In vitro assessment of the influence of different protection plugs over obturation remnant space, after post preparation, on the retention of cast metal posts

Carlos Roberto Emerenciano **BUENO**[1]
Diego **VALENTIM**[1]
Gustavo Sivieri **ARAÚJO**[1]
Rogerio de Castilho **JACINTO**[1]
João Eduardo **GOMES FILHO**[1]
Luciano Tavares Angelo **CINTRA**[1]
Eloi **DEZAN JUNIOR**[1]

DOI: https://doi.org/10.14436/2358-2545.10.2.034-041.oar

ABSTRACT

Objective: To evaluate the influence of different protection plugs over the remaining obturation after post space preparation, on cast metal post retention. **Methodology:** Fifty bovine teeth were decoronated and root canals were manually instrumented up to a Kerr 80 file and then obturated. A Largo drill was used to partially clear the canal at a 10mm depth. Groups were divided, according to different plug materials (n=10): Group I (control, with no plug), Group II (Coltosol® plug), Group III (Sealapex® + zinc oxide in putty-like consistence plug), Group IV (ethyl-cyanocrylate plug) and Group V (zinc phosphate plug). A layer with 1mm of thickness of different plug materials (Groups II, III, IV and V) was adapted over the remaining obturation and specimens were sealed and then stored in 100% humidity for 7 days. After the root canal was molded, cast metal posts were manufactured and cemented with zinc phosphate. The specimens remained in a humid chamber for 45 days before traction test was performed using a universal testing machine. The values were shown in Megapascal (MPa) and submitted to the ANOVA test and Tukey's T est ($P<.05$). **Results:** Ethyl-cyanoacrylate reduced cast metal post retention ($P<.01$), without differences from the other groups ($P>.05$), similar to control. **Conclusion:** The obturation protection with plugs made of ethyl-cyanoacrylate hindered retention when cast metal posts are cemented with zinc phosphate, whereas Sealapex® with added zinc oxide, hardened zinc phosphate cement or Coltosol® do not interfere in the adhesiveness factor.

Keywords: Cementation. Endodontics. Dental Prosthesis Retention. Dental Pulp Cavity.

How to cite: Bueno CRE, Valentim D, Araújo GS, Jacinto RC, Gomes Filho JE, Cintra LTA, Dezan Junior E. In vitro assessment of the influence of different protection plugs over obturation remnant space, after post preparation, on the retention of cast metal posts. Dental Press Endod. 2020 May-Aug;10(2):34-41.
DOI: https://doi.org/10.14436/2358-2545.10.2.034-041.oar

[1] Universidade Estadual Paulista, Faculdade de Odontologia de Araçatuba, Departamento de Odontologia Restauradora, Disciplina de Endodontia (Araçatuba/SP, Brazil).

» The authors report no commercial, proprietary or financial interest in the products or companies described in this article.

» Patients displayed in this article previously approved the use of their facial and intraoral photographs.

Submitted: August 20, 2018. Revised and accepted: February 11, 2019.

Contact address: Eloi Dezan Junior
Rua José Bonifácio, nº 1193, Departamento de Endodontia, Faculdade de Odontologia de Araçatuba, Univ. Estadual Paulista - FOA/UNESP
CEP: 16.015-050 – Araçatuba/SP, Brasil – E-mail: dezan@foa.unesp.br

Introduction

The endodontic treatment aims to heal or preventing apical periodontitis. Thus, a contaminated root canal has to be cleaned, shaped, and obturated with proper filling materials that, along with the coronal restoration, should prevent oral bacteria from re-contaminate the canal and apical tissues.[1]

Coronal destruction may be observed after completion of endodontic therapy and residual dentin influence the clinical survival of restoration[2], whereas intrarradicular post is primordial for retaining coronal restorative material.[3] In general, cast post and cores have been used for several years to restore anatomy and function of endodontically treated teeth, showing elevated success rate,[4] made of different materials as cast metal, pre-manufactured metallic or fiberglass posts[5]. Although fiber posts show advantages, as elastic modulus close to dentin, less dentin removal, and satisfactory aesthetic,[6] cast metal posts are still frequently used by clinicians[7] which are recommended for clinical use, due to its lower stress-induction in dentin[8] and elevated fracture strength,[9] since it's based on the root canal mold and show satisfactory clinical results regarding survival of restoration.[10,11]

