Fracture resistance of pulpless teeth restored with cast post-and-core versus fiber reinforced composite resin

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Abstract

Objectives: To investigate the failure load and crack level in endodontically treated teeth restored by metal cast and fiber reinforced resin post-and-core under compressive and cyclic loading.

Materials and methods: One hundred twenty lower premolar endodontically treated teeth were prepared into 3 conditions; C1: ferrule 2 mm, C2: no ferrule, C3: less dentin wall. In each condition, teeth were restored with metal cast post-and-core (MC) and fiber-reinforced resin post-and-core (RC), total of 6 experimental groups (n=20). Completed crown was fabricated and cemented on the restored core of the teeth and embedded in a stone block. Specimens in each group were random into 2 subgroups (n=10), subjected to compressive load (45°to long axis of specimen) until fracture and to cyclic loading (300000 cycles, 45°to long axis, 250N at 2Hz) under water immersion at 37°C. The failure load was recorded, crack level was classified as: above (A), below (B) of the stone block. The data was analyzed by two-way ANOVA (α=0.05). The number of failed specimens were recorded and analyzed with Fisher Exact Test.

Results: There was statistical significant difference in group C1 to C2 and C3 ($P<0.05$). Predominant mode of failure B was found in group MC1, MC2, MC3 and RC1. There was no statistical significant difference among cyclic loading groups.

Conclusion: With ferrule, restored teeth were more resistant to failure than those with out absent of ferrule. Cast metal post-and-core showed unfavorable result when failure occurred.

Key words: cast metal post-and-core, compressive load, crack level, cyclic loading, ferrule, fiber reinforced resin post-and-core

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Introduction

Endodontically treated tooth is traditionally restored with cast metal post-and-core. The advantages of cast metal post-and-core are high mechanical properties and custom fit to root canal. Some retrospective studies reported that root fracture associated with cast metal post-and-care were higher when compared with other post-and-core material[1, 2]. Another in vitro study stated that cast metal post-and-core tended to produce unrestorable mode of failure[3]. Brandal et al[4] and Kantor et al[5] stated that rigid posts produced higher fracture resistance due to less distortion of the material. de Castro et al[6] reported that rigid post could produce stress in the critical area which caused root fracture. Prefabricated post was alternative to custom cast post-and-core. Carbon fiber post was introduced in 1990s for use as prefabricated post. Studies[7-10] had reported carbon fiber post properties compared to dentin and metal post. Post adaptation was another factor that affected the fracture resistance of the restored teeth[11,12]. Custom cast post adapted well to root surface whereas prefabricated fiber post needed luting cement to secure retention and marginal adaptation to the root. Investigators.[13-16] have studied properties of luting cement and their effect on fracture resistance of the root and suggested resin cement might produce better stress distribution.

The remaining tooth structure was another factor that affect survival rate of endodontically treated tooth. Ferrule effect[17] play role in force distribution that could make the tooth prone to failure. Al-Omiri and Al-Wahadni[18] reported that the more coronal dentin remained the more fracture resistance. In a clinical study by Cagidiaco et al[19] , they reported that ferrule did not affect the survival rate of the restoration when restored with fiber post and composite core. However, Ferrari et al[20] reported in their retrospective study that failure of endodontically treated teeth restored with fiber post related to remaining coronal tooth structure. An in vitro study[21] reported that severe loss of coronal dentin lessen fracture resistance. Appropriate selection of post-and-core material for each remaining tooth structure is controversial[22, 23]. The objective of this study were 1) to investigate failure load and crack level in different remaining premolars restored with cast metal or fiber reinforced resin post-and-core under compressive loading, and 2) to investigate the number of failed endodontically treated premolars restored with cast metal of fiber reinforced resin post-and-core under cyclic loading.

