IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 21, Issue 2 Ser.13 (February. 2022), PP 16-23
www.iosrjournals.org

Influence of Cementation Technique on the Bond Strength of Glass Fiber Dowels to Root Canal Dentin

Aya Khairy Abd ELwahed Fayed [a], Mohamed Farag Ayad[b], Mohamed Seddik Mohamed kamel Seddik[c]
[a]*Tanta University, 3111, Tanta, Egypt*
[b]*Professor of Fixed Prosthodontics, Faculty of Dentistry, Tanta University, 3111, Tanta, Egypt*
[c]*Lecturer of Fixed Prosthodontics, Faculty of Dentistry, Tanta University, 3111, Tanta, Egypt*

Abstract
Statement of problem: *Successful treatment of badly broken teeth depends on good endodontic therapy and prosthetic reconstruction. Dowel cementation helps in retention of the prosthetic restoration and protect the remaining tooth structure, however the efficiency of dentin bonding is still questionable.*
Purpose: *The purpose of this in-vitro study was to evaluate the bond strength of glass fiber dowels to root canal dentin using 3 different cementation techniques.*
Material and methods: *30 human extracted lower premolars with approximately similar dimensions were selected. The coronal part of each tooth was removed, and the remaining root received endodontic therapy. Root canals were prepared with a dowel space of 10-mm and equally divided into three groups (n=10) according to the cementation technique used to cement a glass fiber-reinforced dowels: total-etch (Variolink N, NX3), self-etch (Panavia F 2.0, Duolink), or self-adhesive (Calibra, GCem) with five specimens for each cement. Each root was sectioned horizontally into apical, middle, cervical third. 1-mm thick slice was made for each root third under water cooling using Isomet saw. Bond strength between dowel and root canal dentin was measured using push-out test in a universal testing machine. Data were analyzed with 1-way ANOVA followed Tukey's hoc multiple comparison test (α = 0.05).*
Results: *Push-out bond strength values were significantly different among cements and regions of the root canal (p < 0.001), however, their interaction was not significantly different (p = 0.915). Total-etch Variolink N cement had higher mean bond strength and the lower mean bond strength were found for self-adhesive Calibra cement with all regions of the root canal.*
Conclusions: *The technique of cement used had a significant effect on the bond strength of glass dowels to root canal dentin.*
Clinical implications: *The best adhesive capability is obtained when total-etch resin cement are used with glass fiber dowels, allowing high bond strength to root canal dentin. However, self-etch system could be the option of choice because it had simple application.*

Date of Submission: 08-02-2022 Date of Acceptance: 22-02-2022

I. Introduction

Restoration of endodontically treated teeth has been widely discussed in dental literature. The substantial loss of coronal tooth structure due to caries, fracture and access preparations enhance complications of restoring endodontically treated teeth and reduce resistance to fracture and hence these teeth require coronal-radicular stabilization.[1] To provide retention and resistance form for the restoration, dowel placement is advocated[1].

Compared to metallic dowels with high stress concentrations at the dowel dentin interface and more prone to fatigue, failure and corrosion, fiber-reinforced composite dowel systems are highly preferred by several authors to avoid root fractures because its modulus of elasticity is close to that of dentin, producing a stress field similar to that of natural teeth. Unidirectional quartz or glass fibers are enclosed in a resin matrix in order to improve its mechanical strength[2,3].

Using the current adhesive techniques, when dowels are bonded well to the tooth along with the resin cement, a monoblock type of restoration is achieved. Compared to conventional cement, the retentive effect of adhesive cement improves marginal adaptation, retention, fracture resistance, relieves stresses within the root and optimizes fracture patterns in relation to re-restoration[4].

Nowadays, there are three systems of adhesive resin cement used for fiber dowel cementation available in dental market: total-etch (etch and rinse), self-etch, and self-adhesive systems. The total-etch adhesive system is very sensitive in its use because of many factors, such as etching acid concentration, application time, and rinsing and drying procedures. The self-etch adhesive system is easier to apply and contains acidic primer, which acts as etch and primer, without rinsing and drying procedures. However, self-adhesive system does not require any treatment of tooth structure[5,6].

Tensile or shear bond strength, pull out or push out bond strength were used to evaluate dowel adhesion. It has been suggested that push out test provides better evaluation of bond strength because fracture occurs parallel to dentin bonding interface and less sensitive to small variations among specimens and to the variations in stress distribution during load application7.

