J Indian Prosthodont Soc (Apr-June 2014) 14(2):144–150
DOI 10.1007/s13191-013-0346-7

ORIGINAL ARTICLE

Analysis of Fracture Resistance of Endodontically Treated Teeth Restored with Different Post and Core System of Variable Diameters: An In Vitro Study

S. I. Joephin Soundar · T. J. Suneetha · Mano Christaine Angelo · Lin Cherian Kovoor

Received: 3 February 2013 / Accepted: 22 December 2013 / Published online: 26 January 2014

Abstract The restoration of endodontically treated teeth requires the fabrication of a post and core; to provide retention and support for the final crowns. The purpose of this study was to evaluate fracture resistance of endodontically treated teeth restored with prefabricated zirconia post (CP), milled zirconia post (MZ), pressable ceramic post (PC) and cast metal post (Ni–Cr) of 1.4 and 1.7 mm diameter. 48 freshly extracted human maxillary central incisors were used for this study. The teeth were distributed in four groups of 12 teeth each. From each group, 6 teeth were selected for 1.4 mm diameter post and rest of the 6 teeth, is selected for 1.7 mm diameter post. All teeth were restored with metal crowns. Each specimen from the group was subjected to "load to fracture" in universal testing machine at 130° angle and the maximum load at failure was recorded. Statistically significant difference was found between the failure load of the groups studied. In group I (Ni–Cr)—1.4 mm diameter post and core recorded a maximum fracture load of 534.83 ± 1.28 N and 1.7 mm diameter post and core showed 294.33 ± 1.02 N. In group II (PC)—1.4 mm diameter post and core recorded a maximum fracture load of 205.33 ± 1.61 N and 1.7 mm post and core showed 375.00 ± 1.57 N. In group III (CP)—1.4 mm diameter post and cores recorded a maximum fracture load of 313.00 ± 0.73 N and 1.7 mm post and core showed 638.67 ± 0.81 N. In group IV (MZ)—1.4 mm diameter post and cores recorded a maximum fracture load of 312.00 ± 0.86 N and 1.7 mm post and core showed 415.00 ± 0.89 N. Prefabricated zirconia post (1.7 mm) with pressable ceramic core (Cosmo post)—exhibited higher fracture resistance. Milled zirconia and prefabricated zirconia post—showed same value with 1.4 mm diameter post. Pressable ceramic post and core showed satisfactory result with 1.7 mm post, but showed lesser values with 1.4 mm diameter post.

Keywords Fracture strength · Post and core · Zirconia post, Pressable ceramic post, Cast post and core · Prefabricated post and core

Introduction

When there is extensive loss of coronal tooth structure in an endodontically treated teeth, Post and core is often required to retain a complete crown. Metal post and cores are commonly used because of their superior physical properties. Nevertheless, the increased use of all-ceramic crown provides a rationale for tooth colored core. The alternatives for obtaining tooth color core are: Composite core, prefabricated all-ceramic post with pressable ceramic core, and masking of metal core with opaque ceramic or photo-curing opaque resin. Cast post may also create root discoloration and "blue-gray" effect; if thin bone and gingival tissue are present [1–4].

Failures of post and core, can often occur as a result of their insufficient physical and mechanical strength. The endodontically treated teeth restored with post and core can produce stresses concentrated at the coronal third of root and at the interface of post and core material. If the moduli of elasticity differ between materials, there is potential for separation of core from the post [5]. 1-piece post and core are more reliable than prefabricated post with direct core [6].

