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ORIGINAL ARTICLE

FAILURE LOADS OF ENDODONTIC TREATED TEETH USING ZIRCONIA CONTAINING RESIN CORE MATERIAL IN COMBINATION WITH DIFFERENT POST SYSTEMS- AN IN VITRO STUDY

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ABSTRACT:
Background: The effect of using zirconia (Zr) post in combination with Zr containing cores to restore teeth is not known. The aim was to investigate the failure loads of endodontically treated teeth restored with Zr post in combination with Zr containing core materials. **Methods:** Forty central incisor teeth were sectioned coronally and prepared with 1.5mm chamfer margin. Endodontic treatment was performed using step-back and cold lateral condensation techniques. Teeth were divided into four groups (each group, n=10) based on the combination of the post and cores used. The two core materials included were Zr nano-filler based bulk fill and Zr free bulk fill. The post systems used were fiber post and Zr glass fibre post. An overall 5mm height core was made and controlled loads were applied at 135° to the occlusal surface until failure. The failure modes and loads among different groups were compared using ANOVA and Tukey's multiple comparisons test. **Results:** Maximum and minimum failure loads were observed for specimens in Group C (Zr glass post and Zr based core) (27.41) and Group B (Fibrepost and Zr free core)(20.03) respectively. Failure loads among group C specimens were significantly higher ($p<0.01$) than specimens in groups A (Fibre post and Zr based core) and B. Failure loads in Groups D (Zr glass post and Zr free core) and A were significantly higher ($p<0.01$) than failure loads in group B. Among all groups, failures above CEJ were upto 80% and failures below CEJ were upto 40%. **Conclusions:** Endodontic-treated teeth when restored with Zr based post and Zr nano-particle core display higher failure loads as compared to fiber post and conventional resin core.
Key Words: Endodontic treated teeth, Failure loads, Resin core, Zirconia nano particle

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INTRODUCTION

Endodontic treatment results in loss of tooth structure causing the strength of tooth to reduce.[1] In order to restore teeth with endodontic fillings, different core materials (including resin composite, amalgam and glass ionomers) in combination with posts are used to provide retention and resistance for crowns and to enhance the strength of the remaining tooth structure. Studies have shown that the type and combination of core and post materials along with the clinical techniques impact the prognosis of teeth with endodontic treatments.[2-4]

Fiber-reinforced (FR) posts are commonly employed in clinical dentistry for the restoration of root filled teeth with compromised crown structure.[5, 6] These posts provide improved retention for the core buildup for indirect coronal restorations. In addition, resin composite bonds to the tooth structure and fiber posts, through surface treatments to resist the loading forces on the coronal restoration during function.[2] In recent times, newly developed zirconia (Zr) posts have shown chemical stability, mechanical strength and elastic modulus significantly greater than FR post.[7] In addition Zr posts are easily identified clinically and radiographically due to high radiopacity.[7] It has been observed that fracture resistance of endodontic teeth restored with Zr posts has been similar or greater to those restored using FR post systems.[8] Moreover, use of Zr post allows for multiple post-core techniques including, direct resin cores, direct ceramic cores, indirect and indirect ceramic core processing (IPS Empress Cosmo ingot and Ceracap).[9, 10]

Posts placement in endodontically filled teeth is primarily to retain cores, which provide retention and resistance, for the coronal restoration.[11-13] For core materials to provide long term clinical success they are required to fulfill multiple criteria. One of the desired properties for core materials is resistance to high occlusal forces, optimum compressive strength for predictable prognosis of the tooth-post-core-restoration complex.[13] Novel Zr nano particle filler containing core materials have been introduce for clinical application.[14] It is known that Zr is a chemically stable and biocompatible material, with excellent mechanical properties.[15-17] In a recent in-vitro investigation, Zr nano-hybrid filler containing bulk fill core material was reported to show high compressive strength as compared to conventional Zr free resin based bulk fill materials.[18] However the efficacy of these materials in combination of a post and core in restoration of endodontically treated teeth has not been reported. Therefore, we hypothesized that the used of Zr posts in combination with Zr containing bulk fill core materials should provide significantly better fracture resistance to endodontically treated teeth in comparison to the use of fibre posts in combination with Zr free resin based core materials. Hence the aim of the study was to investigate the failure loads of endodontically treated teeth restored with Zr post in combination with Zr containing bulk fill core materials.

