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ORIGINAL RESEARCH

Evaluation of Coronal Microleakage in Two Different Post-Core Systems

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ABSTRACT

Aims: The aim of this *in vitro* study was to compare the cast metal and ceramic post-core systems, which have similar laboratory and clinical procedures according to coronal microleakage.

Materials and methods: Forty extracted maxillary anterior teeth were endodontically treated. Specimens were randomly assigned to four experimental groups (n = 10). The groups consisted of a cemented metal post-core group (CMPC), a not cemented metal post-core group (NMPC), a cemented ceramic post-core group (CZPC) and a not cemented ceramic post-core group (NZPC). A dual-cure resin cement (Panavia F) was used for both of the cemented groups. All specimens were stained with basic fuchsine and embedded in epoxy resin. Sagittal sections were obtained using a grinding machine and examined under binocular and coal microscopes. Coronal leakages were scored and data were analyzed using Kruskall-Wallis analysis of variance test.

Results: Results were compared between and within groups. No statistically significant differences were found between groups.

Conclusion: Cement alone is not sufficient to provide a barrier against microleakage in post-core restorations. The chosen post-core type or application methods may be more relevant to the leakage issue.

Keywords: Coronal microleakage, Cast metal post-and-cores, Ceramic post-and-core systems, Zirconia post.

INTRODUCTION

Severely damaged endodontically treated nonvital teeth need to be restored with sound restorations. Retention and resistance of these restorations rely on sound post-core foundations. The core is the part, which is built above the post, replacing lost tooth structure and transmits the occlusal loads equally to the apex of the root.[1-5] The post, in turn, provides retention, resistance and stability to the core. The primary objective of a post-and-core buildup is to replace the missing coronal tooth structure to provide required retention and resistance form for the final restoration.[6,7]

There are many types of post and core restorations. Traditionally titanium, carbon, polyethylene fiber and stainless steel posts are used for the anterior region.[8] In the past, metal cast post-cores were considered to be the 'gold standard' for endodontically treated teeth.[9] With ceramic fused to metal crowns that have subgingival margins, metal post-and-cores are never a concern since the crown restorations can mask the underlying structure completely.[10,11] Cast metal post-cores are the best choice for semicircular, wide, conical and irregular root canals, anatomically unfavorable crown-root ratios, and when maximum resistance is required against rotational forces. However, when all-ceramic restorations are preferred, metal posts may negatively affect the esthetic results. Besides, corrosion reactions can cause metallic taste, burning sensation, pain and other allergic reactions.[12] With regard to both esthetic and health concerns, nonmetal posts not only render esthetic superiority over metallic posts, but also preclude the possibility of corrosion[8] and reduce the risk of toxicity.[12] Recently, a wide range of esthetic posts have become commercially available, e.g. fiber-reinforced composite resin posts and yttrium-stabilized zirconia-based ceramic posts.[13] It has been shown that compared to glass fiber posts, zirconium posts provide higher physical quality and increased resistance to fracture.[11,14] Also, the advantages of zirconium posts are their optical properties, esthetic superiority, biocompatibility and resistance to corrosion.[9,15,16]

There are many techniques for post and core reconstruction. Basically there are two types of posts; custom made and prefabricated. Also, there are two ways for building up a core as direct and indirect. With zirconium posts, many core restoration techniques have been applied, such as; direct composite resin curing, direct ceramic core heat pressing and indirect ceramic core processing.[17] In direct ceramic core technique, IPS Empress Cosmo Ingot (Ivoclar, Vivadent) is heat pressed on to zirconium posts and a one-piece restoration which is cemented into root canal is obtained.[18] For indirect ceramic core processing, an example is Ceracap (Komet Brassler) which is a prefabricated glass-ceramic core cemented onto CeraPost with resin cement.[19]

Post-retained restorations may fail for any of the following reasons; caries, endodontic failure, periodontal disease, root fracture, post-dislodgment, post-and-core separation and crown-core separation.[20-22] Poor adaptation of post causes marginal gap which in the presence of inadequate cementation, can lead to microleakage. This leakage causes the separation of the post from the root and is reported to be the most frequent cause of failure of post-cores.[21-23] Penetration of oral fluids, bacterial toxins and all kinds of ions through the interfacial space between the restoration and the tooth leads to marginal discolorations, secondary caries and marginal fractures.[24-27] Morphology of the root canal, preparation of the post space, type of post-and-core material, type of cement and its application, clinical conditions, saliva contamination in the post space, inadequate provisional restoration, thickness of residual dentin, and position of the teeth in the dental arch are reported to affect marginal leakage of cement post-and-core.[28-30]