S. I. J. Soundar (✉) · T. J. Suneetha · L. C. Kovoor
Department of Prosthodontics, Rajas Dental College, Kavalkinaru, Tirunelveli, Tamil Nadu, India
e-mail: Joephinsoundar@gmail.com

M. C. Angelo
Department of Conservative Dentistry, Sree Mookambika Institute of Dental Science, Kulasekharam, Kanyakumari, Tamil Nadu, India

Table 1 Test groups

Group	Post system	Material	Diameter (mm)
Group I	Cast metal post (HI-Chrome soft-7, High Dental, Japan Co., Ltd)	Ni–Cr	1.4 and 1.7
Group II	Pressable ceramic (E-max, Ivoclor Vivadent AG, Germany)	Lithium disilicate (LS_2) glass–ceramic	1.4 and 1.7
Group III	Prefabricated zirconia (Cosmo Post, Ivoclor Vivadent AG, Germany)	Zirconium oxide (ZrO_2) ceramic post and lithium disilicate glass ceramic core	1.4 and 1.7
Group IV	Milled zirconia (Amann Girrbach America, Inc. USA)	Ceramill Zi-presintered Y-TZP zirconium-oxide blanks	1.4 and 1.7

Zirconia as a post and core material use since 1993. Prefabricated zirconia post is present with positive qualities like high strength to bending forces and appropriate optical properties. "Pressed ceramic" core have been used for core build up over prefabricated zirconia post. However, adhesively luted composite resin core materials other than pressed ceramic core, creates several problems in long term; most commonly core delamination. Also available diameter of most esthetic prefabricated post systems; do not permit a conservative post space preparation, which is especially important for mandibular incisor, maxillary premolars and lateral incisors. With these teeth, a custom made post may help to preserve tooth structure [7, 8].

The technique for milling a one piece zirconia post and core. The authors used computer aided design/computer aided manufacturing technology, to fabricate yttrium–tetragonal zirconium polycrystalline ceramic post. The authors stated that this technique provide a post and core with greater toughness, maximal adaptability to the canal and adequate esthetics.

The pressable ceramic post and core systems were added in this study for its reduced cost and ease of fabrication. The average biting forces on anterior teeth are 222 N [9]. The post and core systems needed to with stand forces greater than 222 N to ensure success of the restorations for the anterior segment.

The purpose of this in vitro study, was to evaluate the fracture resistance of endodontically treated teeth, restored with all ceramic post and core system and cast post system of two different diameters.

Materials and Methods

Test groups include metal post and core, pressable ceramic post and core, prefabricated post and core and milled zirconia post and core: of which details, are given in Table 1.

48 human maxillary central incisor teeth which were freshly extracted for therapeutic reasons, were selected for this study. Teeth were selected for similarity in size, shape and root anatomy. The hard and soft deposits were removed with hand scaling instrument. The size of teeth were standardized by measuring the buccolingual and mesiodistal diameter of tooth in cementoenamel junction using vernier caliper. The teeth were stored in artificial saliva (Wet mouth, ICPA Health Product Ltd, India) except during restoration and experimental testing.

The teeth were distributed in four groups of 12 teeth each. From each group, 6 teeth were selected for 1.4 mm diameter post and rest of the 6 teeth, is selected for 1.7 mm diameter post. The coronal portions of all 48 teeth (15 mm from the apex of teeth till cementoenamel junction) were removed using a diamond disc mounted on micromotar hand piece.

Following standard endodontic procedures, sectional root canal filling was done with gutta percha and zinc oxide eugenol as sealer. Canal orifice was sealed with temporary cement and specimens were stored in artificial saliva. Post space preparation of length 11 mm for all teeth was initiated after 7 days. Peso reamer of size #2 was used to remove gutta-percha up to middle 1/3rd of the root of the extracted specimen teeth. By keeping 4 mm of gutta-percha points intact at apical 1/3rd of root; initial enlargement of root canal was done with peso reamers of size #3, 4. Final post space preparation was done by using 1.4 mm diameter cosmo post drill (red) (Ivoclar Vivadent AG, Germany) for 1.4 mm specimen and 1.7 mm diameter cosmo post drill (black) for 1.7 mm specimen. Thus, post space diameter of 1.4 and 1.7 mm diameter and post space length of 11 mm was standardized. Using normal saline the debris was removed and dried with paper point. The schematic representation of specimen preparation is shown in Fig. 1.

