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The Role of Resin Cement on Bond Strength of Glass-fiber Posts Luted Into Root Canals: A Systematic Review and Meta-analysis of *In Vitro* Studies

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Clinical Relevance

There is little clinical evidence on the performance of glass-fiber posts to guide clinical decisions when selecting the cementation strategy. This meta-analysis of *in vitro* studies suggests that the use of self-adhesive resin cement could improve the retention of glass-fiber posts.

SUMMARY

Because there are several ways to cement glass-fiber posts (GFPs) into root canals, there is no consensus on the best strategy to achieve high bond strengths. A systematic review was conducted to determine if there is difference in bond strength to dentin between regular and self-adhesive resin cements and to verify the influence of several variables on the retention of GFPs. This report followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. *In vitro* studies that investigated the bond strength of GFPs luted with self-adhesive and regular resin cements were selected. Searches were carried out in the PubMed and Scopus databases. No publication year or language limit was used, and the last search was done in October 2012. A global comparison was performed between self-adhesive and regular resin cements. Two subgroup analyses were performed: 1) Self-adhesive × Regular resin cement + Etch-and-rinse adhesive and 2) Self-adhesive × Regular resin cement + Self-etch adhesive. The analyses were carried out using fixed-effect and random-effects models. The results showed heterogeneity in all comparisons, and higher bond

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strength to dentin was identified for self-adhesive cements. Although the articles included in this meta-analysis showed high heterogeneity and high risk of bias, the *in vitro* literature seems to suggest that use of self-adhesive resin cement could improve the retention of GFPs into root canals.

INTRODUCTION

The use of glass-fiber posts (GFPs) has increased in recent years compared with other types of posts.[1] In addition to their esthetics,[2] GFPs have similar elastic modulus to that of dentin, providing a more homogeneous dissipation of loading stresses to the tooth/cement/post structure compared with more rigid posts.[3] However, the main reason for failure of GFPs is still debonding,[4] which occurs mainly because of the difficulties in achieving proper adhesion to intraradicular dentin. Cementing GFPs into root canals is a clinical challenge because of the complex cementation techniques and high level of technique sensitivity.[1]

Resin-based cements are commonly used for luting GFPs into intraradicular dentin. A combination of the etch-and-rinse adhesive system and regular resin cement is the approach most often used in dental practice.[1,5,6] In the past decade, self-adhesive resin cements were introduced to provide easier clinical application compared with regular resin cements.[7] Despite some clinical studies testing different types of posts reported in the literature,[5,6,8,9] most information about the retention of GFPs cemented with resin cements is available from *in vitro* studies, which have tested several cementation strategies and performed different bond strength tests.[10,11]

Irrespective of recent advances in materials and techniques to make cementation procedures easier, it is important to understand all factors involved in cementing posts, not only the type of resin cement used but also the different approaches attempted to improve bond strength. It is still difficult for clinicians to choose the best and most efficient strategy for luting GFPs. Clinical studies provide little evidence on the performance of GFPs on which to base clinical decisions, leading clinicians to rely on their clinical experience or on data from *in vitro* studies for choosing a cementation strategy. Therefore, pooled *in vitro* data could provide more solid conclusions on which strategy to use.

The aim of this study was to systematically review the literature for *in vitro* studies comparing the bond strength of GFPs cemented with regular and self-adhesive resin cements and to conduct a descriptive analysis to verify the influence of cementation strategies among studies on the retention of GFPs to intraradicular dentin. The hypothesis tested was that no significant difference in bond strength would be detected between GFPs cemented into root canals with regular resin cements or self-adhesive resin cements.

MATERIAL AND METHODS

Search Strategy

This systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[12] Two electronic databases (Medline and Scopus) were searched to identify articles that met the following inclusion criteria: *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 resin cement and self-adhesive resin cement.

The following strategy was used for the searches: (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 then performed changing the term post for dowel.

Screening and Selection

No publication year or language limit was used, and the last search was done in October 2012. Reference lists of included studies were hand searched for additional articles. Excluded from the investigation were studies including *in vivo* or *in situ* analyses, studies testing posts other than GFPs (ie, carbon-fiber or metal posts), studies with cementation of posts performed in substrates other than teeth (artificial devices), and studies that did not compare bond strength between the two types of resin cements.

Two independent reviewers first screened the titles identified in the searches. If the title indicated possible inclusion, the abstract was then evaluated. After the abstracts were carefully appraised, articles considered eligible for the review were identified; if there was any doubt, the full text of the article was read. In case of disagreement, a third reviewer decided if the article should be included or not (Figure 1).

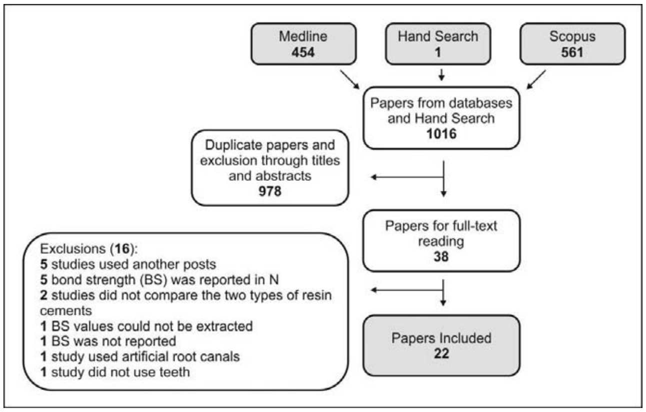

Figure 1. *Selection procedures according to the PRISMA statement.*

Data Collection

Two reviewers extracted all data simultaneously using a standardized outline. To more easily identify variables found in the articles, the authors categorized similar information into two or three groups (eg, cement application mode). In case of measurement of bond strength values for different root thirds (push-out test, for instance), the arithmetic average of the values of the thirds was used. In studies where bond strength test was performed, including other types of cement or post, only the data of interest were extracted.

