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In Vitro Evaluation of the Ferrule Effect and Post Material on Failure Load and Mode in Endodontically Treated Teeth

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Abstract

Aim: To compare the ferrule effect and two types of bonded post material on failure load and mode of crowned endodontically treated teeth.

Methods: Sixty eight extracted human maxillary central incisors were sectioned 15 mm coronal to the root apex using hard tissue cutter. They were then endodontically treated with master apical file size 45 and obturated with gutta percha and AH 26 sealer using lateral condensation technique. Samples were randomly divided into four groups of 17 where Group A was placed with titanium post without ferrule preparation; Group B placed with titanium post and 2 mm ferrule preparation; Group C placed with fiber white post without ferrule preparation and Group D placed with fiber white post and 2 mm ferrule preparation. Next, the core was built with Paracore and Ni-Cr crowns cemented before held in a metal base for the testing using universal testing machine. A compressive load at a crosshead speed of 1mm/min at an angle of 135º to the long axis of the sample was applied until failure.

Results: Kruskal-Wallis test indicated no significant difference in failure load between groups at α=0.05. Chi-square test for independence showed a significant difference in failure mode between the groups at α=0.05.

Conclusion: Ferrule effect preparation and type of bonded post materials give no difference on failure load of endodontically treated teeth. Fiber reinforced composite posts have a more favourable failure mode when compared to metallic posts.

Keywords: Ferrule effect; Endodontically treated teeth; Crown; Dentine bonding

Introduction

Many concepts for restoration of endodontically treated teeth have been proposed during the last 20 years but the best techniques and materials for restoration of endodontically treated teeth is still controversial especially with the development of new post materials. Carbon fiber reinforced posts gained popularity in the 1990s. Their main proposed advantage was that they were more flexible than metal posts and had approximately the same modulus of elasticity as dentin resulting in fewer root fractures. Other types of fiber reinforced posts were also introduced, including quartz fiber, glass fiber and silicon fiber reinforced posts. They are claimed to offer the same advantages as the carbon fiber reinforced posts, but with better esthetics [1].

Cast metal posts advocate the use of ferrule effect to reduce the fracture susceptibility of the remaining tooth structure. Even though some studies found that ferrule effect is important [2-5]; however the importance of it is not clear with recent advancements like bonded titanium posts and fiber reinforced composite posts with adhesive resin cements that could provide internal bracing of the root that substitutes for the ferrule effect [6-8]. The debate about which post material can sustain higher failure loads (thus longer clinical service) and express more favourable failure modes (thus allow re-restoration) is also still unsolved in literature.

The aim of this study was to compare the effect of ferrule and two types of bonded post material on failure load and mode of restored endodontically treated teeth.

Materials and Methods

Sixty eight extracted human maxillary central incisors were collected cleaned and placed in plastic jars containing 5% thymol solution to prevent dryness [6]. Teeth were inspected at 10X magnification using stereomicroscope (SZ2 Olympus, Japan) [9] for any caries, cracks or restorations up to 15 mm from the root apex. Exclusion criteria were teeth with abnormal root forms, open apices, previous endodontic treatments or external root resorption.

A hard tissue cutter (Exakt, Japan) was used to cut the teeth horizontally into two halves coronal and radicular, before the distance between the cutting line and the root apex was gradually reduced using high speed handpiece to a distance 15 ± 0.1 mm measured with a digital calliper (Fowler Co., Inc. USA).

Endodontic instrumentation was done for all the teeth following step-back technique. Using hand files and reamers with master apical file of ISO #45 and three steps back. Irrigating done using normal saline [10,11] and obturation was done with gutta percha (Meta Dental Co. Ltd, Korea) and AH 26 (Dentsply Maillefer, Germany) sealer using lateral condensation technique and finally by vertical condensation with hand pluggers [11]. Gutta percha was then removed using Gates Glidden rotary instruments leaving 5 mm of gutta percha apically [12]. Later post holes were prepared using Tenax drills (Coltene Whaledent, USA) up to size 130 mm in a slow speed handpiece to enlarge the canals to a length of 10 mm from the canal orifice. Tenax posts were then tested for their fitness inside the prepared canals and radiographs were taken to check for any extensive internal resorption, correctness of post whole preparation and any remaining gutta percha [6].