Parallel wall of dentine extending coronal to the shoulder of the preparation is called ferrule [11]. 2 mm ferrule with 1 mm shoulder finish line was prepared using diamond bur of head size ISO No. 010. After post space preparation, resin pattern is prepared for 1.4 mm diameter post and 1.7 mm post separately using pattern resin (GC Corporation, Tokyo, Japan). The core height of all groups is standardized as 5 mm. Resin pattern of post and core for cast post, pressable ceramic post, and milled zirconia were

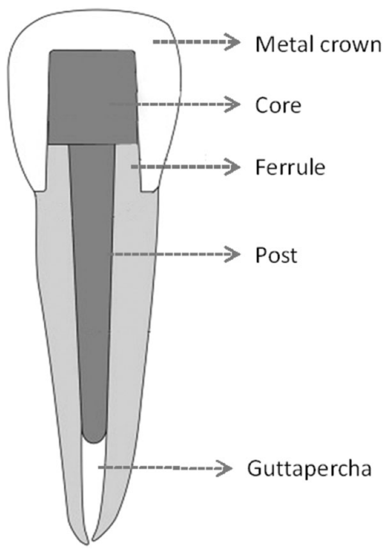

Fig. 1 Schematic representation of test specimen

Fig. 2 Resin pattern of 1.4 and 1.7 mm post

made separately (Fig. 2). For cosmo post, core pattern is made directly on the prefabricated zirconia post of standard size 1.4 and 1.7 mm diameter. Core is made by pressable cermic (Fig. 3) by lost wax technique. For the cast post and pressable ceramic post the resin pattern was made and using "lost wax technique" the fabrication of post were done (Fig. 3). Where as in the fabrication of milled zirconia the resin pattern is scanned in copy milling machine (Ceramill multi-X, Amann Girrbach America, Inc., USA) and post milled by using zirconia blocks (Fig. 3).

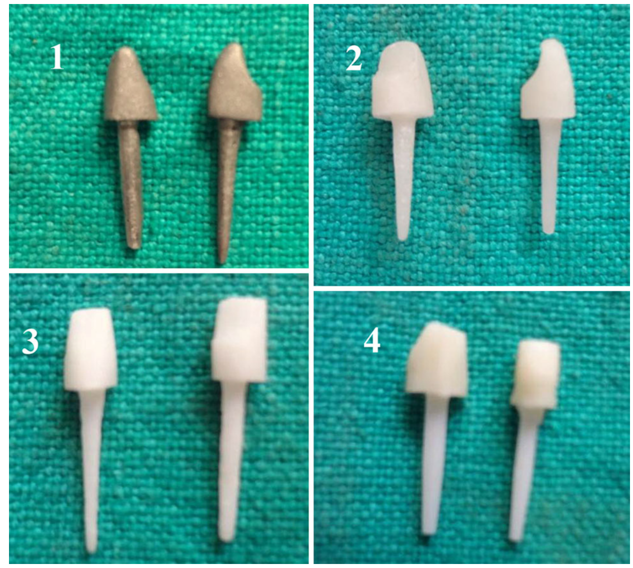

Fig. 3 **1** Cast metal post, **2** pressable ceramic post, **3** millex zirconia post, **4** cosmo post of size 1.4 and 1.7 mm diameter