Assessment of Risk of Bias

Risk of bias was evaluated according to the articles' description of the following parameters for study quality assessment: randomization of teeth, use of teeth free of caries or restoration, use of materials according to the manufacturer's instructions, use of teeth with similar dimensions, endodontic treatment performed by the same operator, description of sample-size calculation, and blinding of the operator of the testing machine. If the authors reported the parameter, the article had a "Y" (yes) on that specific parameter; if it was not possible to find the information, the article received an "N" (no). Articles that reported one to three items were classified as having high risk of bias, four or five items as medium risk of bias, and six or seven items as low risk of bias.

Statistical Analysis

Initially, each possible comparison of the bond strength of regular resin cement and self-adhesive resin cement in each study was carried out; for example, a study using two regular resin cements and four self-adhesive cements resulted in eight possible comparisons. Pooled-effect estimates were obtained by comparing the means of each resin cement and were expressed as the weighted mean difference between groups. A P value $\leq .05$ was considered statistically significant.

Statistical heterogeneity of the treatment effect among studies was assessed using the Cochran's Q test, in which a threshold P value of .1 was considered statistically significant, and the inconsistency I^2 test, in which values greater than 50% were considered indicative of high heterogeneity.[13]

The first global analysis was carried out using a fixed-effect model, and two subgroup analyses were carried out to explore heterogeneity between studies: 1) regular resin cement (etch-and-rinse adhesive) vs self-adhesive resin cement and 2) regular resin cement (self-etch adhesive) vs self-adhesive resin cement. The same analyses were carried out using random-effects models. All analyses were conducted using Review Manager Software version 5.1 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). The influence of cementation strategies among studies on the bond strength of luted GFPs was analyzed using descriptive statistics.

RESULTS

Risk of Bias

Of the 22 studies included, 3 studies presented medium risk of bias and 9 studies showed high risk of bias. The results are described in Table 1, according to the parameters considered in the analysis.

Meta-analysis

Meta-analysis was performed with 23 data sets, although 22 studies were included,[11,14-34] because one study[22] presented two distinct data sets (one from microtensile test and one from push-out test). Characteristics of the 22 studies (23 data sets) are summarized in Table 2. In the global analysis, 148 comparisons were included.

In the first analysis using a fixed-effect model (Figure 2), the self-adhesive resin cements had higher *in vitro* bond strengths (1.25 MPa; $p \leq 0.01$). The values of the Cochran's Q and I^2 tests were $p \leq 0.01$ and 98%. In the subgroup analysis of self-adhesive resin cement vs regular resin cement with etch-and-rinse adhesive, the self-adhesive resin cements had higher bond strengths (0.9 MPa; $p \leq 0.01$). The values of the Cochran's Q and I^2 tests were $p \leq 0.01$ and 98%. In the subgroup analysis of self-adhesive resin cement vs regular resin cement,

Table 1: *Risk of Bias Considering Aspects Reported in the Materials and Methods Section*

	Teeth Randomization	Teeth Free of Caries or Restoration	Materials Used According to the Manufacturer's Instructions	Teeth With Similar Dimensions	Endodontic Treatment Performed by a Single operator	Sample Size Calculation	Blinding of the Operator of the Testing Machine	Risk of Bias
Bitter and others (2009)[11]	Y	N	Y	N	N	N	N	High
Bitter and others (2012)[14]	Y	N	Y	N	N	N	N	High
Calixto and others (2009)[15]	N	N	Y	Y	N	N	N	High
de Durão Mauricio and others (2007)[35]	N	Y	Y	Y	N	N	N	High
Erdemir and others (2010)[19]	Y	Y	Y	N	Y	N	N	Medium
Erdemir and others (2011)[18]	N	N	Y	N	Y	N	N	High
Farina and others (2011a)[16]	N	N	Y	Y	N	N	N	High
Farina and others (2011b)[17]	N	N	Y	Y	N	N	N	High
Goracci and others (2004)[22]	Y	N	Y	N	N	N	N	High
Goracci and others (2005)[21]	Y	N	Y	N	N	N	N	High
Kececi and others (2008)[25]	Y	N	Y	Y	Y	N	N	Medium
Leme and others (2011)[23]	Y	N	N	N	N	N	N	High
Lindblad and others (2010)[24]	Y	N	Y	Y	N	N	N	High
Mumcu and others (2010)[26]	Y	Y	Y	N	Y	N	N	Medium
Radovic and others (2008)[28]	N	N	Y	N	N	Y	N	High
Rathke and others (2009)[27]	N	Y	Y	N	N	N	N	High
Roperto and others (2010)[29]	Y	N	Y	N	N	N	N	High
Sadek and others (2006)[34]	Y	N	N	N	N	N	N	High
Soares and others (2012)[30]	Y	N	Y	Y	N	N	N	High
Xu and others (2011)[32]	Y	N	N	Y	N	N	N	High
Zaitter and others (2011)[31]	Y	N	Y	N	N	N	N	High
Zicari and others (2008)[33]	Y	Y	Y	N	N	N	N	High

Abbreviations: N, no; Y, yes.

the self-adhesive resin cements again had higher bond strengths (1.88 MPa; $p \leq 0.01$). The values of the Cochran's Q and I^2 tests were $p \leq 0.01$ and 96%.