Many studies were conducted to evaluate microleakage between teeth and restorations with different *in vitro* and *in vivo* methods.[28,31-33] However, according to the authors' knowledge, there are no studies comparing coronal microleakage of conventional cast metal post-core foundations and zirconium posts and ceramic cores in literature.[34-38]

Therefore, the aim of this *in vitro* study was to compare the coronal microleakage between a cast metal post-core foundation and a prefabricated zirconium post/ceramic core system with and without cementation. The null hypothesis is that there would be no significant difference between the zirconium post/ porcelain core and cast metal post-core groups especially cemented with resin cement.

MATERIALS AND METHODS

Forty recently extracted, caries, restoration and previous endodontic treatment-free maxillary anterior teeth were selected and stored in saline solution at room temperature. Then they were evaluated by transillumination method for enamel and root cracks. The coronal aspect of each tooth was resected perpendicular to the long axis and 1 mm incisal to the cementoenamel junction (CEJ) with a diamond bur (Diatech; Dental AG, Heerbrugg, Swiss) under water cooling. The sectioned surfaces were flattened and smoothed with 2-μm-grit abrasive paper (Nikon; Tokyo, Japan) under running water.

Root canals were instrumented at a working length with a size 40 K-file (Maillefer; Dentsply, Zürich, Switzerland) using the step-back technique.[39] After intermittent irrigation with 2.5% NaOCl and rinsing with saline solution between file sizes, the canals were dried with paper points (Roeko; Langenau, Germany). The canals were filled with cold lateral condensation of gutta-percha (Dia Dent Group International Inc., Korea) and a calcium hydroxide-based sealer (Sealapex; Kerr, Sybron). Treated root canals were obturated with zinc phosphate cement (Adhesor; SpofaDental, Kerr Co., Frankfurt, Germany) and specimens were stored in saline solution at room temperature for 1 week.

Then, the teeth were randomly grouped for cast metal post-core (MPC) (n = 20) and zirconium post-and-core (ZPC) (n = 20). The post spaces for the cast metal post-core group were enlarged with drills (Peeso Reamer No 3; Produits Dentaire SA, Vevy, Switzerland), leaving the apical 1/3 undisturbed. The post spaces for the ceramic post-core group were prepared with the CosmoPost kit (CosmoPost; Ivoclar, Schaan, Liechtenstein) according to the manufacturer's recommendations. For standardization purposes, the final enlargement was made using 1.4 mm diameter CosmoPost drill for all teeth in both groups.

Cylindrical acrylic rods (Duralay, Reliance Dental Mfg, Worth, Ill), 2 cm long and 1 mm in diameter, were dipped into molten casting wax (Kronenwachs Mittelhart; Bego, Bremen, Germany) and inserted in a gradual manner through the canal spaces to obtain the direct impression of the canals for groups cemented metal post-core (CMPC) and noncemented metal post-core (NMPC). A core (4 mm in height) was fabricated above the acrylic rod and the remaining rod length (2 mm) was thickened to 2.5 mm diameter with casting wax. Metal post-and-cores were cast with nickel-chromium alloy (CeraPlus S; CeraPlus President; München, Germany) (Fig. 1).

Standard zirconium dioxide posts were passively seated into the prepared canals of the cemented zirconium dioxide post-core (CZPC) and noncemented zirconium dioxide post-core (NZPC). Then, casting wax was modeled around the coronal extensions of the posts to obtain cores of 4 mm high as previously described for groups CMPC and NMPC. The wax patterns were sprued and invested using IPS Empress 2 Speed (Ivoclar; Schaan, Lichtenstein). Burn-out was performed according to the manufacturer's recommendations in the Ivoclar EP 600 furnace. Ceramic ingots (IPS Empress 2 Cosmo Ingot C; Ivoclar, Schaan, Lichtenstein) were pressed to form ceramic cores around zirconium posts.