MATERIALS AND METHODS

Preparation and endodontic treatment of selected teeth

Forty freshly extracted maxillary central incisors free of physical deficiency and of similar dimensions (root length not more than 16mm) were selected stored in saline. All teeth were sectioned 2mm coronal to the CEJ with a low speed diamond saw under copious irrigation and were embedded in acrylic block (Duralay; Reliance Dental Mfg Co) with 3 mm vertical space between the cementoenamel junction and the acrylic resin.Teeth were prepared with a torpedo shaped bur to achieve a 2mm ferrule and a 1.5mmdeep chamfer finish margin.Access opening of all teeth was done with a round diamond at slow speed, pulp was extirpated and patency was achieved (15Kfile). Working length was kept 1mm from the apex and preparation was performed from #15 to #60 K files (DentsplyMaillefer) using step-back technique with regular irrigation with 5% sodium hypochlorite. Following preparation canal obturation was performed using non-eugenol sealer (Sealapex; Sybron Endo) andguttapercha (GP) with cold lateral condensation. A single operator performed the endodontic procedure.

Study Groups

All endodontic treated teeth were divided into four experimental groups depending on the type and combination of post and core materials used to for restoration. Two different types of posts used in the study were, fiber post(3M ESPE RelyX Fiber Post, St. Paul, MN,USA) and zirconia (Zr) glass fibre post (Snow light posts, DanvilleMaterials, San Ramon, CA, USA). The two different core materials used were, MultiCore Flow Dual cure (MC), Core Build-Up Material (Ivoclar Vivadent Inc, Amherst, NY, USA) andZirconCore (ZC) (Harvard Dental International, GmbH,Hoppegarten, Germany). The following are the experimental groups.

Group A (n=10): Endodontic teeth restored with Glass fibre post and Zr containing dual cure core material

Group B (n=10): Endodontic teeth restored with Glass fibre post and Zr free dual cure core material

Group C(n=10): Endodontic teeth restored with Zr glass post and Zr containing dual cure core material

Group D (n=10): Endodontic teeth restored with Zr glass post and Zr free dual cure core material

Post Space Preparation and Post Cementation

Post space for group A and B were prepared using the slow speed drills provided by the system to size no.2 tapered, 1.4mm diameter fibre posts. For groups C and D post space was prepared using slow speed drills provided by the Zirconia post system for post diameter of 1.4mm. Using a silicone stopper post on slow speed drills, post space in all groups was prepared to a depth of 10mm from top of coronal dentine. The postswere 10mm in the tooth (8mmbelow the cemento-enamel junction,2mm ferrule and 3mm for the core). The post size was modified to the required length

by cutting off the excess with a diamond disk under water cooling. All posts were cleaned using alcohol (70% ethanol) and dried. Root dentin in all post space preparation was etched with 37.5% phosphoric acid for 30 seconds (sec), dried for 10 sec with air jet and absorbing paper points. Both Zr containing core material, Zircon Core and Zr free core material, Multicore were used to cement both fibre post and Zr glass posts (see above study groups). For cementation using Multicore resin and Zircon Core materials, ExciTE F (Ivoclar Vivadent), dual cure and Harvard Bond TE Mono (Harvard Dental International, GmbH, Hoppegarten, Germany) respectively, was applied to the dentin walls and root canal, after etching. The bonding agents were agitated on the dentin and excess removed carefully. The luting agents Multicore and Zirconcore were applied to the posts and cemented using standard techniques. Excess cements were removed and posts were photopolymerized for 20 sec with an intensity of 650 mWcm-Ç (Bluephase ® C8, Ivoclar Vivadent, Schaan, Liechenstein). The same resin luting agent was used to build up cores of 3mm height beyond the 2mm ferrule, resulting in a 5mm overall core height from the preparation margin. The size and shape of the cores were standardized using a poly (methylmethacrylate) core-forming matrix.