Cast metal posts may be manufactured with metallic alloys such as nickel-chromium (NiCr) or copper-aluminum (CuAl). Despite the aesthetical disadvantage, the cast metal posts improve the distribution of masticatory loads in the root,[5,12] with a high survival rate after 10 years.[13] However, failures in coronal sealing lead to microleakage, that may occur after obturation and before final restoration, increasing possible failures to the endodontic treatment, since there is an exposure to the oral environment allowing microorganisms to reach periapical tissues.[14] The recontamination is mainly due to fracture of restorative material, loss of temporary sealing (delay for definitive restoration), contamination during restorative procedures,[15] or even inadequate retention.[16]

Once the coronal sealing is compromised, microorganisms can invade the coronal portion of root canal filling and reach apical portion in approximately 30 days, even in well-obturated canals.[17] According to Holland et al,[18] the coronal leakage after post space preparation may be even more critical, since there is less obturating material remaining inside the root canal.

Microbial leakage can be avoided or decreased with a 1 mm intraorifice protection plug over the remaining obturation after post space preparation, even with oral exposure,[19,20,21] directing some researches to assess the efficiency of different coronal sealings after endodontic treatment.[19,22,23]

The protection plug can be made of different materials, such as Coltosol,[21] endodontic sealers or even ethyl-cyanoacrylate, which showed less coronal leakage in previous researches[20,24]. However, although ethyl-cyanoacrylate presented elevated protection in those reports and has the advantage of clinical practicality, the authors stated that a thin layer always remains on the canal walls and any occurrences after post cementation are unknown, since its removal is uncertain .

Thus, the material type used to make the plug may interfere with the prosthetic post retention, making it necessary to evaluate the interference of these plugs with the adhesiveness factor. Therefore, the aim of this study was to assess, in vitro, the influence of different protection plugs on cast metal post retention. The null hypothesis was that there would be no significant interference of the plugs on cast metal post retention, showing values similar to those of the control group.

Methodology

This study was approved by the institutional Committee on Animal Research and Ethics at UNESP-Universidade Estadual Paulista (São Paulo, Brazil) and conducted in accordance with relevant guidelines (CEUA/FOA process 00679-2018).

Teeth Preparation

Fifty recently extracted bovine maxillary central incisors with closed apical foramen and almost identical crown and root size were selected to assess post retention. The teeth were immersed in 5,25% sodium hypochlorite (Farmácia de Manipulação Fórmula Ação, Campo Mourão/PR, Brazil) for 60 minutes to remove organic tissues and then kept in 0.1% thymol solution under refrigeration.

The crown was transversely sectioned at their cervical portion, using a double-faced diamond disk on a slow-speed handpiece, cooled with air/water spray, standardizing roots at 16 mm, from root apex to coronal border. Canal patency was achieved with a Kerr hand file #20 (Dentsply Maillefer, USA) introduced into the root canal of each tooth until visualization of the apex. Typically, the anatomical diameter of the root canal corresponded to a Kerr hand file #50. The root canals were manually instrumented up to a Kerr hand file K#80, 1mm short of the apex, with working length set to 15 mm. During instrumentation, teeth were irrigated with 2,5% sodium hypochlorite, and 5 mL of 17% EDTA (Biodinâmica Química e Farmacêutica LTDA, Ibiporã/PR, Brazil) was used for 3 minutes followed by a final irrigation of 2,5% sodium hypochlorite, to remove residual salts, and then dried with absorbent paper point. The roots were obturated with a calibrated gutta-percha point and eugenol-free endodontic sealer Sealapex® (Kerr Endodontics, USA), using lateral condensation technique and accessory gutta-percha points.