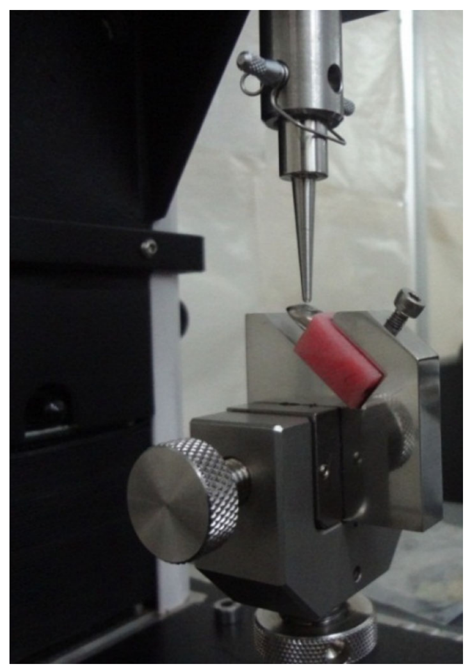

Fig. 4 Mounted specimen in universal testing machine at an angle of 130°

Cementation of post is done by using resin cement (Multilink K, Ivoclar vivadent AG, Germany). After all group were fit with their post, they were prepared for full coverage metal crown restoration; to the height of 10 mm, mesiodistal width 8.5 mm and buccolingual width 7 mm. All coping casting were made using the same alloy (HI-Chrome soft-7, High Dental, Japan Co., Ltd) used for cast metal post and core. The coping were cemented with

Table 2 Comparison of different post having 1.4 mm

Groups	Type of post	Fracture load (N) (mean ± SEM)
Group-I	Cast metal post	534.83 ± 1.28
Group-II	Pressable ceramic (E-Max)	205.33 ± 1.61*
Group-III	Prefabricated zirconia (cosmo post)	313.00 ± 0.73*,#
Group-IV	Milled zirconia	312.00 ± 0.86*,#

* $P < 0.05$ significant difference compared cast metal post with other posts, # $P < 0.05$ significant difference compared pressable ceramic (E-Max) with other posts

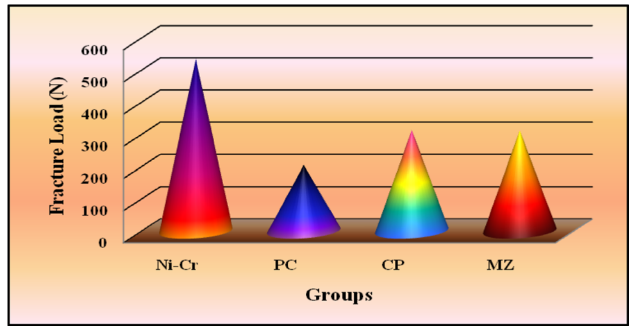

Fig. 5 Comparison of different post having 1.4 mm

Table 3 Comparison of different post having 1.7 mm

Groups	Type of post	Fracture load (N) (mean ± SEM)
Group-I	Cast metal post	294.33 ± 1.02
Group-II	Pressable ceramic (E-Max)	375.00 ± 1.57*
Group-III	Prefabricated zirconia (cosmo post)	638.67 ± 0.81*,#
Group-IV	Milled zirconia	415.00 ± 0.89*,#,$

* $P < 0.05$ significant difference compared cast metal post with other posts, # $P < 0.05$ significant difference compared pressable ceramic post with other posts, $ $P < 0.05$ significant difference compared prefabricated zirconoia post with other posts

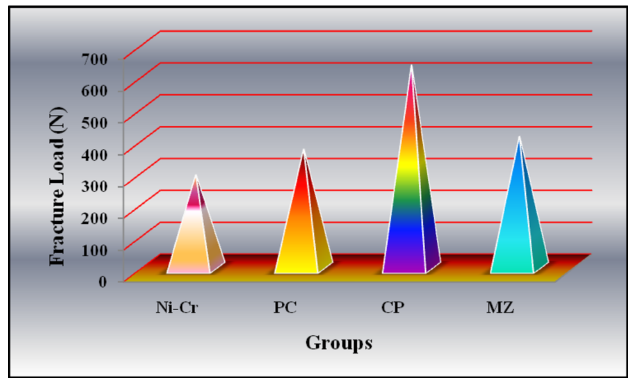

Fig. 6 Comparison of different post having 1.7 mm

glassinomer luting cement (GC-Gold label, GC Corporation, Japan).

The teeth were attached to surveyor to align the long axis and invested in auto polymerizing resin at a level of 2–3 mm, below margin of the preparation to simulate the biological width. Tooth is mounted on acrylic block of size 1.5 × 1.5 mm and is fitted into the jig used for testing the specimen. All teeth were stored in artificial saliva before testing.

