Sains Malaysiana 44(8)(2015): 1189–1194

The Combined Effect of Dental Post and Cement Materials on Fracture Resistance and Fracture Mode of Endodontically-treated Teeth

(Gabungan Kesan Pasca Pergigian dan Bahan Simen ke atas Rintangan Keretakan dan Mod Keretakan Gigi yang Dirawat secara Endodontik)

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ABSTRACT

The aim of this study was to investigate the simultaneous influence of various dental posts and cementation materials on the fracture resistance and failure mode of the endodontically-treated teeth. Sixty endodontically treated upper central incisors were randomly divided into two main groups, each consisted of three subgroups restored with titanium, fiber and stainless steel posts. The posts in the first and second groups were luted with zinc phosphate and composite resin cements, respectively. Composite cores were built-up over the specimens and then retained with nickel-chromium crowns. Specimens were thermocycled and then loaded at 135º until failures were observed. The obtained data of fracture resistances and failure modes were analyzed using Two-way ANOVA and the Chi-Square tests, respectively. The results showed that the zinc phosphate cement resulted in relatively higher fracture resistances. However, luting of dental posts with composite resin provided more restorable failures in endodontically-treated teeth. Moreover, the teeth restored by fiber posts exhibited desirable fracture resistances with more restorable failure modes, compared with those restored by titanium or stainless steel posts.

Keywords: Dental cements; dental posts; fracture resistance

ABSTRAK

Kajian ini bertujuan untuk mengkaji pengaruh serentak pelbagai tiang pergigian dan bahan simen pada rintangan keretakan dan mod kegagalan ke atas gigi dirawat secara endodontik. Enam puluh batang gigi rawatan endodontik gigi kacip atas berpusat dibahagikan secara rawak kepada dua kumpulan utama, masing-masing terdiri daripada tiga subkumpulan yang dipulihkan dengan titanium, serat dan tiang keluli tahan karat. Tiang dalam kumpulan pertama dan kedua telah diikat masing-masing dengan zink fosfat dan simen resin komposit. Teras komposit dibuat ke atas spesimen tersebut dan kemudian dikukuhkan dengan gelang nikel-kromium. Spesimen dikitarhaba dan kemudian dinaikkan pada 135º sehingga kegagalan diperhatikan. Data yang diperoleh untuk rintangan retak dan mod kegagalan dianalisis menggunakan ANOVA dua hala dan ujian khi kuasa dua. Hasil kajian menunjukkan bahawa simen fosfat zink mengakibatkan rintangan retak yang agak tinggi. Walau bagaimanapun, ikatan tiang gigi dengan resin komposit memberikan lebih kegagalan yang boleh dipulihkan dalam gigi dirawat secara endodontik. Selain itu, gigi yang dipulihkan melalui tiang gentian menunjukkan rintangan retak yang diinginkan dengan lebih banyak mod kegagalan yang boleh dipulihkan, berbanding dengan kumpulan yang dipulihkan melalui titanium atau tiang keluli tahan karat.

Kata kunci: Rintangan retak; simen pergigian; tiang pergigian

INTRODUCTION

For more than 25 decades, dental posts have been employed for retaining the restoration and strengthening of the endodontically treated tooth (Stewardson 2001). The posts might be casted or prefabricated from materials such as stainless steel, titanium, gold, chromium-cobalt alloys, fiber, zirconium and ceramic which show high rates of success in studies concerning the fracture resistance in endodontically treated teeth (Al-Wahadni et al. 2008; Sahil et al. 2013; Schwartz & Robbins 2004). A desirable post-and-core system must sufficiently retain the crown, provide a suitable fracture resistance and effectively protect the remaining tooth structure (Fokkinga et al. 2003). In addition to the fracture resistance, the fracture reparability is also a significant feature which determines the clinical success of a post-and-core system. Several studies have reported that the ceramic and metallic posts could increase the risk of vertical fracture due to their high stiffness and modulus of elasticities compared to those of natural dentin (Al-Wahadni et al. 2008; Makade et al. 2011). Therefore, restoring teeth with non-metallic posts, which has modulus of elasticity similar to those of dentin, has been carried out widely recently. Fiber posts could reduce the susceptibility of root to fracture and increase the possibility of tooth survival (Stewardson 2001).

The type of cement used for luting the dental posts to the internal dentin is another parameter that significantly influences the success of endodontic tooth restoration.