Post space preparation

After obturation, specimens were immediately prepared for the post, with partial desobturation of 10mm of depth with a #3 Largo Bur (Fig 1A) in a low speed handpiece, leaving 5 mm of filling material. Vertical condensation was performed on the remaining obturation. Afterwards, roots were randomly assigned to five experimental groups (n=10), according to their plug material, which encompasses Coltosol® (Coltene Vigodent, BR), Sealapex® (Kerr Endodontics, USA) with zinc oxide in putty consistency , ethyl-cyanoacrylate (Super Bonder®, Loctite, BR) or zinc phosphate cement (SS White Duflex, BR) - as described in Table 1. The specimens receiving the protection plug had the length of the remaining filling reduced to 4 mm in order to accommodate the 1mm plug, which was placed over the remaining obturation. Thickness was controlled by a plugger with a rubber stopper cursor, followed by a digital radiographic confirmation (Micro Imagem, BR) (Fig 1B). For group IV, ethyl-cyanoacrylate was applied with the aid of paper points, with any excess being removed with other paper points, respecting the thickness value of 1mm - as verified after set.

The samples were sealed with 2mm of Coltosol® (Coltene, Vigodent, BR) and stored at 37° C in fully saturated humidity for 48 hours before molding the roots to manufacture the posts. After the temporary cement was removed, canals were coated with petroleum jelly (Vaseline®, USA) and molded with methyl methacrylate resin (Duralay®, USA).

The resin pin was molded until it reached the entire length of the desobturated part of the canal. During resin polymerization, the molded pin was removed and introduced several times to prevent it from being retained inside the root canal. After polymerization, the fidelity of the molded pin was checked. The coronary portion was reconstructed in order to adapt to the universal traction machine. Then, the resin pins were sent to the laboratory to be manufactured with the copper-aluminum (CuAl) alloy, while the roots remained in humid chamber. This was done so that the metal posts could be ready for cementation after the sealer's setting time.[25]

Seven days after obturation, the samples were removed from the humid chamber and cast metal posts were cemented with zinc phosphate. Forty-eight hours after post cementation, samples were embedded in a PVC tube ring, 3cm in length and 1.5cm in diameter, with chemically activated acrylic resin. The cervical root surface remained at the same level of the upper surface of the PVC ring, as well as the post that was parallel with the long axis of the PVC tube ring. The coronary cast metal post portion (located outside the root) was attached to an parallelometer prior to resin insertion into the PVC ring, ensuring the necessary parallelism for tensile test and the specimens remained in humid chamber.

After 45 days of post cementation, the PVC ring was attached to a metal platform and then connected to a Universal Testing Machine base (EMIC, Brazil). After that, a metal post coronary portion was attached to a device coupled to the load cell, compatible with the forces generated during the push-out test, being connected to the same machine.

The push-out test was used to analyze bond strength between cast metal post and intra-radicular dentin with different protection plugs, under a tensile force at the speed of 5 mm/min.

The values obtained were expressed in MegaPascal (MPa), recorded in appropriate tables and submitted to the Shapiro Wilk normality test, which indicated a significance level of 5% in ANOVA and Tukey's Test using the SigmaPlot software (Version 12.0, Systat Software, CA, USA).