The specimens of each group were subjected to compressive test in universal testing machine (Instron model 3345). A jig were used to standardized the position of specimens at the base of the apparatus, so that the load could be applied at the angle of 130° in relation to long axis of the post (Fig. 4), an increasing oblique compressive load was applied, 2 mm below the tip with round terminus. A cross head speed of 1.00 mm/min was applied until post fracture. The value of maximum force applied was obtained in newton (N) was recorded for analysis.

Results and Observations

The mean values of post and core having 1.4 and 1.7 mm diameter are given in Tables 2 and 3. The data was analyzed using computer software, Statistical Package for Social Sciences (SPSS) version 16.0 (SPSS, Inc., Chicago IL). One way analysis of variance (ANOVA) and post hoc Ducan's multiple range (DMR) test were carried out. Result shows the significant difference among the four groups $P > 0.05$.

Comparison of Post and Core with Diameter 1.4 mm

The comparison of the fracture loads of four different posts having 1.4 mm diameter was measured (Table 2). Cast metal post have (534.83 ± 1.28 N), pressable ceramic (205.33 ± 1.61 N), prefabricated zirconia (313.00 ± 0.73 N) and milled zirconia (312.00 ± 0.86 N). Cast metal post showed significant difference compared with other post. Pressable ceramic have less fracture load than others. There is no significant difference between prefabricated zirconia and milled zirconia (Fig. 5).

Comparison of Post and Core with Diameter 1.7 mm

Different posts with 1.7 mm diameter was prepared and tested for fracture resistance (Table 3). In this study, prefabricated zirconia (638.67 ± 0.81 N) showed significant results compared with cast metal post (294.33 ± 1.02 N),

Table 4 Multiple comparisons of different post groups in 1.4 and 1.7 mm diameter

Groups	Type of post and diameter (mm)	Fracture load (N) (Mean ± SEM)
Group-I	Cast metal post (Ni–Cr)—1.4 mm	534.83 ± 1.28
Group-II	Cast metal post (Ni–Cr)—1.7 mm	294.33 ± 1.02[1]
Group-III	Pressable ceramic (E-Max) (PC)—1.4 mm	205.33 ± 1.61[1,2]
Group-IV	Pressable ceramic (E-Max) (PC)—1.7 mm	375.00 ± 1.57[1,2,3]
Group-V	Prefabricated zirconia (cosmo post) (CP)—1.4 mm	313.00 ± 0.73[1,2,3,4]
Group-VI	Prefabricated zirconia (cosmo post) (CP)—1.7 mm	638.67 ± 0.81[1,2,3,4,5]
Group-VII	Milled zirconia (MZ)—1.4 mm	312.00 ± 0.86[1,2,3,4,6]
Group-VIII	Milled zirconia (MZ)—1.7 mm	415.00 ± 0.89[1,2,3,4,5,6,7]

[1] $P < 0.05$ significant compared cast metal post (Ni–Cr)—1.4 mm with other posts, [2] $P < 0.05$ significant compared cast metal post (Ni–Cr)—1.7 mm with other posts, [3] $P < 0.05$ significant pressable ceramic (E-Max) (PC)—1.4 mm with other posts, [4] $P < 0.05$ significant compared pressable ceramic (E-Max) (PC)—1.7 mm with other posts, [5] $P < 0.05$ significant compared prefabricated zirconia (cosmo post) (CP)—1.4 mm with other posts, [6] $P < 0.05$ significant compared prefabricated zirconia (cosmo post) (CP)—1.7 mm with other posts, [7] $P < 0.05$ significant milled zirconia (MZ)—1.4 mm with other posts

pressable ceramic post (375.00 ± 1.57 N) and milled zirconia post (415.00 ± 0.89 N). Cast metal post showed low fracture load (Fig. 6).

