Systematic Review
Restorative Dentistry

A systematic review of factors associated with the retention of glass fiber posts

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Abstract: This study aimed to identify factors that can affect the retention of glass fiber posts to intra-radicular dentin based on *in vitro* studies that compared the bond strength (BS) of GFPs cemented with resin cements. Searches were carried out in PubMed and Scopus until December 2013. Bond strength values and variables as type of tooth, presence of endodontic treatment, pretreatment of the post, type of bonding agent (if present), type of cement and mode of cement application were extracted from the 34 included studies. A linear regression model was used to evaluate the influence of these parameters on BS. The presence of endodontic treatment decreased the BS values in 22.7% considering the pooled data ($p = 0.013$). For regular cement, cleaning the post increased BS when compared to silane application without cleaning ($p = 0.032$), considering cleaning as ethanol, air abrasion, or phosphoric acid application. Applying the cement around the post and into root canal decreased the resistance compared to only around the post ($p = 0.02$) or only into root canal ($p = 0.041$), on the other hand, no difference was found for self-adhesive resin cement for the same comparisons ($p = 0.858$ and $p = 0.067$). Endodontic treatment, method of cement application, and post pretreatment are factors that might significantly affect the retention of glass-fiber posts into root canals mainly when cemented with regular resin cement. Self-adhesive resin cements were found to be less technique-sensitive to luting procedures as compared with regular resin cements.

Keywords: Resin Cements; Review; Adhesives; Dental Cements; Dentin-Bonding Agents.

Introduction

In vitro studies are usually used to test materials and techniques before clinical application. Although considered generally of low clinical relevance, it is clear that results obtained *in vitro* are useful to guide protocols for several clinical approaches, especially considering the absence of evidence from well-designed clinical trials in dentistry.[1,2,3,4] Cementation of glass-fiber posts (GFPs) into the root canal can be considered one of those examples, as numerous attempts to improve the adhesion of GFPs to intra-radicular dentin have been tested *in vitro*,[5,6,7] but few clinical evaluations are avalilable.[8]

Recently, a systematic review[9] showed that the type of luting cement used influences the retention of GFPs in root canals but the large degree of

heterogeneity of the studies included was emphasized. This heterogeneity was partly due to the various factors that can influence bonding, including cement application mode, post pretreatment, and sample storage conditions. The influence of some factors on bond strength (BS) of GFPs has been addressed;[10,11,12] however, it is important to evaluate as many variables as possible to determine the interactions between these factors associated with the retention of posts in root canals. Identifying a clear influence of post/sample-related factors will aid researchers in standardizing preclinical and clinical studies.

The aim of this study was to evaluate the influence of variables related to post cementation by systematically reviewing the *in vitro* literature on the retention of GFPs luted into root canals. The hypothesis tested was that factors other than the type of resin cement used for luting the posts would also have a role on the retention of GFPs.

Methodology

This systematic review was carried out according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[13] PubMed and Scopus databases were searched to identify *in vitro* studies that evaluated and compared the retention (bond strength values in MPa) of GFPs cemented into root canals of human or bovine teeth using both regular and self-adhesive resin cements. The search strategy included the following: (glass fiber post) AND (resin cement) AND (bond strength); (glass fiber post) AND (push out); (self* resin cement) AND (glass fiber post) AND (bond strength); (glass-fiber OR glass fiber), and (post) AND (bond* OR adhes*). The same strategy was used changing the term post for dowel, resin cement for luting agent, and fiber for fibre.

The last search was conducted in December 2013 and no publication year or language limits were set. The references of eligible papers were hand-searched for additional studies. *In vivo* or *in situ* studies, posts that were not GFPs, studies that luted the GFPs into artificial devices, and studies that did not compare the BS between regular and self-adhesive resin cements were excluded. Two independent reviewers screened the titles, and shortlisting for inclusion was followed by abstract evaluation. The abstracts were assessed and eligible papers identified. In case of doubt, the paper underwent full text evaluation. In cases of disagreement, a third reviewer decided whether the article should be included (Figure 1).