II. Material And Methods

Specimen selection

Thirty single-rooted freshly extracted human lower premolars were selected from adult patients in the out clinic of Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Tanta University suffering from loosening of their teeth due to severe periodontal disease or uncontrolled diabetes. The purpose of the present study was explained to the patients and informed consents were obtained to use their teeth in the research according to the guidelines on human research adopted by the Research Ethics Committee at Faculty of Dentistry, Tanta University. The inclusion criteria includes, fully developed apices and approximately similar size and shape. The teeth were stored in distilled water with 0.1% thymol disinfectant at room temperature until use.

Specimen preparation

To standardize the root canal length, the coronal part of each tooth was sectioned 15 ± 1 mm coronally from the root apex using the Isomet sawTM) Buehler, An ITW Company, USA) under water cooling. The roots were embedded in self-cure acrylic resin blocks) Acrostone ,Cairo, Egypt.(

The root canals were endodontically instrumented. Each canal was widened manually until an ISO size 15 file (Dentsply/Maillefer, Ballaigues, Switzerland), could be inserted to the working length (15±1mm) with little or no resistance.

The pulpal tissues were removed with a barbed broach (IMD, China) of an appropriate size and root canals were manually instrumented to working length of 1-mm above the apical foramen with K-files #35 (Dentsply/Maillefer). The canals were prepared and irrigated with 2-ml of 15% ethylenediamineteraacetic acid (EDTA) irrigating solution between each file change. Using #35 master file and after filling was complete, canals were obturated with gutta-percha cones (Dentsply, Maillefer) matching the last file size and AH-26 resin sealer (Dentsply DeTrey, Konstnaz, Germany). using lateral condensation technique. Subsequently, gutta-percha were removed from each root canal to a point 5 mm from the apex using Gates-Glidden (Dentsply, Maillefer), with a plastic stop leaving specimens with 10 mm from the coronal surface corresponding to "DentoClic" dowel size 3 with 1.3 mm diameter (iTena, French).

Following dowel space preparation, each root canal was irrigated with sterile water and dried with paper points (Dentsply, Maillefer, Swizerland). A radiograph was taken to evaluate the presence of any residual gutta-percha on the walls of the canals

Specimen grouping

Specimens were divided randomly into 3 groups (n=10) according to the cement used : total-etch (Variolink N - NX3), self-etch) Panavia F 2.0 - Duo-Link (and self-adhesive system (G-Cem - Calibra.(

Total-etch resin cement

Specimens were preconditioned with acid etch 37% phosphoric acid gel for 10-15 seconds, rinsed thoroughly with water for 30 seconds and gently dried with air and paper point (Dentsply ,Maillefer .(A dual cure dental adhesive Te-Econom bond) Ivoclar Vivadent ,Schaan ,Liechenstein ,Germany) was applied for Vaiolink N specimens and Opti-BondTM) Kerr, California, USA) was applied for NX3 specimens with micro brush tips (Micro brush Corp, Grafton, WI, USA) for 10-15 seconds. Excess was removed with an absorbant paper point (Dentsply ,Maillefer ,(and the remaining material was gently air dried with dental syringe tips . Variolink N cement was mixed according to the manufacturer recommendations by dispensing the base and catalyst paste in 1:1 ratio onto a clean mixing pad. The cement was mixed for 10 seconds and spread into the dowel space using lentulo spiral (Dentsply ,Maillefer .(NX3 syringe plungers were gently compressed to begin the flow of the cement using the supplied tips into the dowel space preparation and spread into the dowel space preparation using lentulo spiral (Dentsply ,Maillefer .(Each dowel was seated immediately and stabilized with light pressure using dental twizzer .Excess cement was removed with a dry applicator brush and light cured using light cure source (LED.D Guilin Woodpeaker ,Medical Instrument CO. Ltd, China) for 10 seconds. The light transmitted inside the canal through the glass dowel. The light intensity was 800mW/cm2.