Comparison of Post and Core with 1.4 and 1.7 mm

In this multiple comparison prefabricated zirconia 1.7 mm showed significant difference compared with other groups having different diameters (Table 4). Prefabricated zirconia 1.7 mm (638.67 ± 0.81 N) have high fracture resistance followed by cast metal post 1.4 mm (534.83 ± 1.28 N). Pressable ceramic 1.4 mm have low fracture load compared with other posts. There is no significant difference compared with prefabricated zirconia 1.4 mm and milled zirconia 1.4 mm. From the observations pressable ceramic 1.4 mm (205.33 ± 1.61 N) and cast metal post 1.7 mm (294.33 ± 102 N) showed low fracture load. Milled zirconia 1.4 mm and prefabricated zirconia 1.4 mm both have almost same fracture load (Fig. 7).

In group I all specimens showed tooth fracture, however, tooth fractures were not observed in group II, III, and IV.

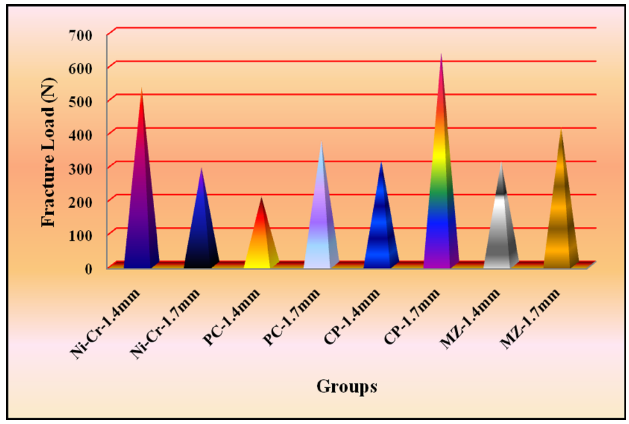

Fig. 7 Multiple comparisons of different post groups in 1.4 and 1.7 mm diameter

Discussion

In the case of substantial horizontal loss of clinical crown, there is no restorative alternative, to fabrication of a post and core build up. The current study attempted to; compare the conventional metal post and core with newer all ceramic post and core. Ideal post and core system should have the following features: physical properties similar to dentine, maximum retention with little removal of dentine, maximum distribution of functional stresses evenly along root surface, esthetic compatibility with the definitive restorations and surrounding tissue, good core retention, ease of use [12–15]. The post should be as long as possible without jeopardizing the apical seal or the strength or integrity of the remaining root structure. A minimum length of 4.0 mm of gutta-percha should remain at the apex to prevent dislodgement and leakage [3, 4, 10]. Studies demonstrated that cast post group showed significantly higher level of microleakage compared with other group under dynamic loading [5].

In the present study, cast metal post of diameter 1.4 mm showed highest fracture resistance; whereas 1.7 mm diameter cast metal post showed the lowest fracture resistance when compared with the other post groups. It has been reported that, more rigid the post and core is susceptibility to root fracture is high [15, 22, 25]. When creating post space, great care must be used to remove only minimal tooth structure from the canal. Excessive enlargement can perforate or weaken the root, which then may split during cementation of the post or subsequent function [16–20]. The prime variable in fracture resistance of the root is the thickness of the remaining dentin [27]. Antony et al. investigated the significant amount of remaining buccal dentine of the dowel channel in resisting root fracture under horizontally directed load showed that 1 mm remaining buccal dentinal walls were apparently more prone to fracture than 2 or 3 mm buccal dentinal wall [26, 27].

In this study, two different diameter post and core are compared for fracture resistance. If the fracture strength of lesser diameter post is adequate as post and core then the larger diameter post is avoided. Mozavi et al. studied the effect of post diameter on stress distribution in maxillary incisor by 3D finite element study. They stated that tensile strength and compressive stress in post increased when the diameter of the post is increased. The amount of stress generated in post increased by increasing the post diameter. So preserving the tooth structure by use of narrow post is recommended [28]. Due to high rigidity and higher modulus of elasticity of the cast metal post the fracture susceptibility of endodontic tooth is high [24, 29, 30].