Materials and methods

One hundred and twenty sound extracted human lower premolars, single root canal with minimum root dimension of 4.1×3.8×12.6×2.1 mm (bucco-lingual, mesio-distal, length, diameter at 3 mm from the apex) were used in this study(24). The root dimension was measured by a digital caliper (Oudi®, Tokyo, Japan). The methods were performed under the ethical approved by MU-DT/PY-IRB. No. 2010/033.0209. Gross debris was removed and the teeth were kept in 0.1% thymol solution at 4°C for no longer than 1 month after extraction. All teeth were rinsed and stored in distilled water for 24 h before use. The teeth were sectioned at 17 mm from the apex of the roots by diamond burs (C850.314 Edenta AG, Hauptstrasse, Switzerland) with high speed handpiece (Kavo, Warthausen, Germany) under cooling water. The access opening was prepared with diamond burs with high speed handpiece. The root canal was prepared with Hedstrom file size #15-#35 (Dentsply Maillefer, Ballaigues, Switzerland), irrigated with 2.5% NaOCl solution, and filled with main cone and lateral cone gutta-percha (Sure-endo, Gyeonggi-do, Korea) with root canal sealer (Research Center, Faculty of Dentistry, Mahidol University). Teeth were random into 3 groups (n=40), Group

C1: 2 mm of ferrule, C2: absence of ferrule, C3: absence of ferrule with minimal dentinal wall thickness (1.5 mm). Ferrule was prepared by 1 mm diameter cylindrical diamond bur (D8 Edenta AG, Hauptstrasse, Switzerland) with high speed handpiece under water coolant. The finishing line was located 2 mm apical to upper part of the root (Figure 1A). The apical portion of tooth in group C2 and C3 was reduced by 2 mm (Figure 1B), then the dentinal wall of the canal of tooth in group C3 was reduced to 1.5 mm thickness for 8 mm apico-coronally (Figure 1C) by 1 mm diameter cylindrical diamond bur (Edenta AG, Hauptstrasse, Switzerland) with high speed handpiece under water coolant. Digital Vernier caliper (Oudi®, Tokyo, Japan) was used to verify the desired wall thickness.

The root canal of all specimens was drilled with FRC Postec Plus reamer size 0 and follow by size 1 (Ivoclar Vivadent AG, Schaan, Liechtenstein) in which gutta-percha was remained 4 mm from the root apex. Twenty specimen form each group was irrigated with 2.5% NaOCl (Faculty of Dentistry, Mahidol University, Research Center, Bangkok, Thailand) and etched with 37% phosphoric acid (Scotchbond™ universal etchant, 3M ESPE, St. Paul, USA) for 15 sec as recommended. The root canal was rinsed with NSS for 15 sec and dried with paper points. Self-etch bond (Excite F DSC, Ivoclar Vivadent AG, Schaan, Liechtenstein) was applied to the post surfaces for 15 sec then rinsed with water and blown dry. The composite resin core (Multicore flow®, Ivoclar Vivadent AG, Schaan, Liechtenstein) was injected from the mixing gun into the canals and around the posts. The posts were inserted into the canals at the determined length and light-cured for 40 sec (Bluephase, Ivoclar Vivadent AG, Schaan, Liechtenstein). The composite cores were fabricated, 8 degree convergence, 5 mm height, and labeled as RC1, RC2 and RC3 group.

The remained specimen (n=20) in each group were restored with cast post-and-core. Wax pattern (Renfert, Hilzingen, Germany) were adapted to the root canal. The core was 5 mm in height, with 8 degree convergence, and casted with nickel-chromium alloy (Noritake super alloy Ex-3, Noritake Dental Supply, Aichi, Japan). The metal post-and-core was try-in and cemented to the canal with dual cured resin

