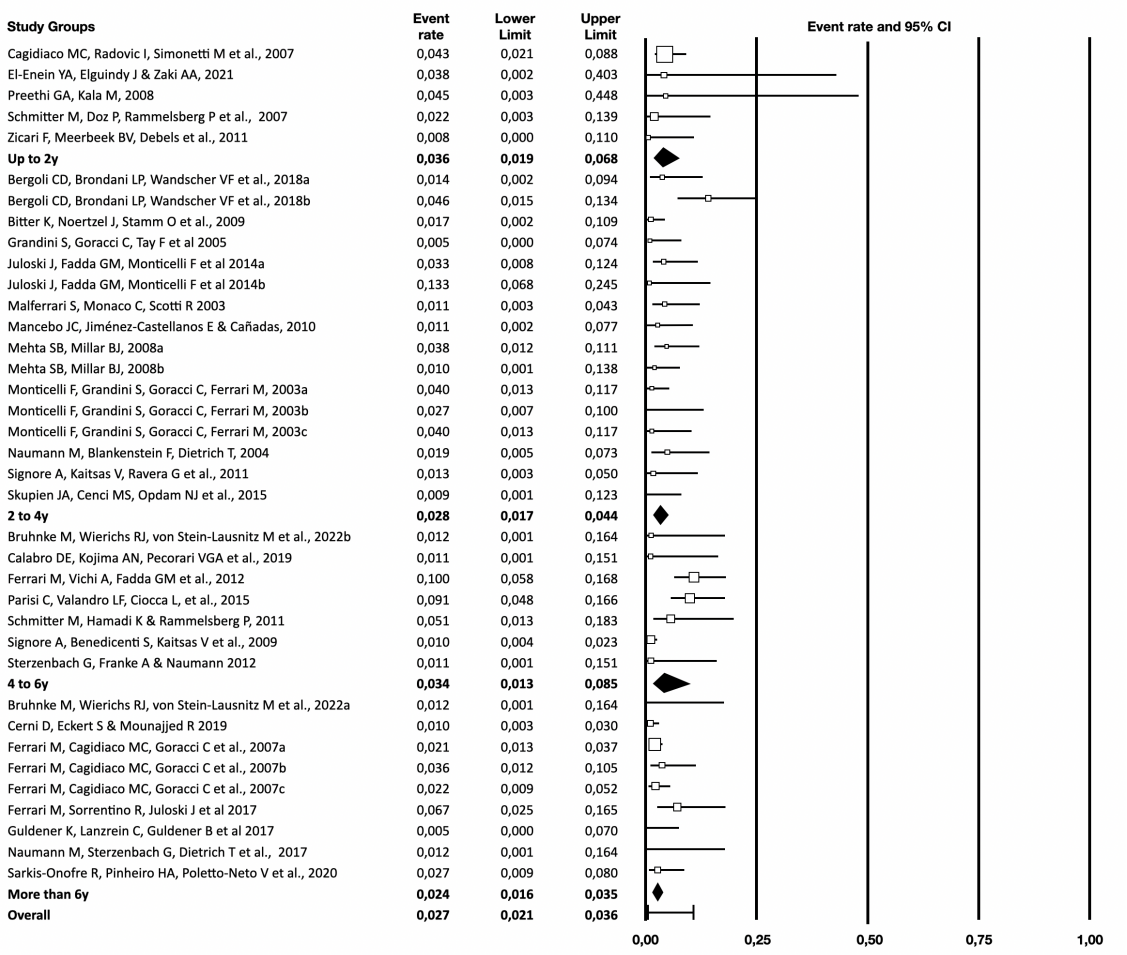

Figure 3: Meta-analysis graph for overall incidence of post-fiber debonding and according to the follow-up time.