Sixty eight samples which comply with the inclusion and exclusion

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Figure 1: Sample from each group from left to right (A, B, C, D).

Figure 2: The metal base used to hold the specimen for testing.

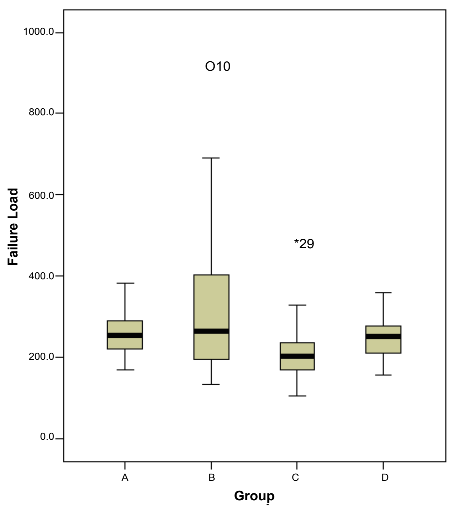

Figure 3: Distribution of scores of failure load (N) for Groups A, B, C, and D.

criteria were randomized into four groups with 17 teeth each. Group A was placed with a titanium post and had no crown ferrule preparation, Group B was placed with a titanium post and had a 2 mm ferrule preparation, Group C was placed with a glass fiber reinforced post without ferrule preparation and Group D was placed with a glass fiber reinforced post and a 2 mm ferrule preparation (Figure 1).

The buccolingual and mesiodistal dimension of each sample was measured using digital calliper and checked with one-way ANOVA between-groups test to confirm no statistically significant difference at the $p<0.05$. Ferrule preparation was performed for samples of groups B and D with the finishing line of 90° shoulder located 2 mm radicular to the sectioned surface of the sample [13]. Two types of posts were chosen which were, Tenax and Tenax fiber white (Coltene Whaledent, USA) which are made of titanium and glass fibre reinforced composite respectively with diameter of 1.3 mm and 13mm in length. Panavia F (Kurary Medical Inc., Japan) a dual cure adhesive was used for cementation of the posts for all groups following the manufacturer's guidelines.

Core buildup was done using Paracore automix dual cure core material (Coltene Whaledent, USA). The parabond non-rinse conditioner was applied to the post and the sectioned sample surface air dried, followed by parabond adhesive applied for 30 seconds and air dried before Paracore material was injected into paraform coreformer #1 (Coltene Whaledent, USA). They were then placed over the post and the sectioned sample surface for 4 minutes to set. Finishing was done diamond burs and the core was shortened so that the length from the root tip to the coronal edge was 21 mm for all samples.

Direct wax patterns were made over the samples, invested and then casted with NiCr alloy to construct all metal crowns. One sample of group C was accidentally fractured thus considered as a drop out. Finishing of the crowns was done and then checked for retention and margin accuracy. The length of each sample with the crown in place was checked using the digital calliper to be 23 ± 0.1 mm. A 1mm depth groove at 3 mm radicular to the incisal edge was drilled mesiodistally on the lingual surface of the metal crown using high speed handpiece to act as a point of force application during mechanical testing. Crowns were cemented with Ketac-Cem (3M ESPE, Germany) following the manufacturer's instructions.