Self-etch resin cement

Following manufacturer recommendation, equal amounts of ED Primer A&B) Kurary ,Otemachi , Chiyoda-Ku, Tokyo, Japan) for Panavia N 2.0 specimens and equal amounts of universal primer A&B (Bisco , Schamburg ,Illinois, USA) for Duolink^{TM} Universal specimens was mixed into a clean mixing well using a brush mix adhesive for 5 seconds. Two separate coats of universal primer were applied to coronal and dowel-hole tooth structure with a micro brush (Micro brush Corp, Grafton, WI, USA) for 15-30 seconds consecutively until it initiates set of cement. Excess primer was removed with paper points (Dentsply ,Maillefer (and gently air dried for 10 seconds. Equal amounts of past A&B of panavia F 2.0 were dispensed from the syringe in 1:1 ratio onto a clean mixing pad and mixed for 20 seconds according to the manufacturer recommendations. The mixed cement was dispensed and spread into the dowel space using lentulo spiral (Dentsply ,Maillefer .(Duo-link ^{TM} Universal syringe plunger was gently compressed to begin the flow of the cement using its mixing syringe tips Each dowel was coated with the mixed cement and seated immediately and stabilized with light pressure using dental tweezer. Excess cement was removed with a dry applicator brush and light cured using light cure source)Woodpeaker ,Medical Instrument, Ltd, China) for 20 seconds.

Self-adhesive resin cement

The self-adhesive G-Cem capsules were triturated in the amalgamator for 10 seconds then applied into the dowel space preparation using its mixing syringe tip and comcompressed by the gun .Calibra syringe plunger was gently compressed into the dowel space to begin the flow of the cement using the supplied tips . Each dowel was seated immediately and stabilized with light pressure using dental tweezer. Excess cement was removed with a dry applicator brush and light cured for 20-40 seconds.

Push-out bond strength test

Each specimen was transversely sectioned perpendicular to the long axis of the root using the Isomet saw to obtain a section 1 mm ± 0.1 in thickness from each root region (coronal, middle, apical). Each slice was measured using a digital caliper (Pachymeter, Electronic Digital Instruments, China.(

Each root slice was mounted in custom made loading fixture composed of metallic block with circular cavity at the middle. This cavity for specimen housing having a central whole to facilitate displacement of extruded filling material. Each sample was subjected to compressive loading at a crosshead speed of 1 mm/min via a computer controlled testing machine (Model 3345; Instron Industrial Products, Norwood,MA, USA).

Load applied by plunger of (1, 0.8, 0.5 mm diameter) corresponding to the radicular thirds (coronal, middle and apical) tested. The plunger tip was sized and positioned to touch only the post, without stressing the surrounding dentin, in apical coronal direction to push the filling toward the larger diameter, thus avoiding any limitation to the post movement possibly owing to the canal taper. This way, it was guaranteed that the overlaying dentin was sufficiently supported during the loading process. The level of the dowel space from which each slice was derived was noted in order to discriminate among the retentive conditions provided by the luting agents at the coronal, middle and apical thirds of the dowel space.

Failure manifested by extrusion of filling piece and confirmed by sudden drop along load-deflection curve recorded by Bluehill Lite computer software. The push-out bond strength was determined for each root slice

The retentive strength of the dowel segment was excompressed in MPa by dividing the maximum failure load (N) by the interfacial area (A) of the dowel fragment, which corresponded to the bonded area, in mm^2. The interfacial area was calculated as the lateral surface of a truncated cone using the following formula:

$$\mathbf{A = \pi\ (R + r)[h2+(R - r)^2]^{0.5}}$$

Where π = 3.14, R = coronal dowel radius, r = apical dowel radius, and h = root slice thickness.

III. Results

Mean values and standard deviations for each cement at different root canal regions are listed in table 1. The data indicate that Total-etch Variolink N cement had higher mean bond strength, and the lower mean bond strength were found for Self-adhesive Calibra cement with all the three regions of the root canal. Regardless of the cement used, coronal region of the root canal had the highest bond strength, and the apical region had the lowest bond strength. However, results of the middle region were intermediate.

Figure 1 showed similar comparison for the cements, regardless to the region of the root canal, Total-etch Variolink N cement had the highest bond strength (15.63 ± 3.15), and self-adhesive Calibra cement had the lowest bond strength (7.40 ± 1.84).

One-way ANOVA revealed no statistically significant difference between regions of the root canal for each luting cement used for bonding glass fiber dowels as shown in table 2.

Comparing each root canal region for all cements, One-way ANOVA showed significant difference between cervical regions (Table 3), middle regions (Table 4) and apical regions (Table 5) of each cement ($P < 0.001$).