Core and tooth margin integrity of all specimens were evaluated using a ×10 magnifying glass. Sprue extensions (2 mm long and 2.5 mm in diameter) remaining on the top of the cores were adjusted to fit the custom-made test device (Fig. 1). All specimens were kept in saline solution at room temperature to avoid dehydration.

Before cementation and adaptation procedures, core-tooth junctions of the specimens were circumferentially covered with a 1 mm band (Fig. 2). The surface of the tooth except this banded

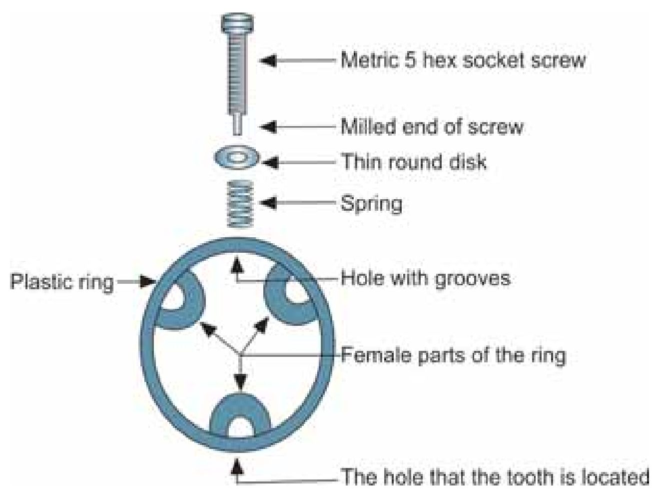


Fig. 1: Custom-made adaptation device

Fig. 2: Circumferentially covered specimens with a 1 mm band

Fig. 3: Specimens that were uncemented and cemented

area was covered with two layers of clear nail varnish. After the nail varnish was set, bands around the teeth were removed.

Each specimen was placed in a prefabricated standard hard bakelite plastic ring (1.5 cm high, 3 mm thick, 4 cm diameter). (Fig. 1) Two holes (3 mm diameter) were reciprocally punched on the ring surface in the same direction with a milling machine (Tezsan; T165-MF, Izmit, Turkey). A guide suitable for metric 5 (m5) hex socket (Allen) screw was placed in one of the holes to provide grooves. The 5 mm diameter end points of m5 hex socket screws used in this study were machined to 2.5 mm diameter under milling machine. An additional 40 springs made of a stainless steel wire of 1 mm thick, 1 cm length and 3 mm in diameter were prepared. The endpoints of the springs were flattened to enlarge the contact surface. The lower part of a screwdriver (ITI Dental Implant System; Straumann Institute, Waldenburg, Switzerland) was modified to fit to the m5 hex socket screw's upper portion.

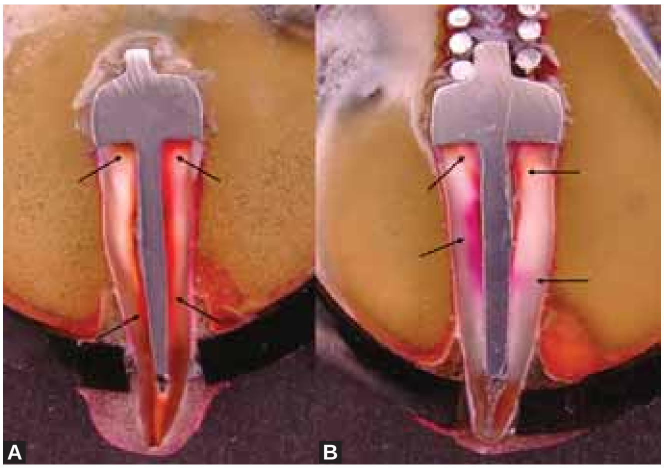
Apical 1 mm portion of all roots were fixed to the unprepared holes of the rings with acrylic resin. Groups NMPC and NZPC (n = 10) were used as controls (Fig. 3). The springs of control groups were placed above the cores and thin round pieces were put on to the springs. The screws were placed inside the rings and they were screwed with the ITI torque device with a force of 15 N [40, 41] for standardization. Cementation of groups CMPC and CZPC was performed with dual cure resin cement (Panavia F; Kuraray Dental, Osaka, Japan). The specimens were placed on the test device and maintained with a 15 N force as described in the control group while the cement was cured with a conventional light source (Translux; Heraus Kulzer, Hanau, Germany) for 20s from each side according to the manufacturer's instructions. Before the curing procedure, access cement was cleaned with a small brush inside the kit and cured with a conventional light source (Translux; Heraus Kulzer, Hanau, Germany) for 20s from each side according to the manufacturer's instructions. After the curing process OxyGuard was applied for 3 minutes to the core-tooth junction to block the oxygen contact for the last hardening of the cement. Access cement was scaled with a periodontal scaler.