The second global analysis using random-effects model showed no statistically significant difference between groups ($p=0.31$). The values of the Cochran's Q and I^2 tests were $p \leq 0.01$ and 98%. The subgroup analysis of self-adhesive resin cement vs regular resin cement with etch-and-rinse adhesive showed no statistically significant difference be-

Table 2:

Article	Pretreatment of Post	Bonding Agent	Cement	Cement Application	Aging/ Storage	Bond Strength	
Bitter and others (2009)[11]	37% phosphoric acid	ED Primer (one-step, self-etch)	Panavia F 2.0 (dual-cure, self-etch)	Not found*	24 h of water storage at 37°C	13.3 MPa	
		PermaFlo DC Primers (three-step, etch-and-rinse)	PermaFlo DC (dual-cure, regular)			9.9 MPa	
		Excite DSC (two-step, etch-and-rinse)	Variolink II (dual-cure, regular)			9.5 MPa	
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)			20.4 MPa	
		New Bond (two-step, etch-and-rinse)	Clearfil Core (dual-cure, regular)			14.9 MPa	
Bitter and others (2012)[14]						**Before Aging**	**After Aging**
	.	ED Primer (one -step, self-etch)	Panavia F 2.0 (dual-cure, self-etch)	Around the post and into the root canal	Stored 7 d in water and after 5000 thermal cycles (58°C/ 558°C, 2 min each cycle) and 1.2 × 106 mastication cycles	13.2 Mpa	3.5 Mpa
	.	Excite DSC (two-step, etch-and-rinse)	Variolink II (dual-cure, regular)	Around the post and into the root canal	Stored 7 days in water and after 5000 thermal cycles (58°C/558°C, 2 min each cycle) and 1.2 × 106 mastication cycles	13.2 Mpa	4.8 Mpa
	.	No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Into the root canal with tip attached to the cement capsule	Stored 7 days in water and after 5000 thermal cycles (58°C/558°C, 2 min each cycle) and 1.2 × 106 mastication cycles	18.3 Mpa	9.8 Mpa
Calixto and others (2009)[15]						**Quartz-ungsten-halogen unit**	
	37% phosphoric acid + silane + bond	ScotchBond Multi-Purpose (three-step, etch-and-rinse)	RelyX ARC (dual-cure, regular)	Around the post and into the root canal	Stored in distilled water for 24 h at 37°C	9.6 Mpa	
	37% phosphoric acid + silane + bond	ED Primer (one -step, self-etch)	Panavia F 2.0 (dual-cure, self-etch)			8.4 Mpa	
	37% phosphoric acid + silane + bond	No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)			6.3 Mpa	
						Light-emitting -diode	
	37% phosphoric acid + silane	ScotchBond Multi-Purpose (three-step, etch-and-rinse)	RelyX ARC (dual-cure, regular)			8.8 Mpa	
	37% phosphoric acid + silane	ED Primer (one -step, self-etch)	Panavia F 2.0 (dual-cure, self-etch)			8.2 Mpa	

Table 2: Continued.

Article	Pretreatment of Post	Bonding Agent	Cement	Cement Application	Aging/ Storage	Bond Strength
	37% phosphoric acid + silane	No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)			6.3 Mpa
de Durão Mauricio and others (2007)[35]	Ethanol + silane	ED Primer (one -step, self-etch)	Panavia F 2.0 (dual-cure, self-etch)	Around the post	None	21.8 MPa
		All Bond 2 (three-step, etch-and-rinse)	C&B Cement (self-cure, regular)	.		15.7 MPa
		Multilink Primer (one-step, self-etch)	Multilink (dual-cure, regular)	Around the post		21.9 MPa
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Around the post		12.2 MPa
		Excite DSC (tqo-step, etch-and-rinse)	Variolink II (dual-cure, regular)	Around the post		22.2 MPa
Erdemir and others (2010)[19]	Ethanol	ED Primer (one -step, self-etch)	Panavia F 2.0 (dual-cure, self-etch)	Around the post	(TC; 5°C/55°C, 5000 cycles; dwell time, 30 s	9.8 MPa
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Into the root canal with tip attached to the cement capsule		8.9 MPa
		Single Bond (two-step, etch-and-rinse)	RelyX Unicem (dual-cure, self-adhesive)	Into the root canal with tip attached to the cement capsule		8.1 MPa
Erdemir and others (2011)[18]	Ethanol	ED Primer (one-step, self-etch)	Panavia F 2.0 (dual-cure, self-etch)	Around the post	Distilled water for 7 days at 37°C	8.8 MPa
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Around the post		9.5 MPa
		No bonding agent used	Maxcem Elite (dual-cure, self-adhesive)	Around the post		8 MPa
		Adper Prompt L-Pop (one-step, self-etch)	RelyX Unicem (dual-cure, self-adhesive)	Around the post		9.9 MPa
		Obtibond all-in-one (one-step, self-etch)	Maxcem Elite (dual-cure, self-adhesive)	Around the post		8.2 MPa
Farina and others (2011a)[16]	37% phosphoric acid for 5 s + silane	Adper Scotchbond Multi-Purpose (three-step, etch-and-rinse)	Cement-Post (self-cure, regular)	Into the root canal with lentulo drill	None	3.3 MPa
		No bonding agent used	Rely-X Unicem (dual-cure, self-adhesive)	Into the root canal with lentulo drill		8.1 MPa
Farina and others (2011b)[17]	37% phosphoric acid for 5 s + silane	Adper Scotchbond Multi-Purpose (three-step, etch-and-rinse)	Cement-Post (self-cure, regular)	Into the root canal with lentulo drill	None	3.3 MPa

Table 2: Continued.