Fracture resistance testing

Using a mounting jig on the universal testing machine, at 24 hours (Hr) fracture resistance was evaluated in a Universal Testing Machine (Instron 1144, Instron Corporation, Canton,MA, USA) with load application at 135° angle to the root long axiswith a crosshead speed of 0.5 mm/min until there was a visible or audible sign of failure in the post and core. In each tooth, the type of failure (core or post-failure) and location of fracture [above or below the cemento-enamel junction (CEJ)] was observed.The failed specimens were evaluated under a 3D digital microscope (Hirox- KH7700, 100 Commerce Way, Hackensack, US). Statistical software (SPSS version 20; IBM Corp) was used to analyze data obtained and the significance level was set at p<0.05.Means and standard deviations of bond strengths were calculated using One-way analysis of variance (ANOVA) and multiple comparisons test.

RESULTS

The mean root length for the extracted teeth was 15.63±1.20 mm and the mean mesio-distal width was 6.71±0.78mm at the CEJ. The means and standard deviations of failure loads are presented in table 1. The highest and lowest failure loads were achieved in group C (Zr glass post and Zr containing dual-cure resin core) and group B (Glass fibre post and Zr free dual cure resin core) respectively. Analysis of variance showed significant difference in failure loads among the study groups (Table 1). Failure loads among group C(Zr glass post and Zr containing dual-cure resin core) specimens were significantly higher than specimens in groups A (Glass fibre post and Zr containing dual cure resin core) and B (Glass fibre post and Zr free dual cure resin core) (Table 2). Failure loads in Groups D (Zr glass post and Zr free dual-cure resin core) and A (Glass fibre post and Zr containing dual cure resin core) were significantly higher than failure loads in group B (Glass fibre post and Zr free dual cure resin core). However group D showed comparable failure loads to specimens in groups A and C (Zr glass post and Zr containing dual-cure resin core) respectively.

The incidence of failures among all groups above the CEJ ranged from 60% to 80%. Group B showed the highest (80%) failures above CEJ whereas specimen in group C showed 60% failures of the same category. Failures in specimens below CEJ level were higher in groups C and D at 40% and 30% respectively. However among groups A and B, 30% and 20% of specimens failed below CEJ level. The frequency of failure modes among all groups is presented in table 3.

DISCUSSION

The study was based on the hypothesis that use of Zr containing resin core materials in combination with the use of Zr posts in the restoration of endodontically treated teeth would show higher resistance to failure as compared to teeth restored with conventional fibre post and Zr free resin core materials. This hypothesis was accepted, as the experiment showed significantly higher failure loads for endodontic teeth restored with Zr based post and cores compared to Zr free post and cores.

Although this investigation was in-vitro, standardization was ensured throughout the study. For instance, all teeth used in the experiments were of similar dimensions (difference was not significant) and were assessed for lengths and widths. All posts used were of 1.4mm diameter and 11mm length (8mm in the root and 3mm coronal). A single operator performed standardized tooth preparations with 2mm ferrule and 1.5mm deep chamfer on all teeth.[19-21] Core build-ups were made using a core former adapted to the coronal tooth section. CEJ was kept 3mm from the embedding acrylic and loads were applied at 135° to the long axis to simulate clinical scenario.[22]

Table 1: Failure loads for specimen among experimental groups

Failure Loads	Group A	Group B	Group C	Group D	P value
Means	23.896	20.030	27.416	25.613	<0.001**
SD	3.418	2.511	3.016	2.212	

SD: standard deviations, ** highly significant
P value is the outcome of ANOVA

Table 2: Comparison of means among experimental groups (Tukey multiple comparisons)

