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Original Article

Comparative evaluation of fracture resistance of various post systems using different luting agents under tangential loading

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ABSTRACT

Objective: The purpose of this in vitro study was to evaluate the fracture resistance of various post system using different luting agents under tangential loading after wet thermocycling.

Material & methods: Seventy freshly extracted maxillary central incisors were endodontically treated and post-spaces were prepared to receive different post system. They were assigned to 7 groups. Composite resin was used as core material in all the groups. Three type of post system: prefabricated post system (ParaPost[®] XP[™]), fibre post (ParaPost[®] fiber Lux[™]), cast nickel–chromium alloy post and two type of luting cements dual cure resin cement (ParaCem[®], Whaledent) and glass ionomer cement (Fuji I, GC) were used. The specimens were thermocycled and subjected to tangential loading at a crosshead speed of 1.5 mm/min. The failure loads were recorded and data were statistically analyzed with one-way ANOVA ($p < 0.05$) and Student's *t* tests ($p < 0.001$).

Results: Significant differences of fracture resistance were detected among groups ($p < 0.001$). The greatest number of repairable fracture mode was recorded in fibre posts and resin cement system.

Conclusions: Within the limitations of this in vitro study, it can be stated that fibre posts can be recommended as a better alternative to the cast post and cores and prefabricated metallic posts in the anterior region and resin cement might give additional fracture resistance when used for post and crown cementation.

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1. Introduction

Endodontically treated teeth are at higher risk of fracture than vital teeth due to the decreased moisture content in dentin and most of the times, compromised structural integrity.¹ For functional and esthetic concerns, complete coverage crown restorations along with post and core is often recommended to enhance retention of crowns. The cast post and core technique has been advocated as the gold standard restoration for decades, but the traditional technique is time consuming and involves great laboratory and material costs. Introduction of prefabricated metallic post systems and esthetic post systems such as fibre-reinforced and zirconia ceramic posts have improved the results significantly.² Compared with the cast post and core technique, use of prefabricated post systems with direct core build-ups is less invasive, less time consuming and can simplify the restoration procedure.

The design, length and surface of endodontic post systems, luting agents, pattern of loading influence the retentive properties of a post system. For a tooth restoration complex, the dentin, cement, post, core, crown and their interfaces might have varying stress concentrations because of their different mechanical characteristics when chewing forces are exerted.^{3–5} It has been suggested that the post material should have similar modulus of elasticity as dentin (18.6 GPa) to distribute the applied forces evenly along the length of the post and root.^{1,3,4} With a number of manufacturers claiming their product's superiority over custom cast and prefabricated post core system, this *in vitro* study was designed to evaluate the fracture resistance of various post systems using different luting agents under tangential loading after wet thermocycling.

2. Material & method

To standardize the procedure, standard instruments and equipments were used to determine the fracture resistance of endodontically treated anterior teeth with various post systems and the different luting agents under tangential loading.

2.1. Sample preparation

Seventy freshly extracted maxillary central incisors were selected for the study with a mean length of 22 mm and were disinfected for 48 h in 2% glutaraldehyde solution. They were stored in saline solution when not under testing. Coronal

portion of all the teeth were removed leaving 2 mm above the cemento-enamel junction (CEJ) using diamond disk. The overall mean root dimension from the CEJ was 14 ± 1.0 mm. Endodontic treatment was carried out in all the specimens using hand ProTaper with the crown down technique and obturated with ISO No. 25 (F-2) gutta percha cones using vertical condensation.

After letting the root canal sealer to set for 48 h, gutta percha was removed from the root canals using reamer no.4 to a length of 9 mm, leaving at least 4–5 mm of root canal filling in the apical third of the root. The final enlargements were accomplished with a 1.5 mm diameter titanium drill (Para-Post) to a depth of 9 mm. The length of the radicular portion was maintained at 9 mm and the coronal portion 2 mm from the CEJ with superior head of post projecting out for retention of core. The specimens were then randomly assigned to seven groups with 10 teeth each (Table 1) (Fig. 1). Posts of diameter 1.5 mm were used. For cementing the prefabricated posts with dual-curing adhesive resin cement system, the root canals were rinsed with water spray and gently air-dried, and then preconditioned with a self-etching primer and cemented. The cast posts were carefully sandblasted with 50- μ m aluminum oxide at 1.5 bars pressure and ultrasonically cleaned. Standardized composite resin core foundations were fabricated over the posts using a vinyl polysiloxane impression material mold made with a core former. The core was then light polymerized for 40 s. All the specimens were stressed in a thermal cycling machine for 5000 cycles (5 °C/55 °C) for aging and to mimic the clinical conditions.