Article	Pretreatment of Post	Bonding Agent	Cement	Cement Application	Aging/ Storage	Bond Strength	
		No bonding agent used	Rely-X Unicem (dual-cure, self-adhesive)	Into the root canal with lentulo drill		8.1 MPa	
Goracci and others (2004)[22]	Not found	Excite DSC (two-step, etch-and-rinse)	Variolink II (dual-cure, regular)	Into the root canal with lentulo drill	One wk in water	6.8 MPa	
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Around the post		5 MPa	
Goracci and others (2005)[21]	Ethanol + silane	Excite DSC (two-step, etch-and-rinse)	Variolink II (dual-cure, regular)	Into the root canal with lentulo drill	None	10.1 Mpa	
		ED Primer (one-step, self-etch)	Panavia 21 (self-cure, self-etch)	Around the post		5 MPa	
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Around the post		5 MPa	
Goracci and others (2004)[22]	Not found	Excite DSC (two-step, etch-and-rinse)	Variolink II (dual-cure, regular)	Into the root canal with lentulo drill	One wk in water	12.3 MPa	
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Around the post		9.1 MPa	
Kececi and others (2008)[25]						**FRC Postec Plus**	**Ever-stick**
	Ethanol + silane	Excite DSC (two-step, etch-and-rinse)	Variolink II (dual-cure, regular)	Around the post and into the root canal	None	3.7 MPa	3 MPa
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)			2.7 MPa	1.9 MPa
Leme and others (2011)[23]						**One Mo**	**Nine Mo**
	37% phosphoric acid for 60 s + silane	Scotchbond Multi-Purpose Plus (three-step, etch-and-rinse)	RelyX ARC (dual-cure, regular)	Around the post and into the root canal	Stored in a light-proof container with 100% humidity at 37°C for 1 or 9 mo. The liquid used for 100% humidity aging was 0.9% thymol solution	2.5 MPa	1.3 MPa
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Into the root canal with tip attached to the cement capsule		5.4 MPa	3.9 MPa
Lindblad and others (2010)[24]						**With Chlorhex-idine**	**Without Chlorhex-idine**
	All-Bond Primer B	All-Bond 2 (three-step, etch-and-rinse, dual cure)	Duo-link cement (dual-cure, regular)	Not found*	Stored in artificial saliva in 37°C for 3–7 d	6.6 MPa	5 MPa
	None	PermaFlo DC Primers (three-step, etch-and-rinse)	PermaFlo DC (dual-cure, regular)	Not found*		12.6 MPa	11.5 MPa

Table 2: Continued.

Article	Pretreatment of Post	Bonding Agent	Cement	Cement Application	Aging/ Storage	Bond Strength	
	None	No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Into the root canal with tip attached to the cement capsule		12.8 MPa	11.2 MPa
Mumcu and others (2010)[26]	Ethanol	ED Primer (one1-step, self-etch)	Panavia F 2.0 (dual-cure, self-etch)	Around the post	Distilled water for 7 days at 37°C	10.6 MPa	
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Into the root canal with tip attached to the cement capsule		10.6 MPa	
		No bonding agent used	Maxcem (dual-cure, self-adhesive)	Into the root canal with tip attached to the cement capsule		10.2 MPa	
Radovic and others (2008)[28]	Ethanol + silane	XPBond (two-step, etch-and-rinse)	Calibra resin cement (dual-cure, regular)	Around the post and into the root canal	None	12.7 MPa	
	Ethanol	XPBond (two-step, etch-and-rinse)	FluoroCore 2 (dual-cure, regular)	Around the post		8.1 MPa	
	34% phosphoric acid + Silane	Excite DSC (two-step, etch-and-rinse)	MultiCore Flow (dual-cure, regular)	Around the post		11.1 MPa	
	Ethanol	ED primer (one-step, self-etch)	Panavia F 2.0 (dual-cure, self-etch)	Around the post		8.7 MPa	
	Ethanol	No bonding agent used	Experimental self-adhesive cement (dual-cure, self-adhesive)	Into the root canal with tip attached to the cement capsule		10.6 MPa	
	Ethanol	No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Into the root canal with tip attached to the cement capsule		12.5 MPa	
Rathke and others (2009)[27]						**With Silane**	**Without Silane**
	Ethanol in all specimens and in half of it, silane	Prime & Bond NT (two-step, etch-and-rinse)	Dyract Cem Plus (self-cure, self-adhesive)	Not found*	None	19.3 MPa	22.2 MPa
		Excite DSC (two-step, etch-and-rinse)	Variolink II (dual-cure, regular)			29.7 MPa	32.4 MPa
		ED Primer II (one-step, self-etch)	Panavia F 2.0 (dual-cure, self-etch)			22.2 MPa	23.4 MPa
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)			23.1 MPa	24.7 MPa
Roperto and others (2010)[29]						**EverStick**	**Reforpost**
	Immersed in 24% H_2O_2 for 10 min + silane	Clearfil SE Bond (two-step, self-etch)	Panavia F 2.0 (dual-cure, self-etch)	Around the post	Stored in water at 37°C and thermocycled for 3000 cycles (5°C to 55°C) for 60 s in each water bath	12.66 Mpa	11.2 Mpa

Table 2: Continued.