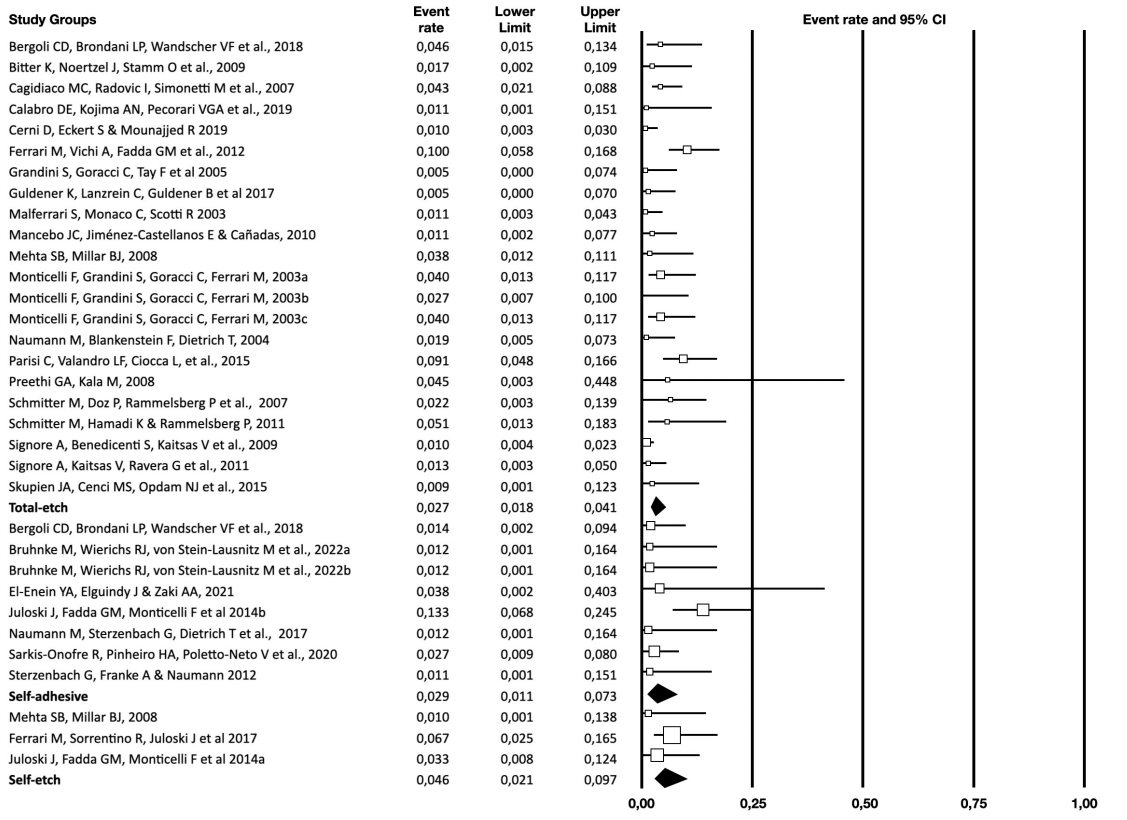

Figure 4: Meta-analysis graph for the sub-group incidence of post-fiber debonding regarding cementing strategy (Self-adhesive, Self-etch, and Total-etch).