2.2. Evaluation of fracture resistance and modes

Root surfaces of all the teeth were dipped into molten wax to a depth 2 mm below the facial CEJ to produce a 0.2–0.3 mm layer to simulate the thickness of the periodontal ligament. Teeth were mounted in acrylic resin blocks (1 × 1 × 1 inch). Each tooth was removed from the resin block when the first signs of polymerization were observed. Once the resin block was polymerized, the wax spacer was removed from the root surface and alveolus of the acrylic resin block and polyvinyl siloxane impression material was delivered with the dispenser gun through the mixing tip into the acrylic resin alveolus. The tooth was reinserted into the test block, and the impression material was allowed to set; and trimmed to provide a flat surface 2 mm below the facial CEJ of each tooth.

The mounted specimens were secured in a universal testing machine and load was applied with a specially made device that allowed loading of the tooth at the middle point of

Table 1 – Overview of experimental groups.

Groups	No. of samples	Post-system	Core material	Luting cement
Group 1	10	Fibre post	Composite	Resin
Group 2	10	Titanium alloy post	Composite	Resin
Group 3	10	Titanium alloy post	Composite	Glass ionomer
Group 4	10	Cast post	Composite	Resin
Group 5	10	Cast post	Composite	Glass ionomer
Group 6	10	Cast post and core	Cast metal	Resin
Group 7 (control)	10	Cast post and core	Cast metal	Glass ionomer

Fig. 1 – Posts systems from left to right: titanium alloy post, fibre post, cast post, cast post and core.

palatal side of the incisal edge 135° to the long axis (Fig. 2). At a crosshead speed of 1.5 mm per min, the specimens were loaded until fracture. The failure loads were recorded from the first fracture point that was represented on a computer connected to the testing machine by the first drop of the load. The modes of fracture were determined and classified as repairable or catastrophic using a stereo-microscope (Olympus SV8). Fractures in the incisal third of root, core fracture and dislodging of posts were deemed repairable, fractures below were deemed catastrophic.

3. Results

Results are summarized in Tables 2 and 3. The highest fracture resistance was observed in group 1, in which fibre post

Fig. 2 – Showing method of fracture load of sample.

and resin cement system were used for restoration. The lowest fracture resistance was recorded for group 5 with cast post and composite core and glass ionomer cement. Table 3 shows that the failure load was significantly higher in groups 1, 2, 3, 4 and 6 when compared with group 7 (control group). There was no significant difference in failure load between groups 5 and 7. Significant differences of fracture resistance were detected among all groups ($p < 0.001$) except between groups 5 and 7. The maximum number of repairable fracture mode was recorded in group 1, then in groups 2, 4, 5 and minimum in groups 3, 6, 7. Failure load was significantly higher in group 6 from group 5. The maximum number of catastrophic fracture mode was recorded in groups 3, 6, 7, then in groups 4, 5 and minimum in group 1. The greatest number of repairable fracture mode was recorded in group 1, in which fibre posts and resin cement system were used for restoration.

4. Discussion

In the current study, the fracture resistance of endodontically treated incisors was evaluated when using three post systems and two luting agents. Parallel glass fibre post with composite core, parallel prefabricated metal post with composite core, cast post with composite core and cast post and core were used with two different type of luting agents i.e. resin cement and glass ionomer cement. These cements were chosen as G.I.C. bonds chemically to tooth structure and resin cement is gaining popularity as various investigators^{6–10} have reported advantages related to its use. Human teeth have been commonly used for the in vitro testing of post restorations. Ottl et al¹¹ used composite filling material, whose modulus of elasticity corresponds to that of dentin, for manufacturing dimensionally standardized roots, but the results could not be compared to clinical situations, as it was not possible to achieve a similar bond like that between the post and natural tooth. Taking this into consideration, extracted human teeth were used for the preparation of the test specimens in this study, even though human teeth show relatively large variation in size and mechanical properties.

Maxillary central incisor was selected as it is the most vulnerable tooth to trauma because of its position and thereby, requires maximum restoration in terms of post core.

Table 2 – Statistical analyses of fracture loads and modes of fracture load.

Groups	Mean (n) $\pm$ s.d.	p -Value	Fracture repairable/catastrophic
1	479.20 $\pm$ 22.2	–	8/2
2	426.80 $\pm$ 22.34	<0.01*	4/6
3	389.20 $\pm$ 21.34	<0.001*	2/8
4	376.00 $\pm$ 20.77	<0.001*	4/6
5	333.40 $\pm$ 17.04	<0.001*	4/6
6	414.20 $\pm$ 14.58	<0.001*	2/8
7	334.00 $\pm$ 22.63	<0.001*	2/8

*Compared with group 1.

Table 3 – Showing comparison of failure loads in different experimental groups (group 1, group 2, group 3, group 4, group 5 and group 6) from group 7 (control group).

	't' Value	'p' Value	Significance
Group 1 vs group 7	10.26	<0.001	*
Group 2 vs group 7	6.053	<0.001	*
Group 3 vs group 7	3.97	<0.01	*
Group 4 vs group 7	3.06	<0.02	*
Group 5 vs group 7	0.05	0.98	+
Group 6 vs group 7	6.66	<0.001	*

't' – Student 't' test, p – probability factor, (*) = significant, (+) = non-significant.