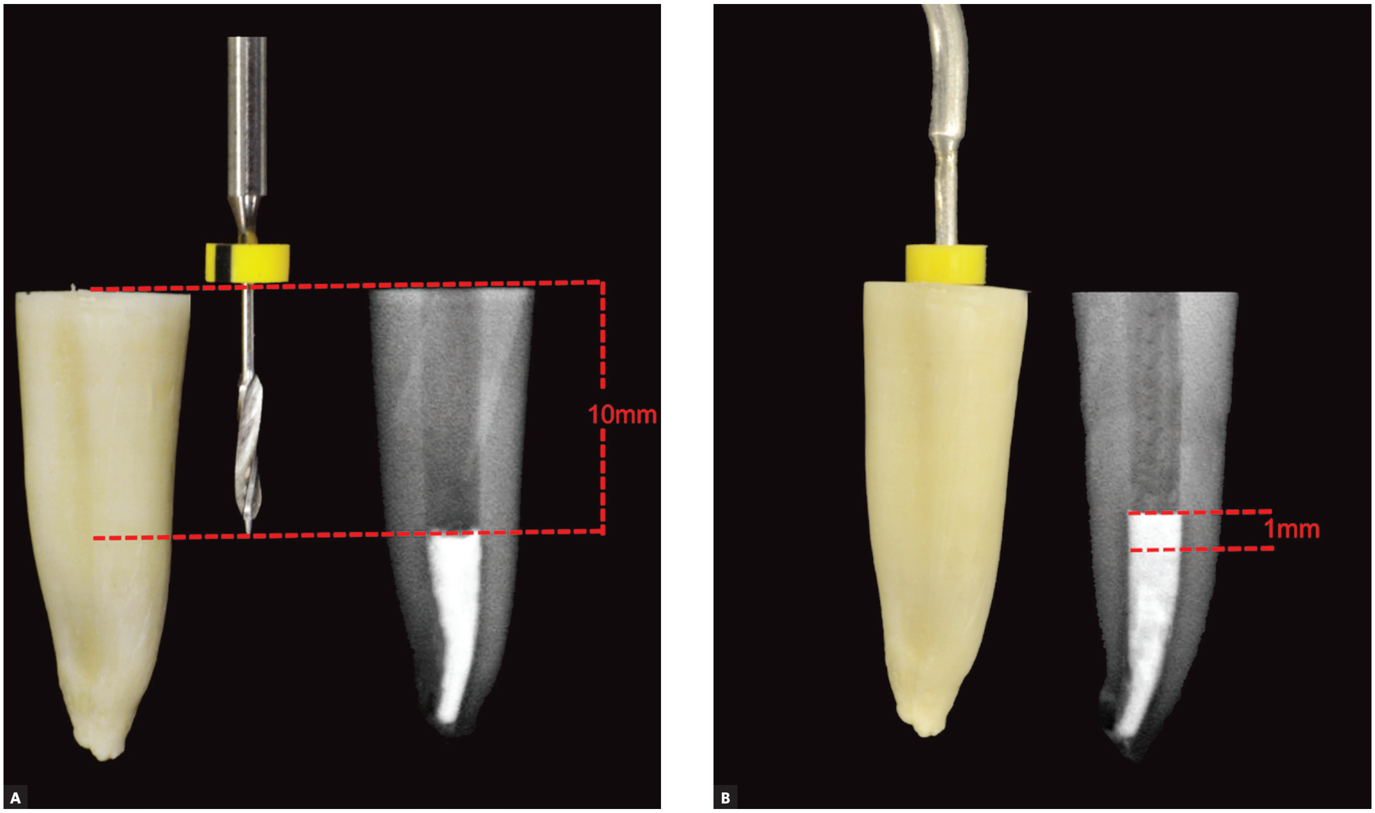

Figure 1. A) Partial desobturation of 10mm of depth with a #3 Largo Bur. **B**) 1mm accommodation of the Coltosol® plug over the remaining obturation, with a rubber stopper cursor adjusted to the desired length, radiographically confirmed.

Table 1. Experimental groups according to each testing plug.

Experimental Groups	Tested Material Plugs
I	Control (no material)
II	Coltosol® plug
III	Sealapex® + zinc oxide (putty)
IV	Ethyl-cyanoacrylate
V	Zinc phosphate

Results

Group I (no plug) showed tensile strength values of 266,00 MPa. Group II (Coltosol® plug) had 317,51 MPa; Group III (Sealapex® with zinc oxide plug) 235,64 MPa; Group IV (Ethyl-cyanoacrylate plug) 134,25 MPa; and 267,07 MPa for Group V (zinc phosphate plug).

Comparison among groups showed that Groups II, III and V had no interference in the cast metal post bond strength, presenting results similar to those of the control group ($P>.05$). Group IV (ethyl-cyanoacrylate plug) negatively interfered, reducing cast metal post retention, cemented with zinc phosphate, in a significant statistical difference ($P<.01$). The different result values for these experimental groups are shown in Table 2.

Table 2. Results of traction test. Tensile strength values expressed in Megapascal (MPa) and standard deviation (SD) in the different experimental groups.

Groups*	Tensile strength (MPa) and SD	n
Control[a]	266,00 ± 53,9	10
Coltosol[a]	317,51 ± 51,4	10
Sealapex + zinc oxide[a]	235,64 ± 33,2	10
Ethyl-cyanoacrylate[b]	134,25 ± 9,0	10
Zinc phosphate[a]	267,07 ± 49,3	10

*Same superscript letters indicate no statistical difference among the groups.