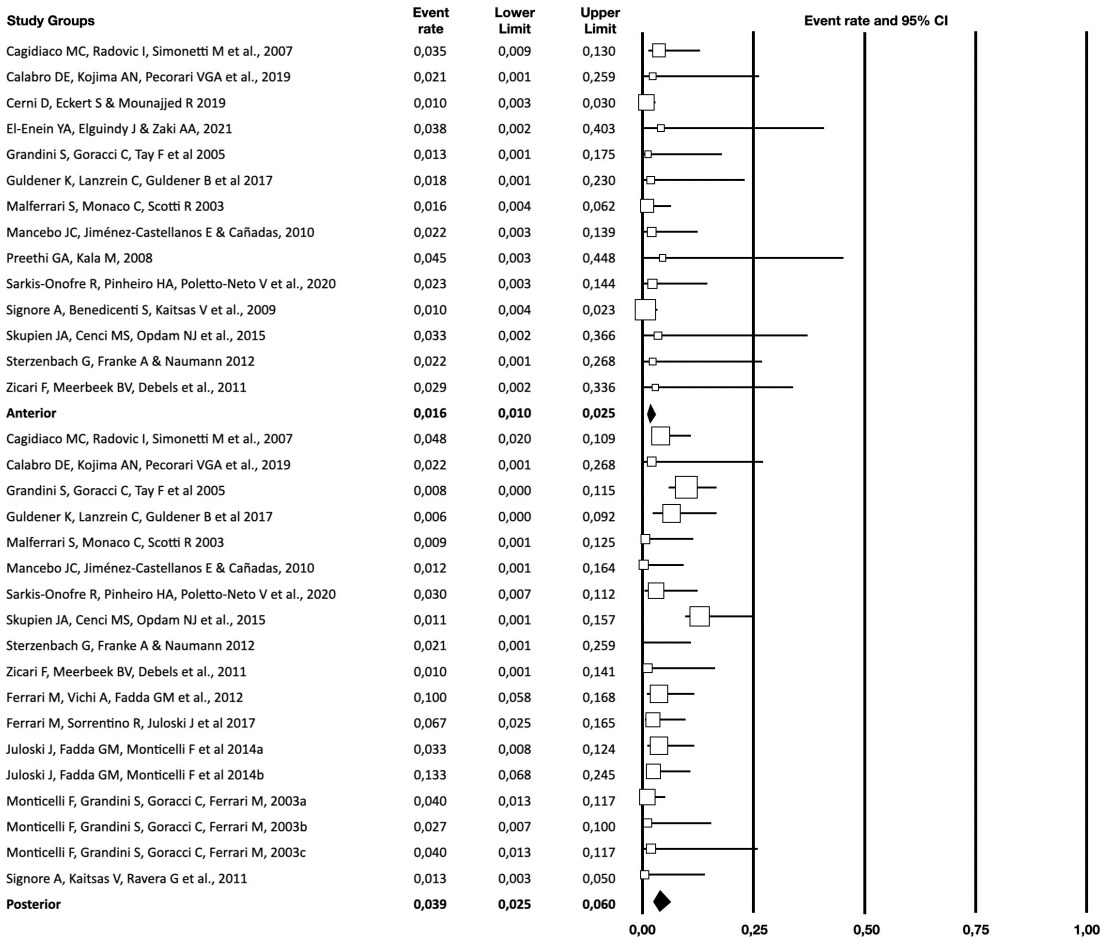

Figure 5: Meta-analysis graph for the sub-group incidence of post-fiber debonding concerning the tooth region (anterior or posterior).

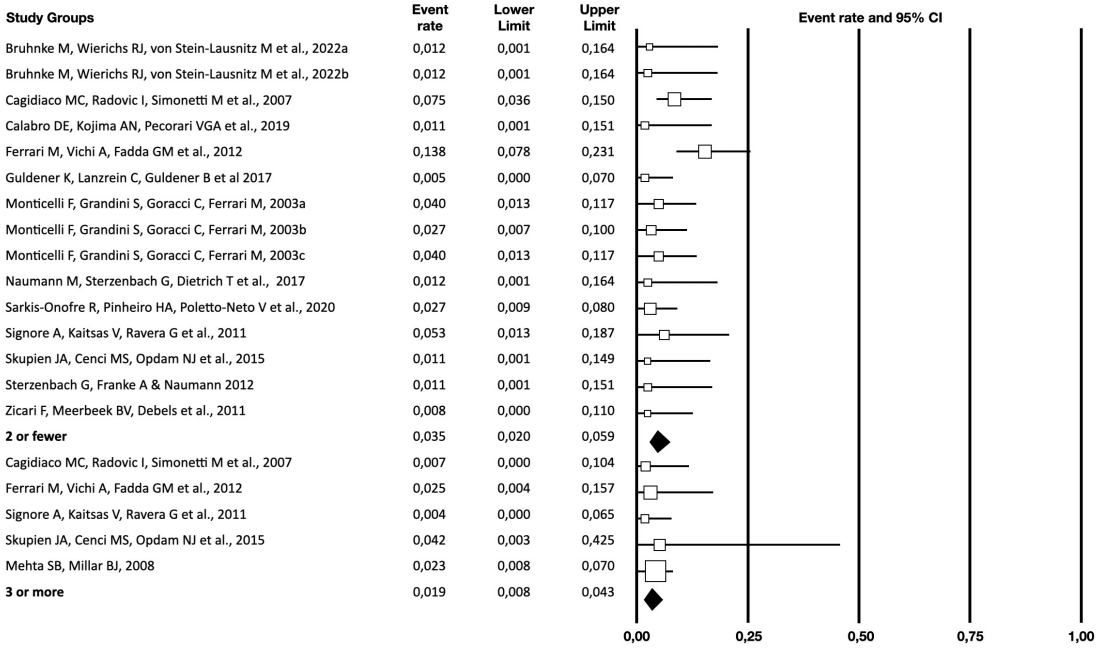

Figure 6: Meta-analysis graph for the sub-group incidence of post-fiber debonding concerning residual coronal walls (2 or fewer or 3 or more).