Four iron metal blocks were constructed to hold specimens during mechanical testing [3] which were right triangle in shape in vertical section with hypotenuse 9.899 cm in length and catheti of 7 cm each. A cylindrical hole was drilled perpendicular to the block hypotenuse at the center of each block with a different diameter for different block (5.5 mm, 6.5 mm, 7.5 mm, and 8.5 mm) to accommodate to different specimens' widths. The depth of the hole was controlled to be 11 mm by condensing amalgam restorative material inside. This metal block served to hold the specimen securely in place during mechanical testing which was angled at 135° to force application tip [14] of the Instron 3366 Universal Testing Machine (Instron, USA) (Figure 2). Examix vinyl polysiloxane impression material (GC America Inc. USA) was injected between the specimen and the hole wall to simulate the periodontal ligament. The cross head speed was 1 mm/min and the specimens were loaded until total failure as indicated by retraction of the machine arm. The maximum load was recorded as the failure load. Failure mode was recorded as either favorable failure (involve the restoration only not the tooth structure) or unfavorable failure (involve the restoration and/or the tooth structure).

SPSS 12.0.1 software was used to analyse the data and Kruskal Wallis test was performed to detect any significant difference in failure loads between the groups. Chi-square test for independence was performed to detect any significant difference in failure modes between the groups.

Results

Descriptive statistics showed that Group B had the highest failure load mean of 349.78N (SD 221.30), followed by Group A at 261.18N (SD 64.24), Group D at 249.89N (SD 55.20), and finally Group C at 217.00N (SD 84.96).The distribution for each group is shown in the box plot (Figure 3).

Variable	Group (treatment)	N	Median (IQR)	x^2 statistic (df)[a]	p-value[a]
Failure load (N)	A (titanium post, no ferrule effect)	16	253.10 (76.6)	6.741 (3)	0.081
	B (titanium post, ferrule effect)	17	265.40 (279.7)		
	C (fiber reinforced composite post, no ferrule effect)	16	203.10 (68.7)		
	D (fiber reinforced composite post, ferrule effect)	16	251.75 (69.2)		

[a]Kruskal-Wallis Test

Table 1: Comparison of failure load between the study groups.

Variable	Group (treatment)	N	Favourable failure n (%)	Unfavourable failure n (%)	x^2 statistic [a] (df)	p- value
Failure mode	A (titanium post, no ferrule effect)	16	6 (37.5)	10 (62.5)	39.181(3)	<0.001
	B (titanium post, ferrule effect)	17	0 (0)	17 (100)		
	C (fiber reinforced composite post, no ferrule effect)	16	14 (87.5)	2 (12.5)		
	D (fiber reinforced composite post, ferrule effect)	16	0 (0)	16 (100)		

[a]Chi-square test for independence

Table 2: Comparison of failure mode between the study groups.

Variable	Groups	x^2 statistic [a] (df)	p- value
Failure mode	A vs. B	7.792(1)	0.007*
	A vs. C	8.533(1)	0.003*
	A vs. D	7.385(1)	0.007*
	B vs. C	25.836(1)	<0.001*
	B vs. D	Constant	Constant
	C vs. D	24.889(1)	<0.001*

[a]Chi-square test for independence
*Significant difference

Table 3: Comparison of failure mode between each pair of study groups.

Results from Kruskal-Wallis Test found that the medians of failure load were not statistically significant across the four groups (p>0.05) (Table 1) with Group B having the highest median of 265.40N (279.7) followed by Group A=253.10N (76.6).

Group D=251.75N (69.2) and finally Group C=203.10N (68.7). Chi-Square value was 6.741(3) and p-value was 0.081.

Failure mode results showed that, Group C had the highest frequency of favorable failures, with 14 (87.5%) favorable failures and 2 (12.5%) unfavorable failures. Group A had 6 (37.5%) favorable and 10 (62.5%) unfavorable failures. Group B had 0 (0%) favorable and 17 (100%) unfavorable failures. Group D had 0 (0%) favorable and 16 (0%) unfavorable failures (Table 2).

Chi-square test for independence was used to compare failure mode values between the treatment groups. Chi-Square statistics was 39.181(3) and a significant difference between the groups was indicated (p<0.05) (Table 1). Group C had a significantly more favorable failure mode (p<0.0083) when compared to groups A, B and D. Group A had a significantly more favorable failure mode (p<0.0083) when compared to groups B and D. No statistics were computed between groups B and D because failure mode was a constant (Table 3).