Turkey's hoc test (Table 6) showed significant difference in cervical region between total-etch cements (Variolink N and NX3) and self-adhesive cements (G-Cem and Calibra) ($P < 0.05$). There is also significant difference between self-etch cement Duolink and self-adhesive cements (G-Cem and Calibra) ($P < 0.05$). However, There is no significant difference between other groups.

A similar comparison for the middle region, Turkey's hoc test (Table 7) showed significant difference in middle region between total-etch cements (Variolink N and NX3) and self-adhesive cements (G-Cem and Calibra) ($P < 0.05$). There is also significant difference between self-etch cement Duolink and self-adhesive cements (G-Cem and Calibra) ($P < 0.05$). There is no significant difference between other groups.

For the apical region, Turkey's hoc test (Table 8) showed significant difference in the apical region between total-etch Variolink N cement and self-adhesive cements (G-Cem and Calibra) ($P < 0.05$). There is no significant difference between other groups

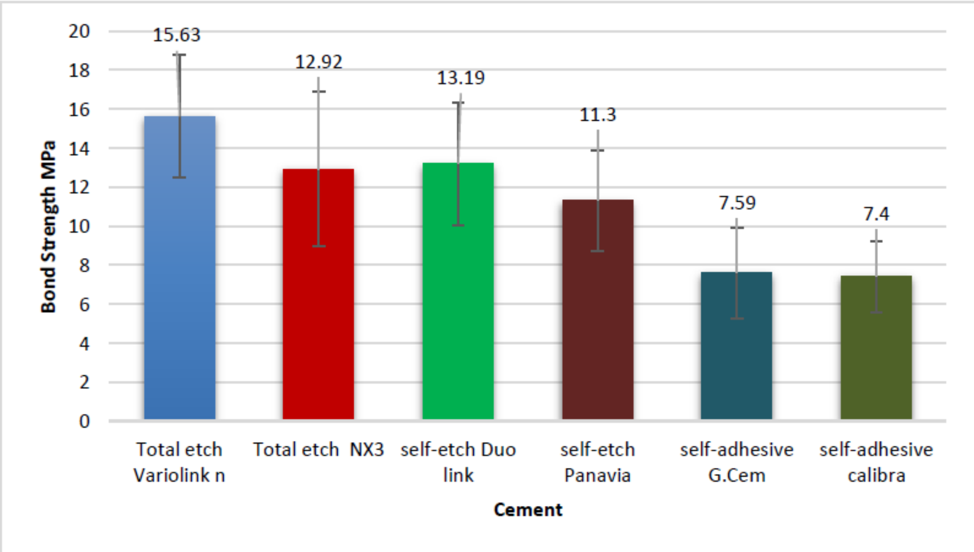

Fig 1. Mean bond strength for each resin cement

Table 1. Bond strength among experimental groups (mean±SD MPa) (n=10)

Material / Region	Cement					
	Total-etch		**Self-etch**		**Self-adhesive**	
	Variolink N	**NX3**	**Duo link**	**Panavia**	**G-Cem**	**Calibra**
Coronal	16.95±2.58	15.08±4.29	15.39±3.48	12.33±1.45	9.28±2.04	8.33±1.74
Middle	15.05±3.65	12.59±3.75	13.73±1.89	11.07±2.48	7.18±1.44	7.23±1.91
Apical	14.88±3.39	11.08±3.56	11.13±2.70	10.51±3.59	6.33±2.59	6.65±1.84

Table 2. One-way ANOVA between regions of root canal within each cement

Variolink N	2	13.242	6.621	0.631	0.549
NX3	2	40.828	20.414	1.357	0.294
Duo link	2	46.083	23.041	3.001	0.088
Panavia	2	8.680	4.340	0.613	0.558
G-Cem	2	22.951	11.476	2.652	0.111
Calibra	2	7.347	3.673	1.099	0.364

Table 3. One-way ANOVA between cervical regions for each cement

Cervical	Variolink N	16.95±2.58	13.49-20.21	7.913	P < 0.001
	NX3	15.08±4.29	9.58-20.09		
	Duo link	15.39±3.48	11.23-20.59		
	Panavia	12.33±1.45	10.95-14.26		
	G-Cem	9.28±2.04	6.96-11.47		
	calibra	8.33±1.74	6.11-10.76		