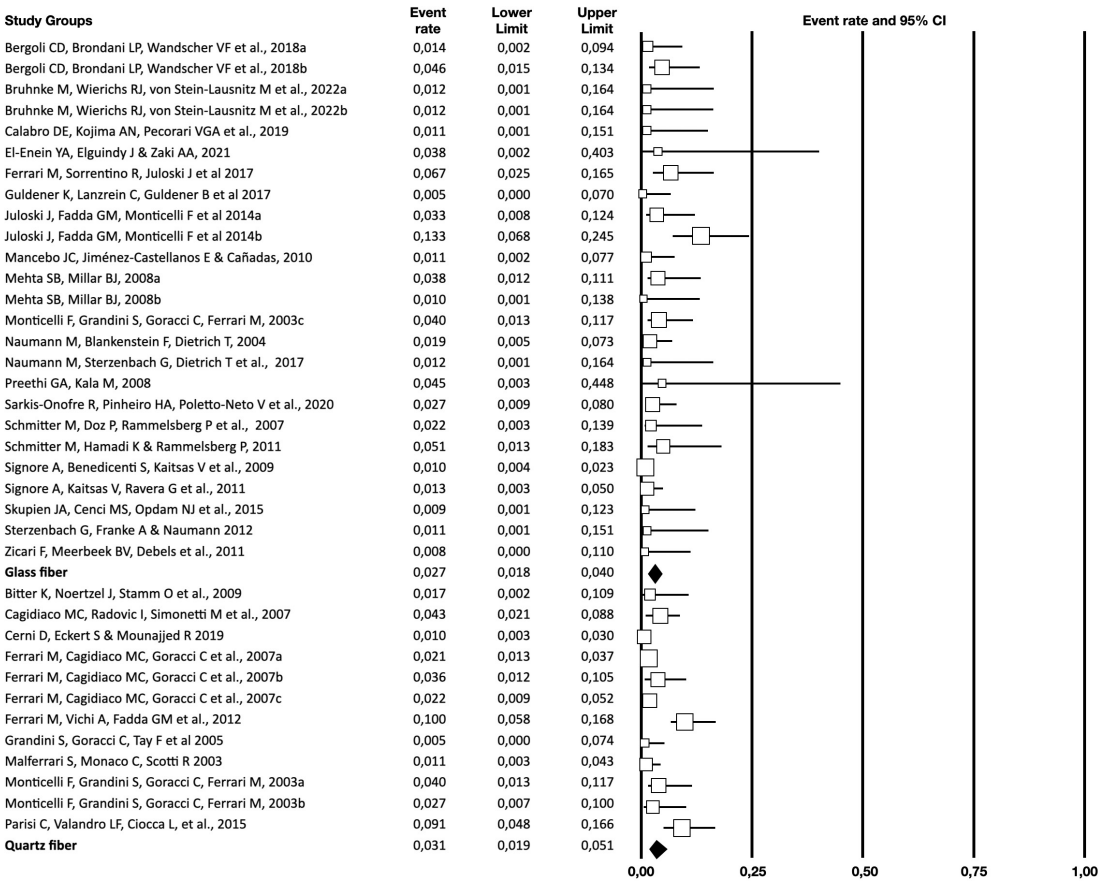

Figure 7: Meta-analysis graph for the sub-group incidence of post-fiber debonding concerning post type (glass fiber or quartz fiber).

systems and total-etch.[10] According to their findings, either choice would be suitable to ensure that restorations survive long enough. However, there is an evident lack of clinical data on this subject. Therefore, guidelines for choosing an appropriate adhesion protocol for fiber post-cementation are essential. To the best of our knowledge, this is the first systematic review that examined clinical data in order to determine debonding rates and the impact of various cementation techniques.

Debonding is one of the primary failures of fiber posts. Regardless of the cementation technique employed, the kind of post, the tooth region, or the follow-up duration, the overall incidence of debonding was 2.7%. This incidence rate did not increase with increasing follow-up time, meaning that it neither exhibited a greater rate in the initial years of function nor did it show an increase in incidence with longer follow-up times. This could be explained by the fact that, in addition to the cementation approach, debonding could be associated with a number of patient-related factors that are unrelated to the chronology, such as occlusal features or hygiene.[10]