Discussion

In this study, the ethyl-cyanoacrylate protection plug hindered cast metal post retention when cemented with zinc phosphate. Thus, the null hypothesis was rejected.

Regarding the obturation technique with Sealapex, endodontic eugenol-free sealers are preferred to avoid unwanted interactions,[26,27] since eugenol was proved to interact with post retention, when cemented with resin or even with zinc phosphate cements.[28]

After partial obturation removal for post placement, the apical remaining of root canal filling shows a significantly more elevated leakage than the full-length root canal filling. Therefore, the sealing provided by a fully obturated root canal may be jeopardized by post space preparation.[29] To minimize leakage possibility, it was recommended the use of a temporary coronal sealer to prevent coronal-apical bacteria penetration.[30]

The plug over the remaining obturation contributes to protection and decrease of coronary infiltration.[21] A previous study showed a reduction of 50% on inflammation levels when using protective plugs when compared to a group without said plugs, stating that their use is beneficial to the delay and prevention of coronal microleakage[31]. Since the main objective of using a plug is to protect the remaining obturation against possible bacterial infiltration, it is important to highlight: a) the antifungal effect of the zinc phosphate cement;[32] b) the antimicrobial activity of ethyl-cyanoacrylate,[33,34] zinc oxide[35,36] and Coltosol®[37,38], with its elevated sealing capacity;[39] and c) the enhanced sealing capacity provided by the addition of zinc oxide to the endodontic sealer Sealapex® used against microbial leakage,[40] similar to the MTA or the Portland cement.[41]

The use of bovine teeth for tests with post cementation was used by previous authors.[42-45] In this study, bovine incisors were used due to the availability/ absence of caries or restorations. Although there is a difference between dentinal tubules in bovine and human dentin, the number and diameter of dentin tubules in bovine reduces from cervical to apical third, without any significant difference.[46]

After obturation, the root canal was immediately desobturated, because according to Portell et al.[47], delayed post space preparations significantly increases leakage. The desobturation of 10mm was due to a previous research, which showed that 8 - 10mm cast metal posts have an elevated resistance to removal.[48]

The use of an intraradicular post is the main technique to retain coronal restoration. Glass fiber posts were introduced as an alternative to metal posts, presenting a faster technique, dismissing the laboratory stage and elastic moduli close to dentin, decreasing the risk of root fracture, besides an aesthetic advantage.[49] However, a systematic review and meta-analysis conducted by Fiqueiredo et al.[50] showed no significant differences in the incidence of root fractures between fiber and metal posts, as corroborated by a posterior study. [51] Serving to show that, when respecting particular indications, both posts have satisfactory results. In addition, the copper-aluminum alloy used to manufacture the cast metal post in the present study was evaluated by Verri et al.[52], whose study recommends metal posts with CuAl alloys instead of fiberglass posts in cases where the teeth has no remaining dentin structure. This is done in order to avoid higher stress, which could jeopardize the entire restoration process.

In order to assess post retention over different protection plugs, cast metal posts were preferred due to its adaptation inside the root canal space, reducing cementation line and increasing retention,[53] since the large canal size would require more cementation and, therefore, minimize possible methodology interference. Because the cast metal post is based on each root canal mold, retention would be enhanced, due to the custom post diameter being compatible with each root canal, which has a positive effect on retention.[54] Another fact was the choice of zinc phosphate cement as the luting agent. Habib et al.[55] assessed two luting agents (resinous and zinc phosphate) for retention of cast post, and observed higher retentive values for cast posts cemented with zinc phosphate.

The ethyl-cyanoacrylate plug showed an elevated capacity to maintain coronary sealing when used as a protective plug, as evidenced by previous reports.[20,24] Despite this, the authors reported a difficulty in creating the plug without leaving any remnants on the root canal wall. Nevertheless, the present study showed that ethyl-cyanoacrylate plug hinders cast metal post retention. Our results are related to the possible residues of ethyl-cyanoacrylate remaining on canal walls, since its high fluidity becomes a notable complication during insertion. This fact was not observed when other plugs were inserted, since they are of more consistent materials, facilitating the handling inside the canal and the cleanliness before post cementation.