Article	Pretreatment of Post	Bonding Agent	Cement	Cement Application	Aging/ Storage	Bond Strength	
		No bonding agent used	Rely-X Unicem (dual-cure, self-adhesive)			11.09 Mpa	9.25 Mpa
		No bonding agent used	MaxCem (dual-cure, self-adhesive)			10.09 Mpa	6.46 Mpa
		No bonding agent used	BisCem (dual-cure, self-adhesive)			12.03 Mpa	8.89 Mpa
Sadek and others (2006)[34]						**Immediate**	**After 24 h**
	Ethanol + silane	All Bond 2 (three-step, etch-and-rinse)	Duo Link (dual-cure, regular)	Around the post	Immediate and after 24 h	5.6 MPa	7.9 MPa
		Optibond Solo Plus (two-step, etch-and-rinse)	Nexus 2 (dual-cure, regular)	Around the post		8.6 MPa	12.0 MPa
		Multilink Primer (one-step, self-etch)	Multilink (dual-cure, regular)	Around the post		8.3 MPa	11.0 MPa
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Around the post		5.1 MPa	9.2 MPa
Soares and others,(2012)[30]	Ethanol + silane	Scotchbond Multi-Purpose Plus (three-step, etch-and-rinse)	RelyX ARC (dual-cure, regular)	Into the canal	Distilled water for 24 h at 37°C	7.1 Mpa	
		Scotchbond Multi-Purpose Plus (three-step, etch-and-rinse)	Cement-Post (self-cure, regular)	Into the canal	Distilled water for 24 h at 37°C	8.7 Mpa	
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Into the canal	Distilled water for 24 h at 37°C	13.8 Mpa	
		No bonding agent used	Maxcem Elite (dual-cure, self-adhesive)	Into the canal	Distilled water for 24 h at 37°C	3.9 Mpa	
		Scotchbond Multi-Purpose Plus (three-step, etch-and-rinse)	RelyX ARC (dual-cure, regular)	Into the canal	Distilled water for 24 h at 37°C	7.3 Mpa	
		Scotchbond Multi-Purpose Plus (three-step, etch-and-rinse)	Cement-Post (self-cure, regular)	Into the canal	Distilled water for 24 h at 37°C	8.7 Mpa	
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Into the canal	Distilled water for 24 h at 37°C	13.4 Mpa	
		No bonding agent used	Maxcem Elite (dual-cure, self-adhesive)	Into the canal	Distilled water for 24 h at 37°C	4.2 Mpa	
Xu and others (2011)[32]						**Monobond - S (Silane)**	**Porcela - Bond Activator (Silane)**
	Silane	No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Not found*	None	9.5 Mpa	14.8 Mpa

Table 2: Continued.							
Article	**Pretreatment of Post**	**Bonding Agent**	**Cement**	**Cement Application**	**Aging/ Storage**	**Bond Strength**	
		ED Primer (one-step, self-etch)	Panavia F (dual-cure,self-etch)			8.6 Mpa	9.8 Mpa
		All Bond 2 (three-step, etch-and-rinse)	Duo-Link (dual-cure, regular)			5.2 Mpa	5.7 Mpa
Zaitter and others (2011)[31]						**Exacto**	**Everstick**
	Immersed in 24% hydrogen peroxide for 10 min and two layers of silane-coupling agent	Clearfil-SE Bond (two-step, self-etch)	Panavia F (dual-cure, regular)	Into the root canal with lentulo drill	Thermocycled 1000 times in water baths between 5°C and 55°C and stored in distilled water at 37°C for 30 d	10.3 MPa	25.9 MPa
		Clearfil-SE Bond (two-step, self-etch)	NAC-100 (dual-cure, self-etch)			14 MPa	29.1 MPa
		No bonding agent used	BisCem (dual-cure, self-adhesive)			16.4 MPa	28.9 MPa
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)			19.8 MPa	30.5 MPa
Zicari and others (2008)[33]	Ethanol	ED Primer (one-step, self-etch)	Panavia 21 (self-cure, self-etch)	Into the root canal with centrix syringe	1 wk of water storage at 37°C	12.6 Mpa	
		ED Primer II (one-step, self-etch)	Clearfil Esthetic Cement (dual-cure, regular)	Into the root canal with centrix syringe		14.6 MPa	
		Excite DSC (two-step, etch-and-rinse)	Variolink II (dual-cure, regular)	Into the root canal with centrix syringe		11.1 MPa	
		No bonding agent used	RelyX Unicem (dual-cure, self-adhesive)	Into the root canal with tip attached to the cement capsule		11.3 MPa	
		No bonding agent used	GC (dual-cure, self-adhesive)	Into the root canal with tip attached to the cement capsule		7.6 MPa	

tween groups (p=0.41). The values of the Cochran's Q and I^2 tests were $p \leq 0.01$ and 98%. The subgroup analysis of self-adhesive resin cement vs regular resin cement with self-etch adhesive showed no statistically significant difference between groups (p=0.63). The values of the Cochran's Q and I^2 tests were $p \leq 0.01$ and 96%.

Descriptive Analysis

From the studies included in the review, a total of 47 experimental groups testing regular resin cements were detected, including 13 studies using Panavia F 2.0 (Kuraray, Osaka, Japan) and eight studies using Variolink II (Ivoclar Vivadent, Schann, Liechtenstein). A total of 39 experimental groups testing self-adhesive resin cements were detected, including 27 studies with RelyX Unicem (3M ESPE, St Paul, MN, USA).

Several attempts to verify how pretreating the post influenced bond strength results were used: cleaning with ethanol,[18,19,26,33] silane application,[15-19,21,23,25-28,30-33,34,35] use of acids,[11] or even no pretreatment of the post.[14] Although no statistical analysis was performed, the retention of GPFs that had been pretreated with silane seemed to be higher compared with posts that were not pretreated or that were pretreated with other products.

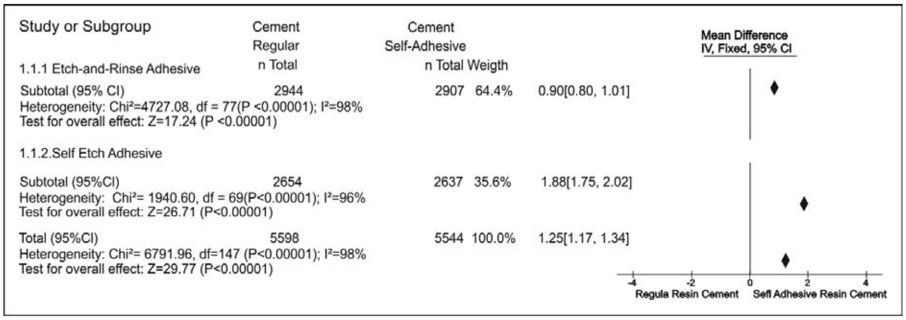

Figure 2. *Results for analysis using fixed-effect model. The analysis 1.1.1 represents the subgroup analysis between self-adhesive resin cement vs regular resin cement with etch-and-rinse adhesive, while the analysis 1.1.2 represents the subgroup analysis between self-adhesive resin cement vs regular resin cement with self-etch adhesive. The total analysis stands for the global results.*

Application of the resin cement was performed using three different approaches: inserting the cement into the root canal, inserting the cement around the post, or inserting the cement into the root canal and around the post. The studies that used mixed techniques showed lower bond strength values.[17,26,30] In two studies that did not perform endodontic treatment before luting,[23,25] the bond strength results were similar or higher than those for studies in which endodontic treatment was performed.