The usage of appropriate post luting cement increases the bonding strength between dentine and post and provides a short-term reinforcement to the root, increasing its retention and fracture resistance (Schwartz & Robbins 2004). Some of the most popular luting cements include zinc phosphate, zinc polycarboxilate, glass ionomer, modified glass ionomer resin and composite resin (Li et al. 2006; Lü et al. 2013). Although zinc phosphate is the preferred choice of cementation due to its high compressive and tensile strengths which minimizes susceptibility to root fracture (Casson et al. 2001), recent studies proved that resin cement results in better retention and less leakage compared to other types of cements and strengthens the root structure for a short period of time (Mezzomo et al. 2003; Reid et al. 2003).

Although the influence of different posts and cements on fracture behavior of the root has been examined in a number of studies, however the combined effect of both these parameters on the fracture resistance and failure mode of the endodontically treated teeth is mostly neglected. Sufficient bonding strength between the dental post and luting cement also plays a role in lowering the risk of tooth extraction due to the root fracture. Different luting cements may not provide bonds with similar strengths when used with various types of dental posts. Therefore, the current study aimed to investigate the impact of different posts (i.e. Titanium, Fiber, and Stainless Steel) and cements (i.e. zinc phosphate and composite resin) on the fracture resistance and failure mode of endodontically treated teeth to determine the posts and cements that provide superior fracture behavior in restored teeth.

MATERIALS AND METHODS

A number of sixty extracted maxillary incisors were collected and stored in distilled water and disinfected in 0.5% chloramine-T trihydrate solution for a week according to (ISO/TS 11405: 2003). Teeth were scaled using ultrasonic scaler (Peizon Master 400, Switzerland) and examined under a stereomicroscope to detect any defects within their structure. The teeth without caries, cracks, abnormalities or previous endodontic treatment, with fully formed roots were only selected for further experiments. Crowns were sectioned 16-mm from the apex using a diamond disc (Edenta, Diamantscheibe, Switzerland) attached to a straight handpiece. Roots canals were prepared using the step-back technique, while 45 K-file (DENTSPLY/Maillefer, Switzerland) was performed as a master file at 15 mm. After obturating the root canals using gutta-percha cones (DENTSPLY/Asia, Hong Kong) with resin-based canal sealer (AH-plus, DENTSPLY DeTrey, Germany), the teeth were further incubated in distilled water for 24 h. Post-space preparations were performed by removing gutta-percha using Gates-Glidden drills (DENTSPLY Maillefer, Switzerland) to place the dental posts with constant working lengths of 10 mm.

The teeth were then randomly assigned into two groups, where each group was in turn divided into three subgroups containing 10 teeth. The teeth in the first group were all restored using the zinc phosphate cement (Elite Cement 100, GC Corporation, Japan) in combination with three different posts including Titanium (Para Post XP, Coltene/Whaledent, USA), Fiber (Para Post Fiber Lux, Coltene/Whaledent, USA) and Stainless Steel (Para Post XP, Coltene/Whaledent, USA) posts. The specimens of the second group were also restored in a similar manner, with the notable exception that the posts were cemented using composite resin cement (Rely X Unicem 2 Automix Self Adhesive Cement Resin, 3M, EPSE, USA) (Table 1).

The periodontal ligament was simulated by mixing and painting light body silicone impression material (Aquasil Ultra XLV, DENTSPLY, Caulk) around the roots surfaces (3 mm below Cemento-Enamel Junction (CEJ)). Roots were then placed vertically into the silicone molds with epoxy resin (PACE Technologies, Quick mount 2 Epoxy Resin, USA). The crowns fabricated from Ni-Cr alloy were cemented over the composite cores (Filtek Z 350 3M/ESPE, USA) using zinc phosphate cement. Then, all specimens were thermocycled for 500 cycles at 5 and 55^{o}C to simulate an oral environment (de V Habekost et al. 2007).