Table 4. One-way ANOVA between middle regions for each cement

Region	Group	Mean±SD	Range	*F*-value	P
Middle	Variolink N	15.05±3.65	9.88-18.97	7.721	P < 0.001
	NX3	12.59±3.75	9.92-18.96		
	Duo link	13.73±1.89	11.22-15.88		
	Panavia	11.07±2.48	8.59-15.24		
	G-Cem	7.18±1.44	5.19-9.01		
	Calibra	7.23±1.91	5.73-10.29		

Table 5. One-way ANOVA between apical regions of each cement

Apical	Variolink N	14.88±3.39	10.83-19.53	5.632	P <0.001
	NX3	11.08±3.56	5.42-15.23		
	Duo link	11.13±2.70	7.98-14.41		
	Panavia	10.51±3.59	6.72-15.61		
	G-Cem	6.33±2.59	4.24-10.77		
	Calibra	6.65±1.84	4.58-9.19		

Table 6. Comparison statistics between cervical regions of each cement

		Variolink N	NX3	Duo link	Panavia	G-Cem	Calibra
Cervical	Variolink N	-------	-------	-------	-------	-------	0.001
	NX3	0.890	-------	-------	-------	-------	0.009
	Duo link	0.922	1.000	-------	-------	-------	0.007
	Panavia	0.127	0.626	0.570	-------	-------	0.242
	G-Cem	0.003	0.031	0.025	0.521	-------	0.994
	Calibra	0.001	0.009	0.007	0.242	0.994	-------

Table 7. Comparison statistics between middle regions of each cement

		Variolink N	NX3	Duo link	Panavia	G-Cem	Calibra
Middle	Variolink n	-------	-------	-------	-------	-------	0.001
	NX3	0.685	-------	-------	-------	-------	0.038
	Duo link	0.925	0.995	-------	-------	-------	0.012
	Panavia	0.201	0.939	0.715	-------	-------	0.231
	G-Cem	0.001	0.035	0.011	0.219	-------	1.000

	calibra	0.001	0.038	0.012	0.231	1.000	------

Table 8. Comparison statistics between apical regions of each cement

		Variolink N	NX3	Duo link	Panavia	G-Cem	Calibra
Apical	Variolink N	-------	-------	-------	-------	-------	0.003
	NX3	0.375	-------	-------	-------	-------	0.223
	Duo link	0.390	1.000	-------	-------	-------	0.212
	Panavia	0.235	1.000	0.999	-------	-------	0.358
	G-Cem	0.002	0.167	0.158	0.278	-------	1.000
	calibra	0.003	0.223	0.212	0.358	1.000	-------

IV. Discussion

The null hypothesis of the study was rejected as the different cementation technique tested in the study has significantly affected the bond strength of the glass fiber dowels to root canal dentin.

Dentoclic glass-fiber dowels were chosen to be used in the current study. They are made of 80% unidirectional parallel oriented glass fibers embedded in 20% of epoxy-resin. This type of dowel enables minimally invasive direct restorations. Dentoclic glass-fiber dowels have excellent mechanical properties for a reduced risk of fracture, homogeneous distribution of the mechanical constrains, excellent resistance to flexion (836) MPa because of its many longitudinal glass fibers.

Single rooted mandibular premolars teeth were stored in 1% thymol solution at room temperature. Thymol has an antifungal action, less influence on adhesive mechanisms in comparison to alternative storage media as saline or formalin, and has been repeatedly described in other studies[8]. In the current study, teeth were endodontically treated and obturated according to the traditional lateral condensation technique. While the eugenol containing root canal sealers inhibit the polymerization of resin based luting agents. Therefore, eugenol free epoxy-amine resin sealer (AH-26) was used to complete the endodontic treatment[9].

Dual cure resin cements may minimize the problems related to the difficulty of light reaching the most apical portions of the root canal, with polymerization being activated by the chemical friction of the activators, and thus, the most cervical portions would be benefited by light sensitization[10].

Push-out bond strength was used using 1-mm thick tooth slices, because this method offers small adhesive areas, which help to avoid the difficulties of micro-tensile specimen preparation[11,12].

A variety of luting agents and the corresponding adhesives can be used to bond fiber dowels into root canals. These adhesives can be total-etch, self-etch or self-adhesive. Previous studies showed that total-etch and self-etch systems sealed the root system much better than the self-adhesive systems[13]. Results of the current study showed that total-etch and self-etch groups revealed high mean bond strength than self-adhesive group. This could be explained by the increase of surface bonding area in the root canal after the total-etching procedure[14]. Application of etching solution can demineralize dentine and promote a deeper hybrid layer and resin tag formation than the self-adhesive system. In the self-adhesive system, a smear layer on the dentine surface is often not cleaned completely, so the hybrid layer and resin tag formation are more superficial[14].