All teeth were shortened 2 mm above the most incisal point of the CEJ as 1.5–2 mm of remaining coronal tooth structure has been shown to significantly enhance fracture resistance of endodontically treated teeth, restored with cast posts and cores and complete crowns.^{12,13} Post diameter 1.5 mm for maxillary central incisor, not exceeding one third the mesio-distal root width, was used in the study¹⁴ and standardized composite resin core foundations were fabricated over the posts. When forces are applied directly on core, there is a wedging effect on the root.¹⁵ However, if the core is covered by a complete crown, the wedging effect disappears with a shift of stress concentration to the CEJ. The crown changed the distribution of forces to the root and the post and core complex, rendering the post characteristics insignificant. It was considered that by eliminating such parameters such as material structure, shape, length, and thickness, by crown restorations, the structural integrity and fracture resistance of a post and core foundation could be tested more precisely.

To simulate the movement of periodontal ligament, each root was embedded in an acrylic resin socket lined with a polyvinyl siloxane impression material,¹⁶ although no measurements of actual mobility were made. Specimens were removed from the resin blocks after the first signs of the polymerization to eliminate the effect of heat of polymerization on dentin. The heat generated leads to decreased moisture content, crazing, and weakening of the sample, which indirectly affects the fracture resistance value.¹⁷ The loading angle of 135° from palatal to labial was selected on the basis that it simulates the average angle of contact between maxillary and mandibular incisors in Class I occlusion¹⁸ and is a test of function.^{19,20} A crosshead speed of 1.5 mm/min was selected to allow time for distribution of the force from the point of application i.e. from the core to throughout the post.^{21,22}

The group 1 (fibre posts) exhibited the highest mean fracture load. This could be explained as fibre posts and composite cores possess a modulus of elasticity much better matched to that of dentin; the creation of mono-block dentin-post-core system through the dentin-bonding allows better distribution of applied forces evenly along the length of the post and root. Therefore, the excessive loads would be absorbed.²³ The higher modulus of elasticity of titanium alloy and cast metal (in other groups) compared with dentin would have lead to the stress concentrations, and might be responsible for root fracture at lower fracture loads.²⁴ Rigid metallic posts were

responsible for stress concentration at the apical end and the coronal third of the canal wall, resulting in catastrophic vertical root fractures.²⁵

The number of repairable fractures in group 1 (fibre posts) (Table 2) was significantly greater than that of any other group, in agreement with the findings reported²⁴ as the type of failure that occurred with fibre post systems were primarily post and core fractures that potentially allow retreatment of the tooth.²⁶ In the present study, groups with the resin luting system showed considerably higher mean fracture loads than those with glass ionomer cement when same metallic posts were used. The statistical analysis also revealed significant difference between the groups of same metallic posts with different luting cements. The results indicate that adhesive composite resin luting systems provided additional fracture resistance to metallic post.

Adhesive composite resin luting systems are generally recommended for the cementation of fibre and zirconia ceramic post.²⁴ However, they were seldom used for metallic posts.²² Cementation of a post with a dentin-bonding system could theoretically provide internal bracing of the root and preserve the critical interface between dentin and post.⁵ In addition to providing flexibility and cushioning effect of the cement layer, resin cements might contribute to uniform stress distribution between the post and the dentinal walls, and absorb micromovements of an artificial crown resulting from occlusal forces more effectively than conventional brittle cements. Thus, loss of cement seal of the artificial crown and damage of post, core and root dentin might be prevented. The restoration of teeth with adhesively cemented internal restorations offered improved mechanical stability over cemented restorations. Glass ionomer powder has been shown to be weak and brittle as compared with resin-based materials.²⁷ Glass ionomers have also exhibited unfavorable in vitro cyclic fatigue characteristics and low compressive strengths compared with resin-based luting cements. Glass-ionomer cements are known to require several days and even several weeks to reach maximum strength, making this choice unsuitable as cement for posts. Nothing conclusive could be drawn on comparing fracture mode between cast and direct core build-ups with metal posts luted with same cement.⁵

In the literature,²⁸ the maximum incisal forces of anterior teeth varied, but the amount was almost always below 200 N which is much lower than the failure loads of fibre post found in this study.

Finally, within the limitations of this in vitro study, it can be stated that fibre posts can be recommended as a better alternative to the cast post and cores and prefabricated metallic posts in the anterior region and resin cement might give additional fracture resistance when used for post and crown cementation.

5. Conclusion

It was observed that the highest fracture resistance was observed with fibre posts luted with resin cement system, and the lowest fracture resistance was observed with cast post and composite core luted with glass ionomer cement. The greatest number of repairable fracture mode was observed with fibre

posts and resin cement system. Hence, they can be recommended as an alternative to the cast post and cores and pre-fabricated metallic posts in the anterior region.

It can be concluded that the resin cement improves the fracture resistance of metallic posts as compared to glass ionomer cement.

Conflicts of interest

All authors have none to declare.

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