Similar debonding rates were observed across the various adhesive strategies utilized for fiber post-cementation. However, as compared to the total-etch (11 groups) and self-adhesive (8 groups) systems, there was a tendency towards a greater debonding rate with the self-etch systems (3 groups). The literature emphasizes the use of total-etch systems for their superior dentin hybridization, even though the use of self-adhesive and self-etch systems represents a less technically sensitive option.[47,48] Likewise, bond strength has been reported to be lower in systems where the smear layer is modified rather than removed.[49,50-53]

Regarding tooth position, while Bruhnke *et al*., 2022[19] found no effect (anterior vs. posterior), the present review demonstrated a higher debonding rate when posterior teeth were restored with fiber posts. The use of fiber posts in posterior teeth were also considered previously as a significant risk factor.[8] This would be associated with the high occlusal forces generated in the posterior region. On the other hand, a higher failure rate has also been reported when the posts are placed in anterior teeth.[10,40] Authors assume that this would be related to the incidence of oblique forces in the anterior teeth, which would be more detrimental than the vertical forces that are generated more frequently in the posterior region.[57]

Different mechanical behaviors have been described concerning post types.[7,55] Quartz posts have been noted for higher fracture toughness while fiber posts have shown excellent load capacity.[7] Moreover, regardless of the post type, the modulus of elasticity has been reported to be similar to dentin.[7] Despite these differences and similarities between the analyzed posts, the debonding rates obtained in the present study were similar which is in agreement with *in-vitro* studies where fiber and quartz posts were tested, and no significant differences were found.[56-58]

Regarding the remaining dental tissues, the results on the present study demonstrated a trend towards higher debonding rates when 2 or fewer residual walls are present. This is in line with the available literature and therefore, further attention is needed when this scenario is observed in clinical practice.[10] It is also important to note that information on this aspect is not reported in a standardized manner in most studies.

Related to the risk of bias, a tool recommended by Cochrane for use in systematic reviews of prognostic factors was used.[59] Prognostic factor is any measure associated with a subsequent clinical outcome.[59] Most studies presented a low risk of bias, as they were mostly randomized clinical trials, where different types of bias can be controlled. The main domain with a high or moderate risk of bias was "Study Attrition" where some studies did not provide reasons for loss to follow-up.

Inevitably, studies included in a systematic review are different. In this review, clinical variability (different participants, interventions), methodological variability (different study designs), and consequent statistical heterogeneity were common. In view of the meta-analysis performed, heterogeneity between studies ranged from unimportant heterogeneity to moderate heterogeneity depending on the outcome analyzed. As a strategy to address the heterogeneity of the studies, a meta-analysis of random effects, and also analysis by subgroups was carried out.[16]

The extensive literature search, analysis, and discussion of the risk of bias of the included studies, meta-analysis with subgroup analysis trying to control in a certain way the heterogeneity of the studies can be considered as strengths of this systematic review. It is important to note that randomized clinical trials comparing different cementation strategies would be the most appropriate type of study to address this question. However, in the absence of this type of clinical studies in the literature, it was only possible to perform a single-arm meta-analysis, addressing the incidence of failures without any comparison. The high heterogeneity between studies, different cementation techniques, post brands, lack of reporting the presence or absence of remaining walls, among others are the limitations of the present studies. In addition, a limitation of this review would be the absence of subgroup analysis stratified by study design (randomized controlled trials, prospective clinical trials, and retrospective studies), which could better indicate potential sources of heterogeneity. This heterogeneity prevents an accurate conclusion of the main factors involved in the debonding rates of fiber posts. Clinical trials with better designed methodologies are needed to validate the findings of this study.

CONCLUSIONS

This systematic review and meta-analysis concluded that the incidence of debonding of fiber posts in root canal-treated teeth is low. The different cementation strategies (total-etch, self-etch, and self-adhesive) can all be considered as viable options when using fiber posts.

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CONFLICT OF INTEREST

Authors have no conflicts of interest to declare.

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Appendix 1. The search strategy used for each of the databases.