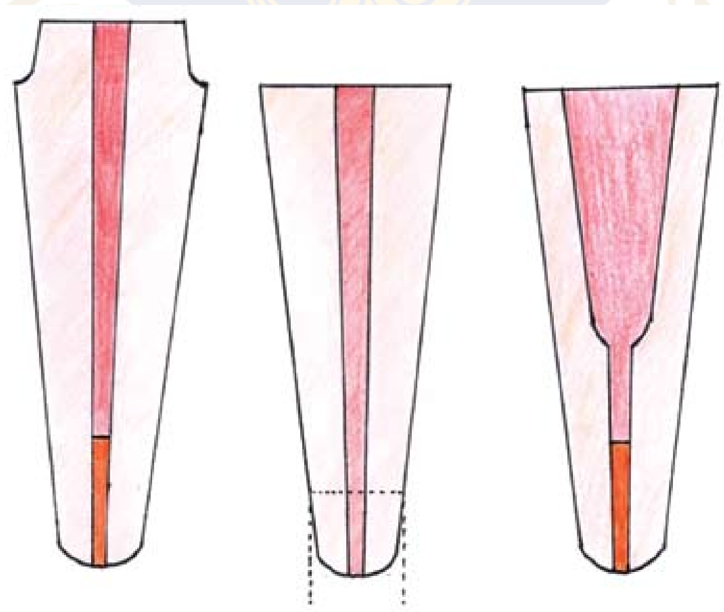

Figure 1 A-C Dimension of tooth structure preparation

cement (Multilink automix, Ivoclar Vivadent AG, Schann, Liechtenstein) according to the manufacturer's recommendation and labeled as MC1, MC2, and MC3 group (Figure 2). Full coverage crown (nickel-chromium alloy) was fabricated on the core of all specimens, 7 mm in height from finishing line, 3 mm of 45°bevel areas at buccal side. The crown was cemented with resin cement (Multilink automix, Ivoclar Vivadent AG, Schann, Liechtenstein). Each specimen was mounted in PVC block (Thai Pipe, Bangkok, Thailand) using type IV stone (Vel-Mix, Kerr, Bioggio, Switzerland).

For the compressive load test, half of the specimens in each group (n=10) were pressed with round head, 5 mm radius, stainless steel rod at the center of beveled area of the crown at 45° to the long axis of the tooth (Figure 3) which mounted to the universal testing machine (Instron 5565, Instron Corp, Canto, Mass, USA) at crosshead speed 2 mm/min until failure. The failure load was recorded, analyzed by SPSS v.16 for Windows. Data distribution was analyzed by Shapiro-Wilk test and Levene's Test. Two-way ANOVA (α=0.05) was used to analyze compressive load. Crack was observed under 40× magnification light microscope (Olympus CX-31, Olympus, Japan). Fracture of crowns, core material or root up to 2 mm below the margin of the crown were classified as above the embedded block (A) or restorable. Whereas fracture were root fracture extended beyond the block, combination of crown, post, core or vertical root fracture were classified as below the embedded block (B) or nonrestorable.

For the cyclic load test, the remain specimens in each group (n=10) were subjected to loading, 45° to the long axis of the tooth, at 250 N 2Hz by round-headed, 5 mm radius, cylinder rod, assembled to Electric Dynamic Test Instrument (Electro Puls E1000, Instron Corp, Canton, Mass, USA) for 300,000 cycles. The loads were performed under water immersion, 37°C. Fisher exact test was used to analyze the number of failed and non-failed specimens to detect the difference between experimental groups (α=0.05).