TABLE 1. Specifications of the restorative materials used in this study

Item	Commercial Name	Manufacturer	Design	Adhesive system	Material
Post	Parapost XP Titanium	Coltene/Whaledent USA	Parallel, passive	-	Titanium
	Parapost Fiber Lux	Coltene/Whaledent USA	Parallel, passive	-	60% fiberglass, 40% resin
	Parapost XP Stainless Steel	Coltene/Whaledent USA	Parallel, passive	-	Stainless steel
Cement	ELITE 100 Zinc phosphate	GC Corp. Japan	-	Conventional	Powder: zinc oxide, magnesium oxide Liquid: orthophosphoric acid
	Rely X Unicem 2 automix	3M, EPSE USA	-	Self-adhesive	Silica, glass, calcium hydroxide, methacrylate, phosphoric ester, dimethacrylate, acetate

A schematic of the relevant components such as crown, core, post and cement used for restoration of the teeth are shown in Figure 1 and the experimental design applied for the fracture tests is shown in Figure 2. The compressive loads were applied 2 mm below the incisal edge on a palatal surface with a speed of 0.5 mm/min until failure occurred. The failure modes were further investigated using a stereomicroscope and were classified as favorable or unfavorable. The favorable (restorable) failures were defined as repairable failures, including adhesive fractures, above the level of bone simulation and unfavorable (catastrophic) failures were defined as non-repairable failures, including (vertical) root fractures, below the level of bone simulation (Fokkinga et al. 2003).

The obtained results were analyzed using Statistical Package for the Social Science (SPSS 20, SPSS Inc., USA). The comparative evaluation of mean fracture resistance between the various experimental subgroups was carried out with two-way univariate analysis of variance (ANOVA). Chi-square test was also used to analyze the effect of both cement and post types on failure modes of the restored teeth. Ethics Committee/IRB Reference Number is DF RD1411/0058(P).

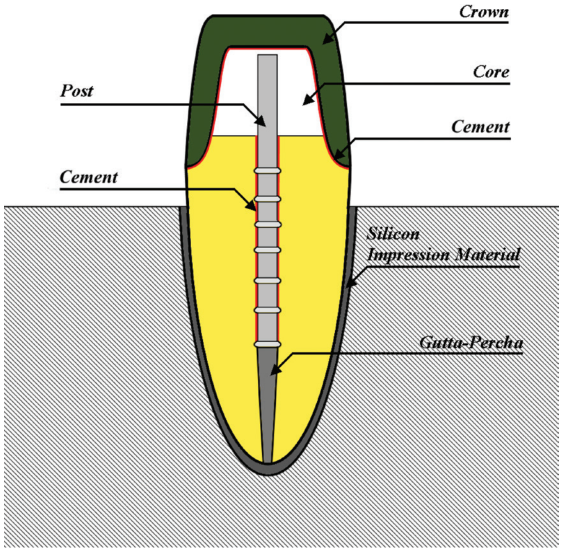

FIGURE 1. Schematic illustration of an endodontically-treated tooth restored by the post-core system

RESULTS

The fracture resistances of the teeth restored with two different cements are given in Table 2. The zinc phosphate cement could provide a higher overall fracture resistance in all specimens compared with the resin cement. The ANOVA results also indicated that the luting cement could significantly influence the fracture strength of teeth restored with Titanium and Fiber posts. However, the type of luting cement might not significantly affect the fracture resistance of the teeth restored by Stainless Steel dental posts.

When considering the effect of post type on the fracture resistance of restored teeth, the ANOVA comparisons (Table 3) showed that the fracture resistances of the teeth luted by resin cement were independent of the post type, while in the specimens cemented by zinc phosphate, the Titanium and Fiber posts provided significantly higher fracture resistances compared to the stainless steel posts. Figure 3 presents the failure mode distribution of the specimens restored by different dental posts and cements.

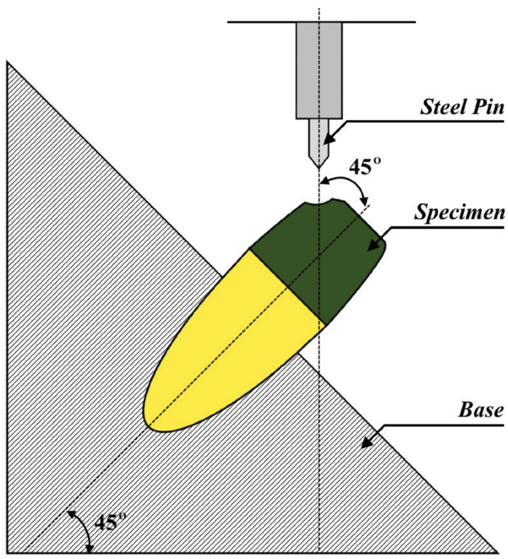

FIGURE 2. Experimental design applied for fracture tests

TABLE 2. ANOVA comparison between the mean fracture resistance of the teeth restored by similar post types and different cements