Each study used its own protocol for aging and storing the samples, including storage for 1 week in water,[18,22,26,33] storage in a light-proof container with 100% humidity at 37°C for 9 months,[23] or storage in water at 37°C + 3000 thermal cycles (between 5°C and 55°C) for 60 seconds in each water bath with a 6-second dwell time.[29] The overall results did not seem to be influenced by the aging protocol.

The type of post cementation failure was not taken into consideration in our analyses, that is, adhesive between the post and cement versus adhesive between the dentin and cement or cohesive within the different types of cement because of the wide variation between the classifications of failure modes in the different studies included. In the same way, we performed no statistical analysis regarding how different types of post pretreatment affected their retention because there were many confounding factors that could influence the results based on the heterogeneity among the studies.

DISCUSSION

This systematic review and meta-analysis is the first to verify the pooled effect of data from *in vitro* studies that tested the retention of GFPs using resin cements. Several cementation strategies and different bond strength tests were used; more consistent results could be obtained if data were analyzed together, giving support for the clinician on evidence-based decision-making.

The global result (regular vs self-adhesive resin cement) using a fixed-effect model favored the use of self-adhesive resin cement. This result could be explained by the different characteristics of the resin cements. The most commonly used self-adhesive resin cement was RelyX Unicem (3M ESPE),[7] which has adhesive properties based on acid monomers that demineralize and infiltrate the tooth substrate, creating micromechanical retention and chemical bonding to hydroxyapatite.[7] The water resulting from the acid-base interactions may improve the tooth-cement interaction and the cement moisture tolerance.[36,37] The consequent use of water available in the cement matrix and ionization of residual acidic methacrylates culminates in transformation to a hydrophobic material with neutral pH values.[7] In addition, the higher bond strength of self-adhesive cements may be a result of the lower polymerization stress compared with regular resin cements.[38] The high C-factor and the conical shape of the root canal are critical for the development of polymerization stress; thus, cements with higher stress values may present poorer bonding to the canal walls. Although the hypothesis was rejected, it is important to highlight that the study was conducted using *in vitro* studies (see the Limitations of the Study section).

Our analysis also demonstrated high heterogeneity (98%); thus, the subgroup analysis was carried out to verify the influence of the adhesive used (etch-and-rinse or self-etch) with regular resin cements in the heterogeneity. The two subgroup analyses favored the use of self-adhesive resin cement. Regular resin cements require multiple bonding steps compared with self-adhesive materials. Etch-and-rinse adhesives require an accurate technique mainly concerning the control of dentin moisture and proper infiltration of the adhesive solution into the root canal, a procedure that might be considered critical and might affect post retention. The etch-and-rinse approach has been also reported to leave a non-encapsulated collagen zone beneath the hybrid layer, which could interfere with the longevity of the bonds.

The rationale of using self-etch adhesives and self-adhesive cements is based on the same principle of dental demineralization and simultaneous infiltration by methacrylate monomers. The bonding mechanism of these adhesive techniques has been linked to an additional chemical bond to tooth structures; the self-etch and self-adhesive strategies, however, have the same possible problem of poorer surface conditioning. Interestingly, the two subgroup analyses favored the use of self-adhesive resin cement; a possible explanation for these results is twofold. On the one hand, application of self-etch solutions into root canals is more complex than self-adhesive cements, particularly regarding proper solvent evaporation, excess adhesive removal, and photopolymerization in the apical areas. On the other hand, some studies use strong self-etch adhesives, which might lead to deposition of calcium phosphates on dentin that are not rinsed and are very unstable in an aqueous environment, thus interfering with the interfacial integrity and bonding ability.[7,39] Compared with the use of regular resin cements associated with conventional or self-etch adhesives, the self-adherence potential and dual-cure mechanism of self-adhesive resin cements seems to improve the bonding of GFPs into the confines of the root canal.

Nevertheless, the subgroup analyses showed high heterogeneity because there are great differences among studies. The articles included in this review demonstrated differences, particularly in such aspects as aging or storage of samples, cement application mode, and approaches used to pretreat the posts. The variability related to multiple steps in the bonding process could increase the retention of GFPs to intraradicular dentin in some cases; in other cases, however, the multiple steps might just make the procedures harder and more time consuming. In addition, the included studies generally had a small number of samples and consequently high standard deviation, favoring heterogeneity. This finding made it hard to identify the reasons and variables that influenced the high heterogeneity.

The global result (regular vs self-adhesive resin cement) using a random-effects model showed no difference between resin cements, although the data remained with high heterogeneity (98%). The subgroup analyses were carried out to verify the influence of the adhesive used (etch-and-rinse or self-etch) with regular resin cement in the heterogeneity. The results demonstrated no difference between groups and high heterogeneity, confirming the differences between methodologies used in the studies included in the review. This finding made it hard to identify the reasons and variables that influenced the high heterogeneity. Furthermore, the parameters the authors developed to assess risk of bias showed that the studies included had high or medium risk of bias, thus demonstrating that the variables that could influence the results of the studies were not controlled by researchers favoring the high heterogeneity of the findings of this study.

Yet, post debonding has been described as the most common mode of failure *in vitro*,[4] and this type of failure can be more related to inappropriate bonding techniques than to problems inherent to the materials themselves. The bonding techniques using either regular or self-adhesive resin cements can still be regarded as good options for the luting of GFPs into root canals. The use of self-adhesive resin cements, however, appears to be a suitable and perhaps less technique-sensitive option than luting strategies that involve pretreating the canals with adhesive solutions.