Noirrit *et al*[15] showed that the hybrid layer and resin tags that resulted from self-etch and total-etch systems were nearly the same, although the conditioning of the canal walls was different. This might be due to the total-etch system is a more technique-sensitive procedure than the self-etch system, which has a high risk of bonding failure between the cement and dentine. This can be explained by the high risk of over wetting and over drying during the rinsing and drying procedure after application of etching solution[15]. The application of etching solution removed the smear layer, demineralized hydroxyapatite inorganic matrix, and then exposed collagen fiber and dentin tubules. Good bonding is formed when monomers in the bonding agent penetrate dentine tubuls and collagen fibers, forming a good hybrid layer and resin tag[6]. If the drying procedure after etching and rinsing is not complete, the dentin would be wet or over wet. On wet dentin, monomer penetration to dentin tubules and collagen fibers would be easily dissolved because monomers tend to be hydrophilic. The dissolved monomers would cause failure of hybrid layer and resin tag formation, resulting in bonding failure. If the drying procedure after etching and rinsing is excessive with over drying, the collagen fibers would be fragile and broken with decreased permeability. As a result, monomers in the bonding agent would not penetrate to collagen fibers and dentine tubules, so hybrid layer and resin tag formation would fail, resulting in bonding failure besides, any residual remaining within the canal[6]. **Bitter *et al***[16] found a significant difference between total-etch and self-etch when used with glass fiber reinforced composite dowels on root canal dentin and noted that the hybrid layer appeared thinner with the self-etch system, than with the etch-and-rinse system. They concluded that demineralization by phosphoric acid led to a deeper penetration of the adhesive than did a self-etch system, which could not completely penetrate the smear layer. Others, however, showed that the strength of the bond was not dependent on the hybrid layer thickness[17,18]. On the other hand, some authors[11,19,120] stated that simplified self-etch and self-adhesive resin cements, such as Panavia 21, exhibited an etching potential insufficient (even with a PH of 2.0) to dissolve the thick smear layers created in the dowel-space preparation, with slow-speed drills. They stated that this fact yielded to the high shrinkage stress in the thin cement layer and the consequent opening of interfacial gaps might account for the relatively low push-out strength recorded for self-etch cements as compared to the results obtained with the use of the total-etch system[21]. This is in agreement with the results of the current study where self-etching cements (Duolink and Panavia) had lower push out bond strength than total-etch cements (Variolink and NX3).Although results of the current study showed the adhesive capability of the self-etch compared to self-adhesive system. This was disagreement with the result of some researches[22] that have claimed that self-adhesive cement had better results by comparing the bond strength rates with those presented by cements of acid etching or self-etching. This is depend on inorganic particle amount by weight in self-adhesive cements is higher than in conventional cements, which reduces the cement polymerization shrinkage and improves stability[23,24.] In contrast, **Calixto et al**[25] showed that bond strength of resin cements used with total-etch and self-etch adhesive systems seem to be adequate for glass fiber dowel cementation. This was likely because, in self-adhesive system, the hybrid layer sometimes formed without the resin tag. The self-adhesive system has three weaknesses that can lead to bonding failure. The first weakness is in the use of one component that is a combination of components[25]. It is difficult to maintain a stable combination of some chemical components for a long time. The self-adhesive system has a high composition of water that tends to hydrolyze and cause chemical reaction failure, especially during exposure to the high temperatures that occur during the application process. A second weakness of the self-adhesive system is its hydrophilic character that can dissolve adhesive sometime after application and polymerization on dentine. The third weakness in the self-adhesive system is that the acidic composition of the adhesive compound relies on a self-cured and dual-cured polymerization system[26]. Acid can degrade the tertiary aromatic amines that are needed for chemical polymerization. These weaknesses could explain why the results of self-adhesive system in the current study had the lowest adhesive capability among the adhesive systems examined[26].

Failures that occur in the push-out test can be due to failures in the adhesion between the resin cement and dentin or between the resin cement and fiber dowels, as well as failures in resin cement cohesion or fiber dowel cohesion. The most common failure is adhesion failure between the resin cement and dentine. In order to minimize this failure[27].