Discussion

Results of the study showed that the teeth placed with titanium post generally has higher failure load than glass fiber reinforced composite post and teeth with 2 mm ferrule has higher failure load than without ferrule preparation even not statistically significant. Previous studies findings lead to the general consensus which need a 2 mm ferrule in prevention of fracture of the endodontically treated teeth [2-5]. The ferrule preparation reinforces the tooth at the external surface by dissipating the forces that concentrate at the narrowest circumference of the tooth [15]. It also resists lateral forces from posts and leverage from the crown in function, thus increases the retention and resistance of the restoration [16].

However, with the production of new materials nowadays, this consensus might need revision. This current study found that no significant effect of ferrule compared to previous studies, which may be due to several factors such as type of luting cement and methods and type of post. Previously, the posts were commonly cemented with conventional zinc-phosphate cement or resin modified glass ionomer cements. These materials depend on friction forces or chemical bonding for retention of the posts, but in this study, resin cement were used which adopt dentinal bonding system and could provide internal bracing of the root that substitute for the extracoronal ferrule [7]. Few other studies found similar conclusion [6,8].

Clinical benefits achieved by omitting the ferrule preparation includes minimize periodontal effect or trauma of extending the finishing line gingivally [6] and also any tooth with minimal remaining coronal dentine not enough for ferrule preparation can be simply restored by bonding the post to the radicular dentine. This is a better option than crown lengthening procedures [17] as it will not affect the crown-root ratio, more cost effective and less time consuming.

The result also shows that groups restored with titanium posts ranked higher in failure load results than groups restored with glass fiber reinforced posts which is in agreement with the findings of other studies [18,19]. Other study shows significant result of higher failure load for titanium posts compared to glass fiber reinforced posts [20]. This might be due to the angle of force application which was horizontally at 90° to the long axis of the experimented teeth whereas in this study the angle of force application was 135° that simulate better the average angle of contact between maxillary and mandibular incisors in a Class I occlusion [21].

The contradict result was found from study by Akkayan and Gulmez where there is significantly higher failure loads for endodontically treated teeth restored with glass fiber reinforced composite posts than those restored with titanium post [22]. The different diameter and design of the tested posts may have led to the observed different result. In this study both titanium and glass fiber reinforced composite posts had the same diameter (1.3 mm) and design (parallel with tapered end). Parallel posts could distribute stresses more evenly along their length than tapered ones and thus less likely to cause root fractures.

The results of this study found that fiber reinforced composite post had a significant higher percentage of favorable failure modes when compared to metal post. This is in agreement with previous studies [22-24]. Recent study by Franco et al. also found that the use of glass fiber posts and composite resin cores gives more repairable failure where no root fracture detected and appears to protect tooth structure against fracture [25]. The modulus of elasticity of the different post systems used in this study should be taken into account to explain the differences in failure mode.

The high modulus of elasticity of titanium compared to dentin may be responsible for the higher percentage of unfavourable failures. Glass fiber reinforced composite posts on the other hand, exhibited a modulus of elasticity much better matched to that of teeth than titanium, leading to higher percentage of favourable failures [22]. Ferrule effect may have neglected that advantage of glass fiber reinforced composite posts.

Conclusions

Within the limitation of this study, titanium posts had higher means of failure load than those with glass fiber reinforced posts and groups with ferrule effect had higher means of failure load than those without when the post material is the same. However, there is no significant difference in failure load results between study groups.

It was found that post material had a significant effect on failure mode, with significantly higher percentage of favourable failures when the glass fiber reinforced post was used compared to titanium post. However no significant difference in failure mode was found between the two materials when the ferrule effect was utilized and groups with the ferrule effect had only unfavourable failures.

Clinical Significance

The results of this study support the bonding of posts to tooth structure as an alternative to the ferrule preparation, especially when the ferrule preparation is not desirable clinically. The study also support the clinical use of fiber reinforced composite posts as they result in more favourable failures than metal posts without significantly decrease the fracture resistance. Thus, re-treatment will be easier if failure occurred.

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