Pressable ceramic post of diameter 1.4 mm showed the lowest values when compared with the other post groups. It's usage in anterior areas as aesthetic post is acceptable, because the average biting forces on anterior teeth are 222 N [9]. According to this study, prefabricated zirconia and milled zirconia post and core exhibit the same fracture resistance. A similar study comparing zirconia post by three different methods reported that milled zirconia post and core and prefabricated zirconia with pressable ceramic core buildups did not demonstrate any difference in fracture resistance [31–32]. On comparison, the ceramic post with diameter 1.4 mm showed lower values than cast metal post. While comparing 1.7 mm diameter post and core groups, the prefabricated zirconia post showed the highest value and cast metal post showed the lowest value and milled zirconia stood next to prefabricated zirconia followed by pressable ceramic. Previous studies of copy milled zirconia post are significantly lower than that of prefabricated zirconia post of same size [21–23]. Zirconia post with ceramic core can be recommended as an alternative to cast post in anterior region [11, 32].

In multiple comparisons, prefabricated zirconia post of 1.7 mm showed the highest value and found to be the best system, followed by cast metal post of 1.4 mm. Prefabricated zirconia and milled zirconia post of 1.4 mm diameter expressed the same values. Low fracture resistance was exhibited by pressable ceramic with 1.4 mm post and cast metal post of 1.7 mm. The specimen with metal post showed tooth fracture with intact post. The fracture of the post was shown by the ceramic post at fracture load but not the tooth.

Limitation of this study was that, it was an in vitro study and result obtained may not be comparable to in vivo situations. No periodontal ligament was stimulated in the design of test specimen. Clinically, it may not be possible to create an ideal canal space. Some factors such as quantity and quality of remaining tooth structure can explain the variation in the result.

Conclusion

In the present study, fracture resistance of cast metal post and ceramic post systems of 1.4 and 1.7 mm diameter was analyzed. Prefabricated zirconia post with pressable ceramic core (Cosmo post) exhibited higher fracture resistance. This post and core system can be considered as ideal material of choice among the tested groups.

Cast metal post and core of lesser diameter (1.4 mm) showed higher fracture resistance. All specimens with cast metal post and core showed fracture of tooth, whereas all ceramic post and core specimen showed fracture of post. So lesser diameter of cast metal post are recommended.

Milled zirconia showed satisfactory result with 1.4 and 1.7 mm diameter post and core. Milled zirconia and prefabricated zirconia post showed the same value with 1.4 mm diameter post. Milled zirconia is a good option as post and core along with cosmo post in prosthodontics.

Pressable ceramic post and core of 1.4 mm showed lower results but better than the cast metal post of diameter 1.7 mm. It's usage is for the restoration of anterior teeth. It is comparatively cheap and easily fabricated by lost wax technique.

References

1. Heydecke G, Peters MC (2002) The restoration of endodontically treated, single-rooted teeth with cast or direct posts and cores: a systematic review. J Prosthet Dent 87:380–386
2. Schwart RS, Robbin JW (2004) Post placement and restoration of endodontically treated teeth: a literature review. J Endod 30(5):289–301
3. Jung S-H, Min K-S (2007) Microleakage and fracture patterns of teeth restored with different posts under dynamic loading. J Prosthet Dent 98:270–276
4. Streacker AB, Geissberger M (2007) The milled ceramic post and core: a functional and aesthetic alternative. J Prosthet Dent 98:486–487
5. Heydeckea G, Butz F, Strub JR (2001) Fracture strength and survival rate of endodontically treated maxillary incisors with approximal cavities after restoration with different post and core systems: an in vitro study. J Dent 29:427–433
6. Bittner N, Hill T, Randi A (2010) Evaluation of a one-piece milled zirconia post and core with different post-and core systems: an in vitro study. J Prosthet Dent 103:369–379
7. Ozkurt Z, Iseri U, Kazazoğlu E (2010) Zirconia ceramic post systems: a literature review and a case report. Dent Mater J 29:233–245
8. Dayalan M, Jairaj A, Nagaraj KR, Savadi RC (2010) An evaluation of fracture strength of zirconium oxide posts fabricated using CAD-CAM technology compared with prefabricated glass fibre posts. J Indian Prosthodont Soc 10:213–218
9. Bakke M, Hoim B, Jensen BL, Michler L, Moller E (1990) Unilateral isometric bite force in 8 68 year old women and men related to occlusal force. Scand J Dent Res 98:149–150
10. Zmener O (1980) The effect of dowel preparation on the apical seal of endodontically treated teeth. J Endod 6(8):687–690