All specimens were immersed in 0.5% aqueous basic fuchsine for 48 hours. Following immersion, all specimens were rinsed under running water. The rings were filled with epoxy resin (Kimetsan Corp; Ankara, Turkey). A grinding machine with iron oxide disks was used to grind and polish the specimens so that sagittal sections of the posts could be obtained. The specimens were then evaluated under binocular and coal microscopes.

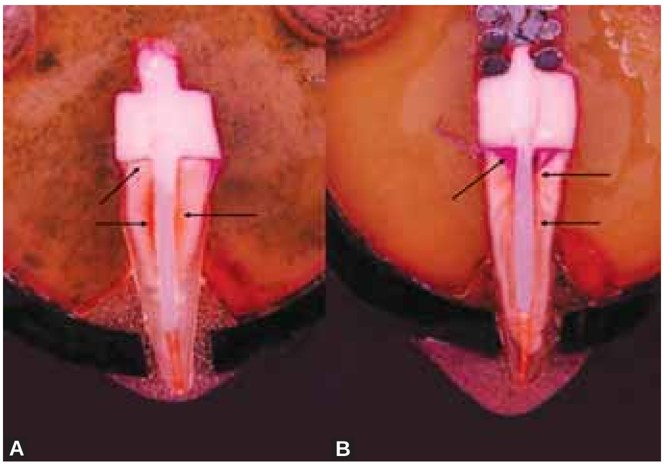
The specimens were photographed with 1:1 macro-objective (Tamron; Tamron Optical Co. Ltd, Shangai, China) followed by an examination under 13.4 magnification (×0.67 objective, ×20 ocular) by a binocular microscope (Leitz; Wetzlar, Germany). Thereafter, a coal microscope (Leitz MPV2; Wetzlar, Germany) was used under 62.5 magnifications (×5 objective, ×10 ocular and ×1.25 interval sum) and specimens were photographed with the digital camera (Leica 350; Solms, Germany). Following image evaluation by a single observer, (Figs 4 to 6) the amount of dye penetration was scored at the mesial and distal surface of the tooth according to the scale[42] seen in Fig. 7. All data were statistically analyzed using Kruskall-Wallis analysis of variance test at a significance level of 0.05.

RESULTS

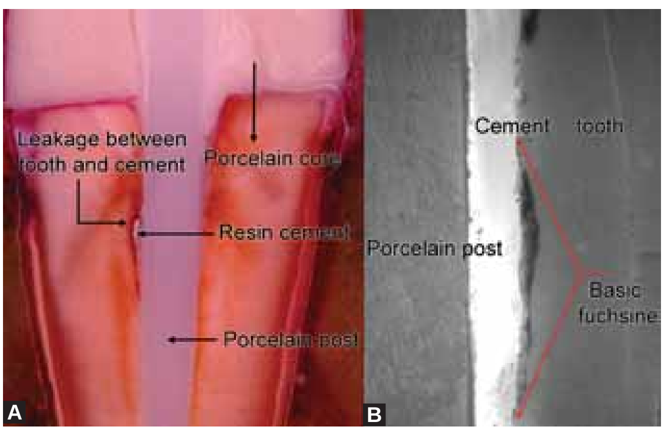
Forty post-core restorations in 4 different groups (n = 10) were inspected under microscopes to investigate the dye penetration amount from the coronal region of the restorations. Results of the investigation were evaluated by grading from both sides of the specimen. Obtained values are presented at Table 1. No significant difference was found either between NMPC and NZPC groups or between CMPC and CZPC groups ($p > 0.05$). However, within group comparisons showed that microleakage in NMPC and NZPC was higher than of the CMPC and CZPC groups. Least microleakage was seen in the CZPC group. As seen in Figure 6, the amount of the dye penetration was most evident at the resin cement-tooth interface traversing through the tooth. Nonetheless, these findings revealed no statistically significant differences ($p = 0.136$).