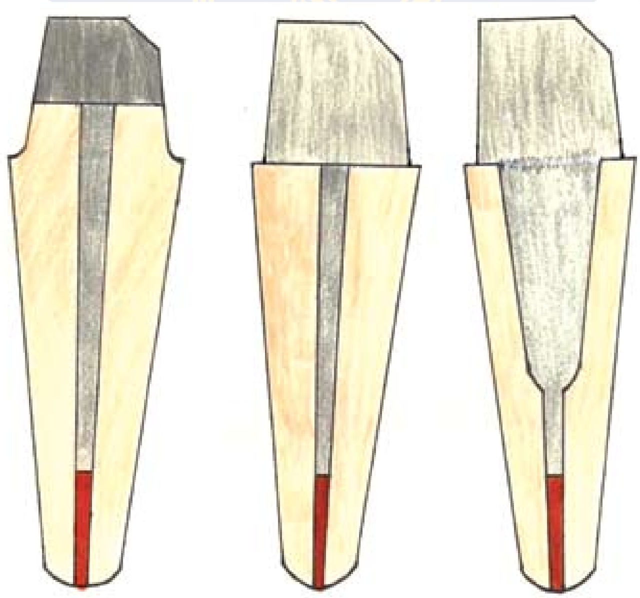

Figure 2 Diagram of prepared specimens of cast post-and-core groups (MC1, MC2, MC3)

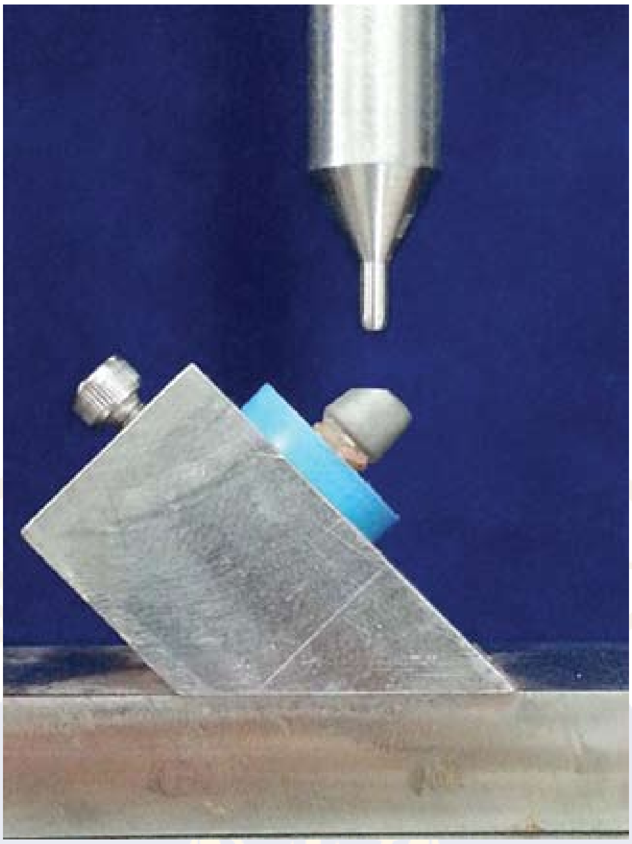

Figure 3 Mounted specimen with the custom-made jig assembled to the universal testing machine

Results

The means and standard deviations of failure loads are shown in Table 1. Shapiro-Wilk test showed data were normal distributed ($P>0.05$), Levene's test demonstrated homogeneous ($P>0.05$). The two-way ANOVA (Table 2) indicated that there were no interactions between remaining tooth structure levels and post-and-core types ($P=0.444$). The remaining tooth structure was further analyzed using Tukey's HSD (Table 3). Group C1, 2 mm ferrule, demonstrated significant higher failure load than groups C2 and C3 ($P<0.05$) whereas no significant difference between group C2 and C3 ($P>0.05$).

Cracked below the block (B) were found in all specimens of cast metal post-and-core groups (MC1, MC2, MC3), specimens restored with fiber-reinforced resin post-and-core with ferrule (RC1), one specimen in group RC2, and 5 specimens in group RC3. Cracked above the block (A) were found in RC2 (n=9), and RC3 (n=5).

For cyclic load, the factor type of post-and-core demonstrated no significant different between cast metal (MC) or fiber-reinforced resin (RC) in each remaining tooth structure ($P>0.05$). The factor remaining tooth structure demonstrated no significant different between the remaining tooth structures (C1, C2, C3) in each post-and-core types ($P>0.05$) (Table 4).