11. Sorensen JA, Engelman MJ (1990) Ferrule design and fracture resistance of endodontically treated teeth. J Prosthet Dent 63:529–536
12. Martinez-Insu A, Da Silva L, Rilo B (1998) Comparison of the fracture resistances of pulpless teeth restored with a cast post and core or carbon-fiber post with a composite core. J Prosthet Dent 80:527–532
13. Butz F, Lennon ÁM (2001) Survival rate and fracture strength of endodontically treated maxillary incisors with moderate defects restored with different post-and-core systems: an in vitro study. Int J Prosthodont 14:58–64
14. Shillinburg HT, Hobo S, Lowell (1997) Fundamental of fixed prosthodontics, 3rd edn. Quintessence Publishing, New Delhi
15. Rosenstiel SF, Land MF, Fujimoto J (2006) Contemporary fixed prosthodontics, 4th edn. Mosby, St. Louis
16. Anusavice KJ (2003) Phillips' science of dental materials, 11th edn. Saunders, Philadelphia
17. Akkayan B, Gülmez T (2002) Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent 87:431–437
18. Fernandes AS, Shetty S (2003) Factors determining post selection: a literature review. J Prosthet Dent 90:556–562
19. Lu Z-Y, Zhang Y-X (2003) Effects of post-core design and ferrule on fracture resistance of endodontically treated maxillary central incisors. J Prosthet Dent 89:368–373
20. Qing H, Zhu Z, Chao Y (2007) In vitro evaluation of the fracture resistance of anterior endodontically treated teeth restored with glass fiber and zircon posts. J Prosthet Dent 97:93–98
21. Lloyd PM, Palik JF (1993) The philosophies of dowel diameter preparation: a literature review. J Prosthet Dent 69:32–36
22. Al-Wahadni AM, Hamdan S, Hatamleh MM (2008) Fracture resistance of teeth restored with different post systems: in vitro study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 106:77–83
23. Stankiewicz N, Wilson P (2008) The ferrule effect. Dent Update 35:222–228
24. Grieznis L, Apse P, Soboleva U (2006) The effect of 2 different diameter cast posts on tooth root fracture resistance in vitro. Stomatologija 8:30–32
25. Azadzadeh N, Seify M (2009) Evaluation of fracture resistance in endodontically treated teeth through four restorative methods. an in vitro study. J Med Sci 9:156–160
26. Kivanc BH, Alacam T, Ulusoy OI (2009) Fracture resistance of thin-walled roots restored with different post systems. Int Endod J 42:997–1003
27. Aquilin SA, Caplan DJ (2002) Relationship between crown placement and the survival of endodontically treated teeth. J Prosthet Dent 87:256–263
28. Cormier CJ, Burns DR (2001) In vitro comparison of fracture resistance & failure mode of fibre, ceramic & conventional post systems at various stages of restoration. J Prosthodont 10:26–36
29. Zhang Y-X, Zhang W-H (2006) Fracture resistance of custom-fabricated celay all ceramic post and core restored endodontically treated tooth. Chin Med J 119:1815–1820
30. Grieznis L, Apse P, Soboleva U (2006) The effect of 2 different diameter cast posts on tooth-root fracture resistance in vitro. Stomatol Baltic Dent Maxillofac J 8:30–32
31. Hochman N, Zalkind M (1999) New all-ceramic indirect post-and-core system. J Prosthet Dent 81:625–629
32. Stockton LW (1999) Factors affecting retention of post systems: a literature review. J Prosthet Dent 81:380–385