Figs 4A and B: Region of die penetration in (A) cemented and (B) uncemented cast post-and-core specimens



Figs 5A and B: Region of die penetration in (A) cemented and (B) uncemented ceramic post-and-core specimens



Figs 6A and B: (A) Ceramic post-and-core in photographically and (B) under coal microscope

Table 1: Statistical results of the microleakage measurements

	Mean values (min-max)
NMPC	4.55 (4.0-5.0)
CMPC	4.30 (2.5-5.0)
NZPC	4.45 (3.0-5.0)
CZPC	3.85 (3.0-5.0)

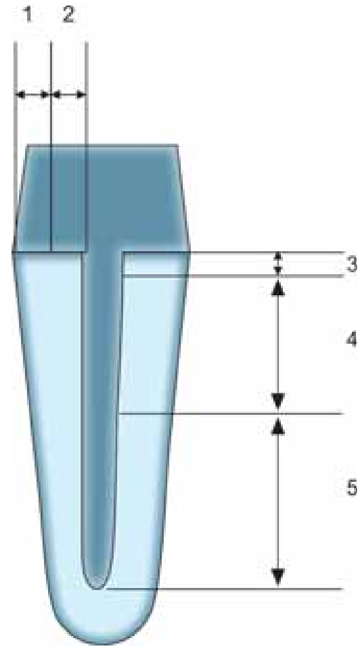


Fig. 7: 1: Dye penetrated no more than halfway from post, 2: Dye penetrated to post, 3: Dye penetrated just into the post space, 4: Dye penetrated to one-half of post length in the post space, 5: Dye penetrated from one-half of post length to beyond full post length

DISCUSSION

In the past, cast metal post-cores were the only viable and available choice for the restoration of severely damaged teeth.[3,7] Existing literature[8-11] does not show the superiority of any post-core systems related to its material or technique. Thus, the aim of the present study was to determine, if there is a difference in coronal microleakage between cast metal post-core system and ceramic post-core system. Coronal microleakage between teeth, MPC and ZPC were evaluated with dye penetration method using aqueous basic fuchsine. The null hypothesis was partly rejected since there were no differences regarding microleakage between post systems, however, adaptation of the post-core system is more important than cementation.

Evaluating the relationship between the quality of coronal restorations and coronal obturation by examining periapical status radiographs of endodontically treated teeth, have in literature it was reported that when good coronal restorations and endodontic treatments were performed, less periradicular inflammatory lesions were seen.[25] When poor endodontically treated teeth were restored with good permanent restorations, the resultant success rate was found as 67.6%. Thus, the authors[25] concluded that apical periodontal health depends significantly more on the coronal restoration than on the technical quality of the endodontic treatment, as supported by other literature.[4,26] Since, post-core is a critical part of the coronal restoration, studying the amount of microleakage between post-core and tooth is crucial for the success of the final restoration.

Usumez et al[34] evaluated the microleakage of different post-core systems by using fluid filtration technique. They found that leakage values were less in resin-supported polyethylene fibers and glass fibers than metal and zirconium posts. On the other hand, Bachicha et al[35] reported that the use of different post types showed no difference with regards to microleakage. However, they reported that when different cements were used to cement the posts, a significant difference in microleakage was seen. Fogel[28] compared microleakage associated with stainless steel posts-cemented with various cements. Evaluation of microleakage with the fluid filtration system showed that none of the post-cement combinations tested were capable of consistently achieving a tight seal. It appeared that the type of cement affects microleakage more than the type of posts used.[11] In the present study, cement type was not compared, however, the effect of adaptation in two different post-core systems was evaluated. The results revealed unlike the other studies in literatures achieving a tight seal are more effective than the cementation procedure.

Because marginal adaptation is an important factor in coronal leakage, noncemented groups of both post-core types have been used in the present study. Although the results were statistically nonsignificant, microscopic evaluations of two different post-core systems showed that ceramic posts were more adapted to the post spaces compared to cast metal ones. However, under the microscope, basic fuchsine penetrated coronally in all specimens for all test groups.