Two authors independently extracted all data. In case of BS values reported separately for different root thirds (for instance, in studies in which the push-out test was used), the BSs of all root thirds were averaged. In studies where the BS tests performed included other types of cement or post, only the data of interest were extracted. Variables that were considered similar among the studies were extracted and classified according to: tooth type (human or bovine); prior endodontic treatment (yes or no); post pretreatment (cleaning/pretreatment, silane application, or both); bonding agent type (if used); and mode of cement application (around the post, into the root canal, or both). Categories were created with indicator variables (reference group) for each category; in case of missing data, the category "Unknown" was created to make regression model statistics possible.

Statistical analyses were performed using SPSS 22 software for Mac (SPSS Inc., Chicago, USA). Analysis of Variance (ANOVA) with Tukey's *post hoc* comparison was used to analyze the bond strength values at a significance level of 5%. To analyze the influence

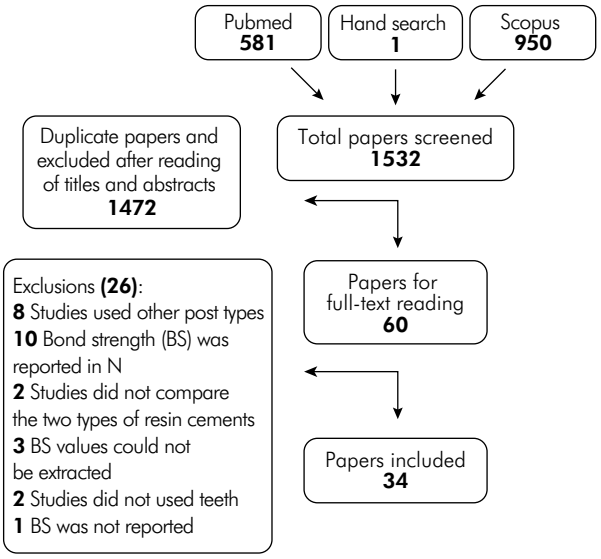

Figure 1. Flow diagram of the study according to the PRISMA statement.

of the studied variables on GFP retention, a model of linear regression was created. The first plot to check whether regression was feasible was doubtful, thus logarithm transformation of bond strength values was performed. Next, for the significant variables, an exponential effect was applied followed by transformation as percentage effect. Thus, two regression analyses were carried out: one for all data and another for the two types of cement separately, to verify the influence of the same factors for each category. Descriptive statistics was used to describe the variables according to the included studies.

Results

From the 34 studies included,[14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47] 35 distinct data sets were extracted because one article had two different data sets.[23] BS values are presented in Table 1. No statistically significant difference was found between resin cements (p = 0.379) or bonding agents (p = 0.068).

Table 2 shows the regression model for all data. Prior endodontic treatment led to a 22.7% decrease in BS values (p = 0.013). Regarding post pretreatment, cleaning or silanizing the post did not statistically affect BS values (p = 0.198 and p = 0.06, respectively) compared with the use of these two pretreatments together. When the cement was applied into the root canal alone, or when the mode of cement application was not described, retention was statistically higher compared with the application of cement both into the root canal and around the post (34.7% with p = 0.003 and 71.7% with p < 0.001, respectively).

The regression model divided according to the type of resin cement used is shown in Table 3. For self-adhesive resin cement, only the "Unknown" category of cement application presented statistically significant differences (p = 0.001), increasing GFP retention by 106% compared with application both around the post and into the root canal. Regarding regular resin cement, post retention was influenced by: (i) cleaning the post prior to its cementation, which increased retention in 43.4% compared with silane application without cleaning (p = 0.032); (ii) applying the cement around the post and into root canal, which decreased retention compared to cement application around the post only (p = 0.02) or into root canal only (p = 0.041), and when the method of cement application was unknown (p = 0.004). In all conditions, cleaning was defined as ethanol or phosphoric acid application or air abrasion. In contrast to the results obtained using the regression model for all data, prior endodontic treatment did not influence post retention using the regression model divided according to the type of resin cement used (p = 0.137 and p = 0.81, respectively). In both models, BS values were unaffected by tooth type (human or bovine).

Discussion

This systematic review is the first study to evaluate factors related to the selection of materials and luting procedures that may influence the retention of GFPs in root canals. Although conducted based on *in vitro* studies because of the dearth of clinical trials, the parameters taken into account in this study may affect the performance of GFPs. Several cementation strategies have been proposed, mainly

Table 1. Bond strength values (MPa) from the included studies.