Table 1 Mean and standard deviation of failure load (N) between type of post-and-core (MC, RC) and remaining tooth structure (C1, C2, C3)

Type of post-and-core	Remaining tooth structure		
	Ferrule 2mm (C1)	No ferrule (C2)	No ferrule and minimal dentin wall (C3)
Cast metal (MC)	978±89	530±128	652±146
Fiber-reinforced (RC)	995±143	493±54	473±98

Table 2 2-way ANOVA of failure load between remaining tooth structure and type of post-and-core (α=0.05)

Variation	SS	MS	p-value
Remaining tooth structure	2946256.722	1473128.361	0.000
Type post-and-core	22944.273	22944.273	0.282
Remaining tooth structure* Type post-and-core	31990.632	15995.316	0.444

Table 3 Mean and standard deviation of failure load between remaining tooth structures. Multiple comparisons by Tukey's HSD

Remaining tooth structure (n=20)	Failure Load (N)
Ferrule 2 mm (C1)	987±128
No ferrule (C2)	512±127[a]
No ferrule with minimal dentin (C3)	522±174[a]

[a] Mean difference is significant at α=0.05

Table 4 Cyclic loading, multiple comparisons between post-and-core types, remaining tooth structure by Fisher's Exact (α=0.05)

	Type	*P*-value
Type of post-and-core	MC1	0.211
	RC1	
	MC2	0.303
	RC2	
	MC3	0.057
	RC3	
Remaining tooth structure	MC1	0.531
	MC2	
	MC3	
	RC1	1.000
	RC2	
	RC3	

Discussion

This study investigated the influence of remaining tooth structures and post-and-core materials under compressive and cyclic loaded. During compressive loaded, force was applied to the testing specimens, 45° to long axis of the tooth, at crosshead speed of 2 mm/min. to simulate lateral parafunctional force rather than chewing or impact force[25, 26]. Results revealed that the presence of 2 mm coronal dentin influenced fracture resistance of the specimens which resembled to previous studies[3,18,27]. For group C2 and C3 which were different in diameter of remaining dentin wall, failure loads were not significant difference. This can be explained by the indicated guideline from Sorensen[28] which proposed to preserve at least 1 mm of minimal dentin wall. Group C3 had 1.5 mm of remaining dentin wall which was within the limit of the proposed guideline. In situation that remaining dentin wall less than 1 mm, the failure loaded might have been different[29].

For material of post-and-core, the failure loaded demonstrated no significant different between factor of type of post-and-core which resembled to previous studies[30,31]. However, all specimens in group C1 had unrestorable mode of failure since crack propagated below the block. This could be explained that C1 had higher failure load, dislodgement of post were not occurred, but cracked instead. Group MC2 and MC3 exhibited unrestorable mode of failure, cracked extended below the block. Whereas 9 specimens in group RC2 and 5 specimens in group RC3 were above the block. This could be explained that the modulus of elasticity of Nickle-Chromium alloy was ten times to that of dentin whereas fiber reinforced-resin had modulus of elasticity closed to those of dentin. When forces were applied, loaded were transmitted from the restoration to the post and to the root dentin and caused root fracture. Group RC2 and RC3 demonstrated breakage of core or debond of fiber post-and-core from root dentin. This could reduce incidence of root fracture and made possible for another restoration.

The cyclic load at 250 N for 300,000 cycle simulated functional load in clinical used for around 1 year[24,32]. Result from this study was not different between remaining tooth structure and types of material used for post-and-core. This can be interpreted that different remaining tooth structures had no effect on the number of failed specimens.

The limitation of this study were the number of specimens in each testing groups, use of finger pressure for seating post-and-cores and crowns, which may affected seating force. Further investigation should include thermocycling and higher cyclic loading cycle.

Within the limitations of this study, it can be concluded that pulpless teeth with ferrule had higher failure loaded than those without ferrule. Without ferrule, pulpless teeth restored with fiber-reinforced resin post-and-core mostly exhibited restorable mode of failure. Cyclic loading test yielded no significant different between type of post-and-cores.

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