Researchers determined that the total-etch system must be performed carefully to prevent bonding failure because this system is very technique-sensitive, particularly during cementation of fiber dowels. The operator's skill in applying the total-etch adhesive system is very important[27]. The other adhesive systems had easier adhesive application procedures, including the self-etch system, which had adhesive capability similar to the total-etch system. In the current study, regardless to the cement used, the highest bond strength values were achieved in the coronal region, followed by the middle region. However, the apical region had the lowest bond strength values. Previous studies[14] reported that dentinal tubules density are higher in the cervical region and significantly decreases in the middle and apical thirds. This was in agreement with the results of the current study. However, other recent studies[11,28] have reported that bond strength to root canal is not affected by the region in the root canal. Some studies [29,30] have reported higher bond strength values in the apical third than those in other parts of the root canal. A study by **Perdigao et al**[31] showed higher bond strength values in the coronal region when using total-etch cements, and this is because of difficulties in conveying sufficient amount of primer-adhesive solution to the apical region of canals and manipulation problems arising from inadequate root canal access are the reasons for lower apical bond strength values in total-etch cements[32].

V. Conclusions

Within the limitations of this in-vitro study, the following conclusions can be drawn:

1. The luting cement used had a significant influence on the bond strength of glass dowels to root canal dentin. Moreover, the bond strength was affected by root canal region.
2. Use of total-etch resin cements appeared to be the method of choice if a high bond strength of glass dowels to root canal dentin were preferred.
3. Self-etch resin cements produced higher bond strength of glass dowels to root canal dentin than did self-adhesive resin cements. However, further development of this adhesive system may help resolve its weaknesses.
4. The selection of luting cement for glass dowel cementation may influence the retention and adhesion of resin restorative materials as a function of root canal region.

References

[1]. Al-Omiri MK, Mahmoud AA, Rayyan MR, Abu-Hammad O. Fracture resistance of teeth restored with dowel-retained restorations: An overview. J Endod 2010;36:1439-49.

[2]. Schwartz RS, Robbins JW. Dowel Placement and restoration of endodontically treated teeth: A literature review. J Endod 2004;30:289-301.

[3]. Spazzin AO, Galafassi D, Meira-Junior AD, Braz R, Garbin CA, Influence of dowel and resin cement on stress distribution of maxillary central incisors restored with direct resin composite. Oper Dent 2009;34:223-9.

[4]. Makade CS, Meshram GK, Warhadpande M, Patil PG. A comparative evaluation of fracture resistance of endodontically treated teeth restored with different dowel core systems. An in–vitro study. J Adv Prosthodont 2011;3:90-5.

[5]. Hochman N, Feinzaig I, Zalkind M. Effect of design of pre-fabricated dowels and dowel heads on the retention of various cements and core materials. J Oral Rehabil 2003;30:702-7.

[6]. Monticelli F, Ferrari M, Toledano M. Cement system and surface treatment selection for fiber dowel luting. Med Oral Patol Oral Cir Bucal 2008;13:E214-21.

[7]. Teixeira CS, Alfredo E, Thome' LH, Garbia-Silver R, Silva-Sousa YC, Sousa-Neto MD. Adhesion of an endodontic sealer to dentin and gutta-percha: shear and push-out bond strength measurements and SEM analysis. J Appl Oral Sci 2013;17:129-35

[8]. Kogan P, He J, Glickman GN, Watanabe. The effects of various additives on setting properties of MTA. J Endod 2006;32:569-72.

[9]. Bayindir F, Akyil MS and Bayindir YZ. Effect of eugenol and non eugenol containing temporary cement on permenant cement retention and microhardness of cured composite resin. Dent Mater J 2003;22: 592-9.

[10]. Galhano GA, de Melo RM, Barbosa SH, Zamboni SC, Bottino MA, Scotti R. Evaluation of light transmission through translucent and opaque dowels. Oper Dent 2008;33:321-4.

[11]. Goracci C , Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso pdec. The adhesion between fiber dowels and root canal walls: comparison between micro tensile and push-out bond strength measurements. Euro J Oral Sci 2004-112:353-61.

[12]. Bouillaguet S, Scu"tt A, Alander P, et al. Hypothermal and mechanical stresses degrade fiber-matrix interfacial bondstrength in dental fiber-reinforced composites. J Biomed Mater Res B Appl Biomater 2006;76:98-105.