		Mean ± SD	95% confidence interval for mean		Minimum	Maximum
			Lower bound	Upper bound		
Resin cement	Self-adhesive	11.3 ± 5.8	10	12.6	1.9	30.5
	Regular	10.5 ± 5.7	9.4	11.6	1.3	32.4
	Total	10.9 ± 5.7	10.0	11.7	1.3	32.4
Bonding agent	Self-etch	11.9 ± 5.7	10.2	13.7	3.5	29.1
	Etch-and-rinse	9.9 ± 5.6	8.5	11.3	1.3	32.4
	Total	10.7 ± 5.7	9.6	11.8	1.3	32.4

Table 2. Regression model considering all data (r-square = 0.23).

Variable		Effect	95% confidence interval		p-value
			Lower	Upper	
Type of tooth		-6.8%	-25.1%	15.8%	0.522
Endodontic treatment		-22.7%	-36.8%	-5.5%	0.013
Pretreatment of the post	Post cleaning*	12.7%	-6.1%	35.3%	0.198
	Silane application*	-21.2%	-38.5%	1%	0.06
	Unknown/no treatment*	-11.9%	-32.3%	14.7%	0.346
Cement application method	Around the post**	24.1%	-2.7%	58.2%	0.082
	Into root canal**	34.7%	10.5%	64.2%	0.003
	Unknown**	71.7%	35.6%	117.3%	< 0.001
Resin cement		-10.8%	-24.3%	5.1%	0.171
Adhesive		19.7%	-1.4%	45.4%	0.069

*Reference for post pretreatment – Post cleaning and silane application.
**Reference for cement application – Around the post and into root canal.

Table 3. Regression model for self-adhesive and regular resin cement. R-square = 0.309 and 0.237 respectively.

Variable		Self-adhesive resin cement				Regular resin cement			
		Effect	95% confidence interval		p-value	Effect	95% confidence interval		p-value
			Lower	Upper			Lower	Upper	
Type of tooth		-18.5%	-41.8%	14.1%	0.229	8.6%	-19.1%	45.8%	0.578
Endodontic treatment		-20.9%	-42.1%	8%	0.137	-21.4%	-40.1%	3.1%	0.81
Post pretreatment	Post cleaning and silane application*	30.3%	-13.8%	97%	0.205	12.9%	-18.9%	57.1%	0.47
	Post cleaning*	38.3%	-11.7%	116.8%	0.154	43.4%	3.2%	99.2%	0.032
	Unknown/no treatment*	26.5%	-27.7%	121.4%	0.404	10.2%	-25.1%	62%	0.62
Cement application method	Around the post**	3.7%	-30.6%	54.8%	0.858	47.9%	6.6%	105.1%	0.02
	Into canal**	34%	-2%	83.2%	0.067	32.6%	1.2%	73.8%	0.041
	Unknown**	106%	35.7%	212.8%	0.001	56.9%	16.4%	11.5%	0.004
Adhesive		3%	-51.7%	119.8%	0.938	20.9%	-1.7%	48.8%	0.72

*Reference for post pretreatment – Silane application.
**Reference for Cement application – Around the post and into root canal.

in vitro, to improve the retention of GFPs. The analysis of luting-related variables may support clinicians during evidence-based decision-making. Although BS values were considered in this study, the aim was not to compare different adhesive or luting materials but rather to evaluate factors associated with the retention of GFPs. A previous systematic review[9] adopted a statistical approach to evaluate the influence of resin cements and adhesives on the retention of GFPs and demonstrated that self-adhesive cements perform best. However, the articles included in this study exhibited a large degree of heterogeneity;[9] therefore, our regression model considered other variables to increase the reliability of our results. Tooth type, type of endodontic sealer used, and type of post used were considered in our model; however, because few studies included these variables, the comparisons were unfair, decreasing the reliability of the regression model.