Post	fracture resistance (N) *(Mean ± SD)*		Mean difference *(Zph-Res)/n*	95% Confidence interval		*P* value
	Zph	Res		Lower bound/n	Upper bound/n	
TIP	530.9±34.7	406.7±33.4	124.2	10.6	237.8	0.022*
FBP	535.6±54.6	360.5±25.2	175.1	61.5	288.7	0.000*
SSP	417.4±50.3	348.8±42.4	68.6	-45.0	182.2	1.000

Abbreviations. TIP: Titanium post; FBP: Fiber post; SSP: Stainless Steel post; Zph: Zinc Phosphate cement; Res: Composite Resin cement; n: number of specimens.
*Statistically significant difference

TABLE 3. ANOVA comparison between the mean fracture resistance of the teeth restored by different post types and similar cements

Cement	Post		Mean difference (I-J)/N	95% confidence interval		*P* value
	I	J		Lower bound /N	Upper bound/N	
Zph	TIP	FBP	-4.7	-109.6	100.2	0.993
	TIP	SSP	113.5	8.5	218.4	0.032
	FBP	SSP	118.2	13.2	223.2	0.025
Res	TIP	FBP	46.2	-30.1	122.4	0.306
	TIP	SSP	57.9	-18.3	134.1	0.163
	FBP	SSP	11.7	-64.5	87.9	0.923

Abbreviations. Zph: Zinc Phosphate cement; Res: Composite Resin cement; TIP: Titanium Post; FBP: Fiber Post; SSP: Stainless Steel Post

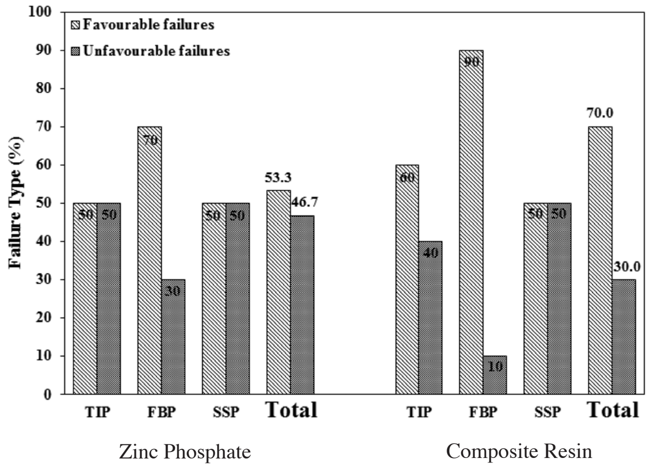

FIGURE 3. Numbers of favourable and unfavourable failures in the teeth restored with different dental posts and cements. Abbreviations. TIP: Titanium Post; FBP: Fiber Post; SSP: Stainless Steel Post

The Chi-square test showed that the teeth luted by resin cement provided more restorable failures compared to those restored with zinc phosphate cement (sig. 0.184). Moreover, the specimens restored by Fiber posts showed higher percentage of restorable failures in comparison to those restored with both titanium and stainless steel posts (sig. 0.112). Therefore, in spite of providing higher fracture resistance, the teeth cemented by zinc phosphate are less favorable in terms of failure mode than those luted by resin cement.

Figure 4 also shows the typical failure modes, which were most observed in each subgroup. In the specimens restored by titanium and stainless steel posts, the positions of the fracture lines within the roots were almost similar, independent of the cement used. In the specimens treated by stainless steel posts, the fracture lines were often initiated from the crown-dentin interface and extended down below the bone simulation level, whereas in the restored teeth containing titanium posts, the fracture was mostly occurred from the cervical dentin. On the contrary, the teeth restored by Fiber posts mostly demonstrated fractures above the bone simulation level, making the teeth amenable to retreatment. However, in the teeth restored by Fiber and luted with zinc phosphate, the fracture occurred at the post-core-dentin contact point; while horizontal fracture lines above bone simulation level were often observed in the specimens treated with Fiber posts and resin cements.