To date the literature has no clinical studies comparing different cementation strategies for GFPs, and clinical studies with self-adhesive resin cements are still scarce. The few clinical studies available[40,41] using regular or self-adhesive resin cements to lute GFPs show high survival rates in the short term. The differences between resin cements shown by *in vitro* studies could be clinically irrelevant, but longer clinical follow-ups are not available.

Limitations of the Study

The results of the present review should be interpreted with caution because laboratory studies have intrinsic limitations when trying to simulate *in vivo* conditions. In addition, there was a predominance of one particular self-adhesive resin cement (RelyX Unicem) in the studies included, and this should be taken into account when comparing regular resin cements with other self-adhesive cements. Well-designed randomized controlled trials with long follow-up periods are needed to provide the ultimate answer as to whether self-adhesive resin cement will result in improved clinical success rates compared with regular resin cements.

CONCLUSION

Although the articles included in this meta-analysis showed high heterogeneity and high risk of bias, the *in vitro* literature seems to suggest that the use of self-adhesive resin cement could improve the retention of GFPs into root canals.

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Conflict of Interest

The authors of this article 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.

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REFERENCES

1. Naumann M, Koelpin M, Beuer F, & Meyer-Lueckel H (2012) 10-year survival evaluation for glass-fiber-supported postendodontic restoration: A prospective observational clinical study *Journal of Endodontics* **38(4)** 432-435.
2. Giachetti L, Grandini S, Calamai P, Fantini G, & Scaminaci Russo D (2009) Translucent fiber post cementation using light- and dual-curing adhesive techniques and a self-adhesive material: Push-out test *Journal of Dentistry* **37(8)** 638-642.
3. Silva NR, Castro CG, Santos-Filho PC, Silva GR, Campos RE, Soares PV, & Soares CJ (2009) Influence of different post design and composition on stress distribution in maxillary central incisor: Finite element analysis *Indian Journal of Dental Research* **20(2)** 153-158.
4. Rasimick BJ, Wan J, Musikant BL, & Deutsch AS (2010) A review of failure modes in teeth restored with adhesively luted endodontic dowels *Journal of Prosthodontics* **19(8)** 639-646.
5. Ferrari M, Vichi A, Fadda GM, Cagidiaco MC, Tay FR, Breschi L, Polimeni A, & Goracci C (2012) A randomized controlled trial of endodontically treated and restored premolars *Journal of Dental Research* **91(Supplement 7)** S72-S78.
6. Signore A, Benedicenti S, Kaitsas V, Barone M, Angiero F, & Ravera G (2009) Long-term survival of endodontically treated, maxillary anterior teeth restored with either tapered or parallel-sided glass-fiber posts and full-ceramic crown coverage *Journal of Dentistry* **37(2)** 115-121.
7. Ferracane JL, Stansbury JW, & Burke FJ (2011) Self-adhesive resin cements—Chemistry, properties and clinical considerations *Journal of Oral Rehabilitation* **38(4)** 295-314.
8. Piovesan EM, Demarco FF, Cenci MS, & Pereira-Cenci T (2007) Survival rates of endodontically treated teeth restored with fiber-reinforced custom posts and cores: A 97-month study *International Journal of Prosthodontics* **20(6)** 633-639.
9. Naumann M, Blankenstein F, & Dietrich T (2005) Survival of glass fibre reinforced composite post restorations after 2 years—An observational clinical study *Journal of Dentistry* **33(4)** 305-312.
10. Salas MM, Bocangel JS, Henn S, Pereira-Cenci T, Cenci MS, Piva E, & Demarco FF (2011) Can viscosity of acid etchant influence the adhesion of fibre posts to root canal dentine? *International Endodontic Journal* **44(11)** 1034-1040.
11. Bitter K, Paris S, Pfuertner C, Neumann K, & Kielbassa AM (2009) Morphological and bond strength evaluation of different resin cements to root dentin *European Journal of Oral Science* **117(3)** 326-333.
12. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JP, Clarke M, Devereaux PJ, Kleijnen J, & Moher D (2009) The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration *British Medical Journal* **339** b2700.
13. Higgins JPT, & Green S (2009) Cochrane handbook for systematic reviews of interventions; Retrieved online March 2, 2013 from: http://www.cochrane-handbook.org2009
14. Bitter K, Perdigao J, Exner M, Neumann K, Kielbassa A, & Sterzenbach G (2012) Reliability of fiber post bonding to root canal dentin after simulated clinical function in vitro *Operative Dentistry* **37(4)** 397-405.
15. Calixto LR, Bandéca MC, Silva FB, Rastelli ANS, Porto-Neto ST, & Andrade AM (2009) Effect of light curing units on push out fiber post bond strength in root canal dentin *Laser Physics* **19(8)** 1867-1871.
16. Farina AP, Cecchin D, Garcia Lda F, Naves LZ, Sobrinho LC, & Pires-de-Souza Fde C (2011) Bond strength of fiber posts in different root thirds using resin cement *Journal of Adhesive Dentistry* **13(2)** 179-186.
17. Farina AP, Cecchin D, Garcia Lda F, Naves LZ, & Pires-de-Souza Fde C (2011) Bond strength of fibre glass and carbon fibre posts to the root canal walls using different resin cements *Australian Endodontic Journal* **37(2)** 44-50.
18. Erdemir U, Sar-Sancakli H, Yildiz E, Ozel S, & Batur B (2011) An in vitro comparison of different adhesive strategies on the micro push-out bond strength of a glass fiber post *Medicina Oral Patologia Oral y Cirugia Bucal* **16(4)** e626-e634.
19. Erdemir U, Mumcu E, Topcu FT, Yildiz E, Yamanel K, & Akyol M (2010) Micro push-out bond strengths of 2 fiber post types luted using different adhesive strategies *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **110(4)** 534-544.