Our results show that prior endodontic treatment can affect the BS of GFPs. We assumed that all studies performed some degree of preparation of the postholes before inserting the GFPs: it is full treatment of the endodontic canal that affects the performance of luted posts. Some types of canal sealer (*e.g.*, calcium hydroxide cements) can be difficult to remove from the root canal walls and sealer residues can interfere with bonding. The presence of eugenol in other cements has been

linked to reduced polymerization of adhesives and resin cements.[48,49] It is clear that endodontic treatment should always be performed prior to BS testing of GFPs. Conversely, the type of tooth used in the studies (human or bovine) did not influence the results. This finding can be considered relevant because the use of extracted human teeth, particularly single-root anterior teeth, is increasingly difficult.

Our findings also show that applying the cement into the root canal increased post retention when compared with the technique where the cement is also applied around the post. The use of lentulo drills or syringes for cement insertion could reduce the presence of voids and bubbles that could affect correct cementation of GFPs. However, lentulo drills might heat up the resin cement and speed up polymerization, reducing the cement working time.[50,51] A longer time is necessary to apply the cement inside the canal and around the post, affecting working time and polymerization of self-and dual-cure cements. In addition, as cement application around the post is usually carried out with a spatula, this may not be a reliable procedure to prevent incorporation of voids. Interesting is the fact that unknown cementation procedures provided statistically higher post retention compared to the reference. Despite no information regarding the method of cement application was found in several studies, and due to the good results achieved for the unknown technique, it is hypothesized that manufacturers' instructions were followed without distinct cement application strategies when no information was available in the article.

The results of the regression model divided according to resin cement type show that post retention following the use of regular resin cements is more greatly influenced by the variables, suggesting that self-adhesive resin cements are less technique-sensitive. A recent study[37] showed that, in contrast to regular resin cements, the performance of self-adhesive resin cements for luting GFPs was not influenced by operator experience. Nevertheless, for regular cements, luting the post without applying cement around it outperformed luting the post and applying cement around it. Cleaning the post before cementation with ethanol, air abrasion, or phosphoric acid also improved retention compared with silane application without cleaning.

Different variables were grouped according to their similarity, which could be considered a limitation of this study. For instance, post cleaning included studies that used ethanol, phosphoric acid, or air abrasion before cementation. Although air abrasion and ethanol are approaches that could have significant differences, the model might have been weak and unreliable if another category was created. Post cleaning and silane application was defined as the use of the above methods plus immersion in 24% H_2O_2, followed by silane application. Studies that did not provide any information about post pretreatment before silanization were categorized separately. Consequently, the findings for post pretreatment should be interpreted with caution and could be considered interesting topics for analysis in future research.

Two additional variables were considered important but discarded from the analysis because limited data was available: intra-radicular dentin pretreatment and aging/storage procedures. Dentin pretreatment before post cementation, was scarcely addressed in the papers included in this review,[15,25] and the role of chlorhexidine in the stability of dentin bonds was already demonstrated,[52] thus, additional studies on this topic could be advised. The same trend occurred for phosphoric acid application prior to use of self-adhesive resin cements.[39,40,41] Besides the known benefits of selective enamel etching,[53,54] dentin acid-etching before use of self-etch adhesives or self-adhesive resin cements may perform differently. The dentin bonding mechanism of self-adhesive cements could actually be jeopardized by previous acid-etching, and investigation regarding that effect on the retention of GFPs is recommended. For aging/storage conditions, the wide variability in protocols among studies would result in too many comparisons. Several studies did not perform any kind storage, which should be considered in *in vitro* studies as it is one of the only mechanisms that may simulate the aging taking place during clinical service.[55] Several studies also did not compare bond strengths between resin cements. Standardized *in vitro*

protocols for testing and aging specimens of GFPs cemented into root canals would be useful.

Our results, although based on *in vitro* studies, provide evidence that may prepare the ground for clinical studies and/or protocols. For instance, because the use of post pretreatment was found to affect post retention in almost all studies, post pretreatment should be considered as a mandatory clinical step and evaluated in a clinical study. In addition, the mode of cement application must be considered an important factor influencing post retention. Following the manufacturers' instructions is strongly suggested in all situations, and using endodontically treated teeth as testing substrate should be a protocol since this factor seems to significantly affect the results of *in vitro* tests.

Conclusion

We can concluded that endodontic treatment, method of cement application, and post pretreatment are factors that might significantly affect the retention of glass-fiber posts into root canals, mainly when cemented with regular resin cement. Self-adhesive resin cements were found to be less technique-sensitive to luting procedures as compared with regular resin cements.

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