DISCUSSION

The main function of the post is to hold the core which will retain the crown and dissipate the stresses regularly through the root (Mittal et al. 2013). When load is applied to a structure with components of different rigidity, the stresses will concentrate on the components possessing higher modulus of elasticities without elastic deformation. In order to decrease the susceptibility of root fracture, the restorative substance should possess modulus of elasticities close to the root dentin to allow the distribution of the applied forces evenly along the length of the post and root (Barjau-Escribano et al. 2006) at which modulus of elasticities for dentin (20 GPa), Titanium (120 GPa), Fiber (54 GPa), Stainless Steel (220 GPa). When the failure mode was considered, only the fiber post group showed favorable fracture above the bone simulation level, sparing

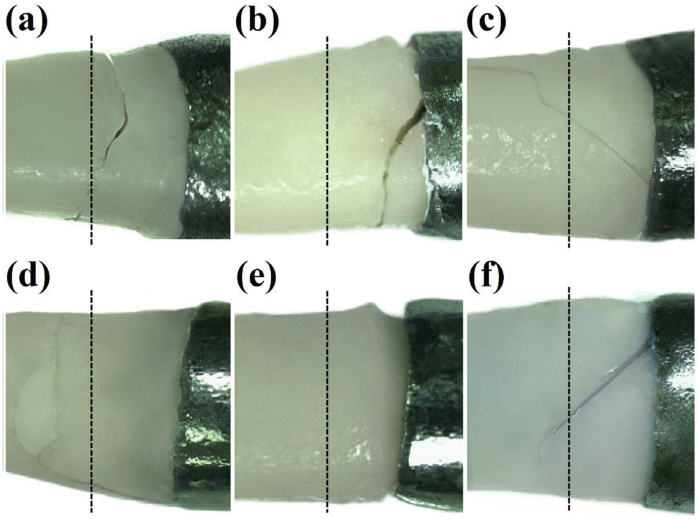

FIGURE 4. Typical failure modes that were mostly observed in various subgroups restored with different cements and dental posts. (a-c) tooth restored with zinc phosphate cement and titanium, fiber and stainless steel posts, respectively and (d-f) tooth restored with composite resin cement and titanium, fiber and stainless steel posts, respectively

the remaining tooth structure while the metal post groups showed unfavorable root fractures. The root fractures observed for various metallic post groups can be explained based on high modulus of elasticity of the metallic post materials and the favorable mode of failure for fiber posts can be attributed to their low modulus of elasticity which is close to that of dentin. This allows fiber post to flex under pressure and when load is applied it is more likely to act as stress absorbent and dissipate the stress to the post/cement/core/tooth interface regularly leading to the decrease in the stress on the tooth which cause more restorable failures (Seefeld et al. 2007).

The fracture resistance analysis of the teeth restored by different dental posts and cements also indicated the significant influence of cement type on the fracture resistance of the specimens treated by titanium and fiber posts. The zinc phosphate cement exhibits high compressive and tensile strengths and its modulus of elasticity is higher compared to the composite resin which allow zinc phosphate cement to withstand higher stresses than composite resin cement (Mittal et al. 2013). However, in spite of presenting lower fracture resistance values, the composite resin cements presented a higher percentage of favorable failures in comparison to the zinc phosphate cement. Luting dental post in the root with a cement who has modulus of elasticity similar to that of dentine, will transmit the stress of the applied forces more evenly to the root surfaces producing more favorable failures, reduces the susceptibility of root to fractures (Li et al. 2006). Furthermore, resin cement will provide a stronger union between post, core and tooth structure, resulting in monobloc type of restoration. This could improve the stress distribution and extensions of high stress areas could be avoided (Mohammadi et al. 2009).

CONCLUSION

Due to the *in vitro* nature of the experimental design, the present study presented some intrinsic limitations. For instance, the application of static loading does not perfectly reflects the intraoral situation. Moreover, the teeth selected in this study were upper central incisors and thus, the results may not completely applicable for prediction of the fracture behavior of the posterior teeth. However, within the limitations of this *in vitro* study, the following conclusions were drawn:

The correct selection of the post and cement materials could essentially increase the clinical success and longevity of the rehabilitation of endodontically treated teeth; teeth restored with posts and luted with zinc phosphate cement, showed a higher fracture resistance compared to those cemented with resin cement. In zinc phosphate cement group, specimens restored with titanium and fiber posts exhibited significantly higher fracture resistances compared to those restored with stainless steel posts. However, in the resin cement group, the differences between the fracture resistances of the subgroups were insignificant; teeth cemented with composite resin demonstrated more favorable failures compared to those luted with zinc phosphate cement; in both cement groups, the specimens restored with fiber post showed more favorable failures than those restored with titanium and stainless steel posts.

ACKNOWLEDGEMENTS

This research was supported by grant No. UM.C/625/HIR/MOHE/DENT/14, from the Ministry of Education, Malaysia. The authors have no conflicts of interest relevant to this article.

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Received: 16 October 2014
Accepted: 13 April 2015