20. PJ, de Durao Mauricio Gonzalez-Lopez S, Aguilar-Mendoza JA, Felix S, & Gonzalez-Rodriguez MP (2007) Comparison of regional bond strength in root thirds among fiber-reinforced posts luted with different cements *Journal of Biomedical Materials Research Part B: Applied Biomaterials* **83(2)** 364-372.
21. Goracci C, Sadek FT, Fabianelli A, Tay FR, & Ferrari M (2005) Evaluation of the adhesion of fiber posts to intraradicular dentin *Operative Dentistry* **30(5)** 627-635.
22. Goracci C, Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso PC, Tay F, & Ferrari M (2004) The adhesion between fiber posts and root canal walls: Comparison between microtensile and push-out bond strength measurements *European Journal of Oral Sciences* **112(4)** 353-361.
23. Leme AA, Coutinho M, Insaurralde AF, Scaffa PM, & da Silva LM (2011) The influence of time and cement type on push-out bond strength of fiber posts to root dentin *Operative Dentistry* **36(6)** 643-648.
24. Lindblad RM, Lassila LV, Salo V, Vallittu PK, & Tjaderhane L (2010) Effect of chlorhexidine on initial adhesion of fiber-reinforced post to root canal *Journal of Dentistry* **38(10)** 796-801.
25. Kececi AD, Ureyen Kaya B, & Adanir N (2008) Micro push-out bond strengths of four fiber-reinforced composite post systems and 2 luting materials *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **105(1)** 121-128.
26. Mumcu E, Erdemir U, & Topcu FT (2010) Comparison of micro push-out bond strengths of two fiber posts luted using simplified adhesive approaches *Dental Materials Journal* **29(3)** 286-296.
27. Rathke A, Haj-Omer D, Muche R, & Haller B (2009) Effectiveness of bonding fiber posts to root canals and composite core build-ups *European Journal of Oral Science* **117(5)** 604-610.
28. Radovic I, Mazzitelli C, Chieffi N, & Ferrari M (2008) Evaluation of the adhesion of fiber posts cemented using different adhesive approaches *European Journal of Oral Science* **116(6)** 557-563.
29. Roperto RC, El-Mowafy O, Porto-Neto ST, & Marchesan MA (2010) Microtensile bond strength of radicular dentin to non-metallic posts bonded with self-adhesive cements *International Journal of Clinical Dentistry* **3(2)** 73-80.
30. Soares CJ, Pereira JC, Valdivia ADCM, Novais VR, & Meneses MS (2012) Influence of resin cement and post configuration on bond strength to root dentine *International Endodontic Journal* **45(2)** 136-145.
31. Zaitter S, Sousa-Neto MD, Roperto RC, Silva-Sousa YT, & El-Mowafy O (2011) Microtensile bond strength of glass fiber posts cemented with self-adhesive and self-etching resin cements *Journal of Adhesive Dentistry* **13(1)** 55-59.
32. Xü N, Hu SH, Yang Y, Ren X, & Zuo EJ (2011) Effect of different resin cements and silane coupling agents on bond strength of glass fiber post to root dentin *Journal of Dalian Medical University* **33(4)** 321-324, 329.
33. Zicari F, Couthino E, De Munck J, Poitevin A, Scotti R, Naert I, & Van Meerbeek B (2008) Bonding effectiveness and sealing ability of fiber-post bonding *Dental Materials* **24(7)** 967-977.
34. Sadek FT, Goracci C, Monticelli F, Grandini S, Cury ÁH, Tay F, & Ferrari M (2006) Immediate and 24-hour evaluation of the interfacial strengths of fiber posts *Journal of Endodontics* **32(12)** 1174-1177.
35. PJBT, Mauricio De Durão Gonzalez-Lopez S, Aguilar-Mendoza JA, Félix S, & González-Rodríguez MP (2007) Comparison of regional bond strength in root thirds among fiber-reinforced posts luted with different cements *Journal of Biomedical Materials Research - Part B Applied Biomaterials* **83(2)** 364-372.
36. Forberger N, & Gohring TN (2008) Influence of the type of post and core on in vitro marginal continuity, fracture resistance, and fracture mode of lithia disilicate-based all-ceramic crowns *Journal of Prosthetic Dentistry* **100(4)** 264-273.
37. Bitter K, Meyer-Lueckel H, Priehn K, Kanjuparambil JP, Neumann K, & Kielbassa AM (2006) Effects of luting agent and thermocycling on bond strengths to root canal dentine *International Endodontic Journal* **39(10)** 809-818.
38. Frassetto A, Navarra CO, Marchesi G, Turco G, Di Lenarda R, Breschi L, Ferracane JL, & Cadenaro M (2012) Kinetics of polymerization and contraction stress development in self-adhesive resin cements *Dental Materials* **28(9)** 1032-1039.
39. Van Meerbeek B, Yoshihara K, Yoshida Y, Mine A, De Munck J, & Van Landuyt KL (2011) State of the art of self-etch adhesives *Dental Materials* **27(1)** 17-28.
40. Sterzenbach G, Franke A, & Naumann M (2012) Rigid versus flexible dentine-like endodontic posts—clinical testing of a biomechanical concept: Seven-year results of a randomized controlled clinical pilot trial on endodontically treated abutment teeth with severe hard tissue loss *Journal of Endodontics* **38(12)** 1557-1563.
41. Zicari F, Van Meerbeek B, Debels E, Lesaffre E, & Naert I (2011) An up to 3-year controlled clinical trial comparing the outcome of glass fiber posts and composite cores with gold alloy-based posts and cores for the restoration of endodontically treated teeth *International Journal of Prosthodontics* **24(4)** 363-372.