Database	Search 2nd August
Cochrane	("post-retained" OR "fiber post" OR "fiber posts" OR "fibre post" OR "fibre posts" OR "glass fiber-reinforced posts" OR "glass fiber-reinforced post" OR "Glass-fiber post" OR "glass-fiber posts" OR "fiberglass post" OR "quartz fiber") in All Text AND ("Dental Prosthesis" OR "Dental Prostheses" OR "restoration" OR "restorations" OR "prosthesis" OR "Crowns" OR "Crown" OR "prosthetic restoration" OR "denture, partial, fixed" OR "Fixed Bridge" OR "Fixed Bridges" OR "Fixed Partial Denture" OR "Fixed Partial Dentures" OR "Composite Resins" OR "Composite Resins") in All Text - (Word variations have been searched)
Embase	('post-retained' OR 'fiber post'/exp OR 'fiber post' OR 'fiber posts' OR 'fibre post' OR 'fibre posts' OR 'glass fiber-reinforced posts' OR 'glass fiber-reinforced post' OR 'glass-fiber post' OR 'glass-fiber posts' OR 'fiberglass post' OR 'quartz fiber') AND ('dental prosthesis'/exp OR 'dental prosthesis' OR 'dental prostheses'/exp OR 'dental prostheses' OR 'restoration'/exp OR 'restoration' OR 'restorations' OR 'prosthesis'/exp OR 'prosthesis' OR 'crowns'/exp OR 'crowns' OR 'crown'/exp OR 'crown' OR 'prosthetic restoration' OR 'denture, partial, fixed'/exp OR 'denture, partial, fixed' OR 'fixed bridge'/exp OR 'fixed bridge' OR 'fixed bridges'/exp OR 'fixed bridges' OR 'fixed partial denture'/exp OR 'fixed partial denture' OR 'fixed partial dentures'/exp OR 'fixed partial dentures' OR 'composite resins'/exp OR 'composite resins')
LILACS	("pino de fibra de vidro" OR "postes de fibra de vidrio") AND ("Prótese dentária" OR "Prótesis Dental" OR "restauração" OR "restaurações" OR "prótese" OR "coroa" OR "coroas" OR "corona" OR "resina composta" OR "resina compuesta" OR "Restauración Dental")
PubMed	("post-retained"[All Fields] OR "fiber post"[All Fields] OR "fiber posts"[All Fields] OR "fibre post"[All Fields] OR "fibre posts"[All Fields] OR "glass fiber-reinforced posts"[All Fields] OR "glass fiber-reinforced post"[All Fields] OR "quartz fiber"[All Fields] OR "Glass-fiber post"[All Fields] OR "glass-fiber posts"[All Fields] OR "fiberglass post"[All Fields]) AND ("Dental Prosthesis"[MeSH Terms] OR "Dental Prosthesis"[All Fields] OR "Dental Prostheses"[All Fields] OR "restoration"[All Fields] OR "restorations"[All Fields] OR "prosthesis"[All Fields] OR "Crowns"[MeSH Terms] OR "Crowns"[All Fields] OR "Crown"[All Fields] OR "prosthetic restoration"[All Fields] OR "denture, partial, fixed"[MeSH Terms] OR "Fixed Bridge"[All Fields] OR "Fixed Bridges"[All Fields] OR "Fixed Partial Denture"[All Fields] OR "Fixed Partial Dentures"[All Fields] OR "Composite Resins"[MeSH Terms] OR "Composite Resins"[All Fields])
Scopus	(TITLE-ABS-KEY (("post-retained" OR "fiber post" OR "fiber posts" OR "fibre post" OR "fibre posts" OR "glass fiber-reinforced posts" OR "glass fiber-reinforced post" OR "glass-fiber post" OR "glass-fiber posts" OR "fiberglass post" OR "quartz fiber")) AND TITLE-ABS-KEY ("dental prosthesis" OR "dental prostheses" OR "restoration" OR "restorations" OR "prosthesis" OR "crowns" OR "crown" OR "prosthetic restoration" OR "denture, partial, fixed" OR "fixed bridge" OR "fixed bridges" OR "fixed partial denture" OR "fixed partial dentures" OR "composite resins" OR "composite resins")))
Web of Science	(ALL=(("Glass-fiber post" OR "glass-fiber posts" OR "fiberglass post" OR "post-retained" OR "fiber post" OR "fiber posts" OR "fibre post" OR "fibre posts" OR "glass fiber-reinforced posts" OR "glass fiber-reinforced post"))) AND ALL=(("Dental Prosthesis" OR "Dental Prostheses" OR "restoration" OR "restorations" OR "prosthesis" OR "Crowns" OR "Crown" OR "prosthetic restoration" OR "denture, partial, fixed" OR "Fixed Bridge" OR "Fixed Bridges" OR "Fixed Partial Denture" OR "Fixed Partial Dentures" OR "Composite Resins" OR "Composite Resins"))
Google Scholar	allintitle: "fiber post"
OpenGrey	"fiber post"

Appendix 2. Excluded articles and reasons for exclusion (n = 38).