There are many methods to inspect microleakage. In the dye penetration method, the particle size of the dye must be larger than the diameter of dentinal tubules (1-4μ).[36] Furthermore, the cavity walls and the restoration material must be distinguishable for microscopic evaluation. Methylene blue, basic fuchsine, fluorescent dye, crystal violet, Indian ink and eosine are the commonly used dyes in microleakage studies.[23,27,37] In the present study 0.5% aqueous basic fuchsine dye was preferred as it has the best contrast under microscope compared to other dyes.

A limitation of the present study was that crowns were not prepared on core foundations, which might have been a factor in determining the amount of leakage. Also, dynamic loading or artificial saliva media may be needed to mimic the *in vivo* conditions for coronal microleakage. Therefore, further *in vivo* and *in vitro* research should be conducted in order to have a better understanding in microleakage.

All-ceramic restorations are the most esthetic foundations for the anterior region. However, when coronally extensively damaged teeth need a treatment, zirconium dioxide post/ceramic core foundations may be safely used clinically as their microleakage values were comparable to that of cast metal post-core foundations.

CONCLUSION

Within the limitations of this study, the following conclusions were drawn:

1. Microleakage was seen in all test groups (CMPC, NMPC, CZPC and NZCP).
2. No statistically significant difference was found between cemented (CMPC and CZPC) and noncemented (NMPC and NZPC) groups ($p > 0.05$).

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REFERENCES

1. The glossary of prosthodontic terms. J Prosthet Dent 2005; 94(1):24,56.
2. Millstein PL, Yu H, Hsu CS, Nathanson D. Effects of cementing on retention of prefabricated screw posts. J Prosthet Dent 1987; 57:171-74.
3. Malone WF, Koth DL. Tylman's theory and practice of fixed prosthodontics (8th ed). St Louis: Mosby 1989.
4. Rosenstiel SF, Land MF, Fujimato J. Contemporary fixed prosthodontics (2nd ed). St Louis: Mosby 1995.
5. McLean A. Predictably restoring endodontic teeth. J Can Dent Assoc 1998;64:782-87.
6. Stockton LW. Factors affecting retention of post systems: A literature review. J Prosthet Dent 1999;81:380-85.
7. Sokol, DJ. Effective use of current core and post concepts. J Prosthet Dent 1984;52:231-34.
8. Ozkurt Z, Iseri U, Kazazoglu E. Zirconia ceramic post systems: A literature review and a case report. Dent Mater J 2010; 29(3): 233-45.
9. Heydecke G, Butz F, Hussein A, Strub JR. Fracture strength after dynamic loading of endodontically treated teeth restored with different post-and-core systems. J Prosthet Dent 2002; 87:438-45.
10. Freedman GA. Esthetic post-and-core treatment. Dent Clin North Am 2001;45:103-16.
11. Morgano SM, Brackett SE. Foundation restorations in fixed partial prosthodontics: Current knowledge and future needs. J Prosthet Dent 1999;82:643-57.
12. Kedici SP, Aksut AA, Kilicarslan MA, Bayramoglu G, Gokdemir K. Corrosion behavior of dental metals and alloys in different media. J Oral Rehabil 1998;25:800-08.
13. Oblak C, Jevnikar P, Kosmac T, Funduk N, Marion L. Fracture resistance and reliability of new zirconia posts. J Prosthet Dent 2004;91:342-48.
14. Schneider RL. A one appointment procedure for cast post and core restorations. J Prosthet Dent 1994;71:420-22.
15. Akkayan B, Gülmez T. Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent 2002;87:431-37.
16. Hochmann N, Zalkind M. New all ceramic indirect post-and-core system. J Prosthet Dent 1999;81:625-29.
17. Paul SJ, Werder P. Clinical success of zirconium oxide posts with resin composite or glass-ceramic cores in endodontically treated teeth: A 4-year retrospective study. Int J Prosthodont 2004;17:524-28.
18. Ivoclar Vivadent. CosmoPost/IPS Empress Cosmo Ingot Scientific Documentation, 2002, pp. 9.
19. Pontius O, Hutter JW. Survival rate and fracture strength of incisors restored with different endodontically treated incisors without coronoradicular post and core systems endodontically treated incisors without coronoradicular reinforcement. J Endod 2002;28:710-15.