[13]. Zicari F. Couthino E, Munck JD. Bonding effectiveness and sealing ability of fiber post bonding. Dent Mater 2008;24:967-77.

[14]. Ferrari M, Mannocci F, Vichi A, Cagidiaco MC and Mjör IA. Bonding to root canal: structural characteristics of the substrate. Am J Dent 2000;13 255-60.

[15]. Noirrit E, Grégoire G, Cournot M. Morphological study of fiber-reinforced dowel-bonding system-root dentin interface by evaluation of two bonding systems. J Dent 2008;36:204-13.

[16]. Bitter K, Priehn K, Martus P, Kielbassa AM. *In vitro* evaluation of push-out bond strengths of various luting agents to tooth-colored dowels J Prosthet Dent 2006;95:302-10.

[17]. Akgungor G, Akkayan B. Influence of dentin bonding agents and polymerization modes on the bond strength between translucent fiber dowels and three dentine regions within a dowel-space. J Prosthet Dent 2006;95:368-78.

[18]. Yoshiyama M, Matsuo T, Ebisu S, Pashley D. Regional bond strengths of self-etching/self-priming adhesive systems. J Dent 1998;26:609-16.

[19]. Goracci C, Sadek FT, Fabianelli A, TayFR, Ferrari M. Evaluation of the adhesion of fibre dowels to intraradicular dentin. Oper Dent 2005;30:627-35.

[20]. Rathke A, Haj-Omer D, Muche R, Haller B. Effectiveness of bonding fiber dowels to root canals and composite core build-ups. Eur J Oral Sci 2009;117:604-10.

[21]. Goracci C, Simone G, Maurizio B, Egidio B, Ferrari M. Laboratory assessment of the retentive potential of adhesive dowels. A review. J Dent 2007;35:827-35.

[22]. Karkera, R, Raj, AP, Isaac L, Mustafa M, Reddy RN, Thomas M, 2016. Comparison of the solubility of conventional luting cements with that of the polyacid modified composite luting cement and resin-modified glass ionomer cement. J Contemp Dent Pract 2016;17,1016–21.

[23]. Aleisa, K, Al-Dwairi, ZN, Alghabban R, Goodacre CJ. . Effect of luting agents on the tensile bond strength of glass fiber dowels: an in vitro study. J Prosthet Dent 2013;110,216-22.

[24]. Silveira-Pedrosa, DM, Martins LR, Sinhoreti MA, CorrerSobrinho L, Sousa-Neto MD, Junior CE, et al. Push-out bond strength of glass fiber dowels cemented in weakened roots with different luting agents. J Contemp Dent Prac 2016;17,119-24.

[25]. Calixto LR, Bande´ca, MC, Clavijo V, Andrade MF, Vaz, LG. Campos EA. Effect of resin cement system and root region on the push-out bond strength of a translucent fiber dowel. Oper Dent 2012;37,80-6.

[26]. Mumcu E, Erdemir U and Topcu FT 2010Micro push-out bond strengths of two fiber dowels luted using simplified adhesive approaches. Dent Mater J 2010;29:286-96.

[27]. Wang Z, Ji Y and Zhang F Bond strengths of an epoxy resin–based fiber dowel with four adhesive systems. Quintessence Int 2010;41 e173-80.

[28]. Foxton RM, Nakajima M, Tagami J, Miura H. Adhesion to root canal dentine using one and two-step adhesives with dual-cure composite core materials. J Oral Rehabil 2005;32:97-104.

[29]. Muniz L. Mathias P. The influence of sodium hypochlorite and root canal sealers on dowel-retention in different dentin regions. Oper Dent 2005;30:533-9.

[30]. Bitter K, Meyer-Lueckel H, Priehn K, Kanjuparambil JP, Neumann K, Kielbassa AM. Effects of luting agent and thermocycling on bond strengths to root canal dentine. Int Endod J 2006;39:809-18.

[31]. Perdigão J, Geraldeli S, Lee IK. Push-out bond strengths of tooth colored posts bonded with different adhesive systems. Am J Dent. 2004;17:422-6.

[32]. Bolhuis P, de Gee A, Feilzer A. Influence of fatigue loading on four dowel-and-core systems in maxillary premolars. Quintessence Int 2004;35:657-67.