Study	Reason for exclusion
Akbari M, Ameri H, Jamali H et al., 2016[1]	1
Amaral M, Coppo PP, Rosalem CGC et al., 2015[2]	2
Agarwal S, Gupta DA, Sharma Y et al., 2021[3]	1
Basrani B & Matthews D, 2004[4]	3
Bhatnagar M, Tomer L, Saxena P et al., 2021[5]	4
Cagidiaco MC, Garcia-Godoy F, Vichi A et al., 2008[6]	5
Cai J, Zhang-xin Y, Jin-zhi W, Xin-qing L, 2013[7]	6
Chang Z, 2013[8]	6
Cloet E, Debels E, Naert I, 2017[9]	1
da Costa RG, de Morais ECC, Leão MP et al., 2011[10]	3
Ferrari M, Vichi A, Mannocci F et al., 2000[11]	5
Ferrari M, Cagidiaco MC, Grandini S et al., 2007[12]	5
Ferrari M, Cagidiaco MC, Goracci C et al., 2019[13]	7
Garcia P, Cappoani A, Schelbauer R et al., 2020[14]	1
Gbadebo O, Ajayi D, Oyekunle O et al., 2014[15]	4
Gbadebo S, Ajayi D, Abiodun- Solanke I et al., 2013[16]	4
Ghavamnasiri M, Maleknejad F, Ameri H et al., 2011[17]	1
Glazer B, 2000[18]	2
Hedlund SO, Johansson NG, Sjogren G, 2003[19]	2
Jirathanyanatt T, Suksaphar W, Banomyong D et al., 2019[20]	1
Jurema A, Bresciani E & Caneppele T, 2021[21]	4
King PA, Setchell DJ, Rees JS, 2003[22]	2
Kong D, 2015[23]	6
Kramer EJ, Meyer-Lueckel H, Wolf TG et al., 2019[24]	1
Lazari PC, Carvalho MA, Cury A et al., 2017[25]	3
Liu X, Liu Y, Liu S, 2011[26]	6
Luz-Silva G, Vetromilla B, Pereira-Cenci T et al., 2021[27]	1
Mannocci F, Bertelli E, Sherriff M et al., 2002[28]	2
Manocci F, Qualtrough AJE, Worthington HV et al., 2005[29]	2
Martino N, Truong C, Clark AE et al., 2020[30]	1
Mohan M, Gowda M, Shashidhar MP, 2015[31]	4
Naumann M, Sterzenbach G, Franke A, 2007[32]	5
Patel SS & Sethuraman R, 2022[33]	8
Phang ZY, Quek SHQ, Teoh KH et al., 2020[34]	1
Salvi GE, Guldener SBE, Amstad JA, Lang NP, 2007[35]	2
Sarkis-Onofre R, Jacinto R, Boscato N et al., 2014[36]	5
Zhou X, Liu X, Zhao J, 2013[37]	6
Willershausen B, Tekyatan H, Krummenauer F, Marroquin BB, 2005[38]	1

Reasons for exclusion:

1. **Not reported or insufficient information on adhesive/cementation system or failure or**
2. **Other type of post than glass fiber post**
3. **Reviews, letters, books, conference abstracts, case report, commentary, opinion articles, technique articles, posters, guidelines, in vitro studies.**
4. **Follow-up less than 1 year**
5. **Studies with repeated samples**
6. **Studies published in other languages rather than the Latin (Roman) alphabet**
7. **Other restoration than full contour crowns**
8. **Studies that did not investigate the outcomes of interest**

APPENDIX 2 REFERENCES

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Appendix 3. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020.

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	1,2
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	2
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	2
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	2
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	12
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	2
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	3
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	3
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	3
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	3
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	3
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	3
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	3
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	3
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	3
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	3
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	3
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	3
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Not applicable
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	3
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	3
Study characteristics	17	Cite each included study and present its characteristics.	3
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	3
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Not applicable
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	3-4
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	3-4
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	3-4
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Not applicable
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Not applicable
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Not applicable
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	4,9
	23b	Discuss any limitations of the evidence included in the review.	9
	23c	Discuss any limitations of the review processes used.	9,10
	23d	Discuss implications of the results for practice, policy, and future research.	10
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	2
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	2
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	2
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	10
Competing interests	26	Declare any competing interests of review authors.	10
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Not applicable

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71