20. Stockton LW. Factors affecting retention of post systems. J Prosthet Dent 1999; 81:625-29.
21. Sorenson JA, Engelman MJ. Effect of post adaptation on fracture resistance of endodontically treated teeth. J Prosthet Dent 1990; 64:419-34.
22. Shillingburg HT, Hobo S, Whitsett LD. Fundamentals of fixed prosthodontics (3th ed). Chicago: Quintessence Pub Co Inc, 1997 p.194.
23. Coleman AJ, Moses MS, Rickerby HHD. Macromolecular leakage beneath full cast crowns: A 2 years in vitro investigation. J Prosthet Dent 2001;85:20-25.
24. Manocci F, Ferrari M, Watson TF. Microleakage of endodontically treated teeth restored with fiber posts and composite cores after cyclic loading: A confocal microscopic study. J Prosthet Dent 2001;85:284-91.
25. Heling I, Gorfil C, Slutzky H, Kopolovic K, Zalkind M, Goldberg SI. Endodontic failure caused by inadequate restorative procedures: Review and treatment recommendations. J Prosthet Dent 2002;87:674-78.
26. Lindquist TJ, Connolly J. In vitro microleakage of luting cements and crown foundation materials. J Prosthet Dent 2001;85: 292-98.
27. Wu MK, Pehlivan Y, Kontakiotis EG, Wesselink PR. Microleakage along apical root fillings and cemented pots. J Prosthet Dent 1998;79:264-69.
28. Fogel HM. Microleakage of pots used to restore endodontically teeth. J Endod Jul 1995;21(7):376-79.
29. Rogic-Barbic M, Segovic S, Pezelj-Ribaric S, Borcic J, Jukic S, Anic I. Microleakage along Glassix glass fibre pots cemented with three different materials assessed using a fluid transport system. Int Endod J 2006;39:363-67.
30. Aquilino SA, Caplan DJ. Relationship between crown placement and the survival of endodontically treated teeth. J Prosthet Dent 2002;87:256-63.
31. White SN, Furuichi R, Kyomen SM. Microleakage through dentin after crown cementation. J Endod 1995;21:9-12.
32. Kydd WL, Nicholls JI, Harrington G, Freeman M. Marginal leakage of cast gold crowns luted with zinc phosphate cement: An in vivo study. J Prosthet Dent 1996;75:9-13.
33. Gladys S, Van Meerbeek B, Lambrechts P, Vanherle G. Microleakage of adhesive restorative materials. Am J Dent 2001;14:170-76.
34. Usumez A, Cobankara FK, Ozturk N, Eskitascioglu G, Belli S. Microleakage of endodontically treated teeth with different dowel systems. J Prosthet Dent 2004;92:163-69.
35. Bachicha WS, Difiore PM, Miller DA, Lautenschjager EP, Pashley DH. Microleakage of endodontically treated teeth restored with posts. J Endod 1998;24:703-08.
36. Taylor MJ, Lynch E. Microleakage. J Dent 1992;2:3-10.
37. Swanson K, Madison S. An evaluation of coronal microleakage in endodontically treated teeth. Part I. Time periods. J Endod 1987;13:56-59.
38. Fox K, Gutteridge DL. An in vitro study of coronal microleakage in root-canal treated teeth restored by the post and core technique. Int J Endod 1997;30:361-68.
39. Haidet J, Reader A, Beck M, Meyers W. An in vivo comparison of the step-back technique versus a step-back/ultrasonic technique in human mandibular molars. J Endod 1989;15:195-99.
40. Gross M, Abromovich I, Weiss EI. Microleakage at the abutment-implant interface of osseointegrated implants: A comparative study. Int J Oral Maxillofac Implants 1999;14: 94-100.
41. Cehreli M, Akca K, Tonuk E. Accuracy of a manual torque application device for morse- taper implants: A technical note. Int J Oral Maxillofac Implants 2004;19:743-48.
42. Tjan AHL, Grant BE, Dunn JR. Microleakage of composite resin cores treated with various dentin bonding systems. J Prosthet Dent 1991;66:24-29.