Experiment Groups [mean (SD)]	P value	Experimental Groups [mean (SD)]	P value
Gp Avs Gp B: 23.89 (3.41) vs20.03 (2.51)	0.020*	**Gp Bvs Gp C**: 20.03 (2.51)vs27.41 (3.01)	<0.01**
Gp Avs Gp C: 23.89 (3.41) vs27.41 (3.01)	0.040*	**Gp Bvs Gp D**: 20.03 (2.51)vs25.61 (2.21)	<0.01**
Gp Avs Gp D: 23.89 (3.41) vs25.61 (2.21)	0.533ns	**Gp Cvs Gp D**: 27.41 (3.01) vs25.61 (2.21)	0.491ns

* significant, ** highly significant, ns not significant

Table 3: Frequency of fractures according to location in the experimental groups

Groups	Above CEJ		Below CEJ	
	No.	%	No.	%
A	7	70	3	30
B	8	80	2	20
C	6	60	4	40
D	7	70	3	30

In addition, the testing conditions and the techniques, which were employed, have been used extensively among similar studies.[23, 24]

Interestingly specimens restored with Zr post showed higher failure loads as compared to teeth restored with fibre posts. Previous studies have reported that failure loads for endodontically treated teeth are affected by multiple factors, including, bonding procedure, laboratory technique, ferrule ad remaining tooth structure, testing methods, post and core material type and coronal restoration.[9, 10] In the present study preformed zirconia glass posts were bonded using silane surface treatment and resin bonding, which has been reported to positively effect the bond strengths of Zr posts.[25] In addition, the fracture strengths of the Zr post itself is known to be higher as compared to FR.[26, 27]These factors could be considered probable reasons for the observed outcomes.

Furthermore, specimens restored using Zr nano filler containing resin core showed increased failure loads in comparison to specimens restored with Zr free resin core material. A possible explanation for this finding could be related to the higher compressive strength of Zr nano filler cores as compared to Zr free cores as shown in previous studies.[18, 28]In addition, the nano filler particles of Zr allow for higher filler content along with increase in filler density by fillings gaps among micro and macro filler particles.[29] Zr filler is also reported to improve the filler/polymer chain interaction, which favorably impacts the internal stresses within resin core.[30]

In the present study, tooth failures were divided into categories, namely above and below the CEJ, as teeth having fractures below the CEJ show poor prognosis as compared to those having fractures above CEJ. These can also be regarded as salvageable (above CEJ) and non-salvageable (below CEJ) tooth fractures. The majority of fractures in the present study were above CEJ upto 80%, however a greater percentage (30%-40%) of non-salvageable fractures were found in specimen restored with Zr posts (groups C and D). It has been reported that Zr posts have little to no plastic behavior having high stiffness values.[31] This creates stress points within the root dentin resulting in observed fractures.[32] In addition, an optimum bond with the core material and coronal dentin along with high fracture strengths among Zr posts further increase the probability of root fractures.[32, 33]These findings are in line with previous studies.[21, 28]

Although Zr based post and cores showed higher failure loads, from a clinical perspective, failure loads among all study groups were acceptable. Studies have shown, in-vitro fracture loads to be higher as compared to loads during mastication.[26, 34]Therefore it is the authors opinion that although the failure load of post and core systems is a critical property in the decision making for selection of post and core systems. Others factors such as ability to bond to core and dentin, failure modes, radiodensity and microleakage should also be considered. In addition, the selection of post and core system should not just be based on the failure loads of different materials, but also on vital factors such as clinical occlusal loads and parafunction, remaining tooth structure and type of coronal restoration. It is therefore recommended that in order to assess the efficacy of different post and core systems (including Zr post and cores) randomized controlled trials with standardized protocols and long-term follow up should be performed.

CONCLUSION

Within the limitations of the study it can be concluded, that endodontic-treated teeth when restored with Zr based post and Zr nano-particle infiltrated core systems display higher failure loads as compared to Fiber post and conventional resin cores.

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