It's also important to emphasize that the canal size of bovine incisors used in this study facilitate the material accommodation over obturation, in contrast to a clinical situation involving human teeth. In our study, the difficulty of handling ethyl-cyanoacrylate inside the canal in human teeth would be increased due to its diameter, with an even higher probability of residues remaining inside the canal .

Another fact observed in our results was the tendency of the Coltosol® plug to improve the cast metal post retention with the zinc phosphate cement. There is no substantiated explanation, but it should be better analyzed through other studies concerning the bond between Coltosol® and zinc phosphate cement. We hypothesize that the bond may be related to their composition, based on zinc oxide/zinc sulfate for Coltosol®,[56] and zinc oxide/magnesium oxide (powder) and phosphoric acid/aluminum phosphate (liquid), which form a zinc-aluminophosphate gel, for the zinc phosphate cement.[57]

Conclusion

Based on this study , it is possible to state that protective plugs made with Sealapex with added zinc oxide, hardened zinc phosphate cement or Coltosol® , did not interfere with cast metal post retention, suggesting that these materials protect the remaining obturation after post space preparation. Thus, Coltosol® improved post retention when cemented with zinc phosphate.

Although ethyl-cyanoacrylate previously showed minimal microleakage when used as plug over obturation, its fluidity interferes with the handling, adhering to dentin walls and hindering cleanliness, decreasing post retention. This fact contraindicates its use as a material for protective plug when the cementation of a cast metal post with zinc phosphate is indicated.

Acknowledgements

This research was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) in Brazil.

References

1. Barthel CR, Zimmer S, Wussogk R, Roulet JF. Long-term bacterial leakage along obturated roots restored with temporary and adhesive fillings. J Endod. 2001;27(9):559-62.
2. Naumann M, Blankenstein F, Dietrich T. Survival of glass fibre reinforced composite post restorations after 2 years – an observational clinical study. J Dent. 2005;33(4):305-12.
3. Ferrari M, Vichi A, Fadda GM, Cagidiaco MC, Tay FR, Breschi L, et al. A randomized controlled trial of endodontically treated and restored premolars. J Dent Res. 2012;91(7):72-8.
4. Torbjorner A, Fransson B. A literature review on the prosthetic treatment of structurally compromised teeth. Int J Prosthodont. 2004;17(3):369-76.
5. Mankar S, Kumar NS, Karunakaran JV, Kumar SS. Fracture resistance of teeth restored with cast post and core: an in vitro study. J Pharm Bioallied Sci. 2012;4(2):197-202.
6. Fernandes AS, Shetty S, Coutinho I. Factors determining post selection: a literature review. J Prost Dent. 2003;90(6):556-62.
7. Prado MAA, Kohl JCM, Nogueira RD, Geraldo-Martins VR. Retentores intrarradiculares: revisão da literatura. Cient Ciênc Biol Saúde. 2014;16(1):51-5.
8. Nokar S, Bahrami M, Mostafavi AS. Comparative evaluation of the effect of different post and core materials on stress distribution in radicular dentin by three-dimensional finite element analysis. J Dent (Tehran). 2018;15(2):69-78.
9. Ni CW, Chang CH, Chen TY, Chuang SF. A multiparametric evaluation of post-restored teeth with simulated bone loss. J Mech Behav Biomed Mater. 2011;4(3):322-30.
10. Sarkis-Onofre R, Jacinto RC, Boscato N, Cenci MS, Pereira-Cenci T. Cast metal vs. glass fibre posts: a randomized controlled trial with up to 3 years of follow up. J Dent. 2014;42(5):582-7.
11. Soares CJ, Valdivia AD, Silva GR, Santana FR, Menezes MS. Longitudinal clinical evaluation of post systems: a literature review. Braz Dent J. 2012;23(2):135-40.
12. Mendonça CG, Almeida JRV, Takeshita WM, Martins F, Paixão MS. Radiographic analysis of 1000 cast posts in Sergipe state, Brazil. Rev Odontol Unesp. 2017;46(5):255-60.
13. Gomez-Polo M, Llido B, Rivero A, Del Rio J, Celemin A. A 10- year retrospective study of the survival rate of teeth restored with metal prefabricated posts versus cast metal posts and cores. J Dent. 2010;38(11):916-20.
14. Pisano DM, DiFiore PM, McClanahan SB, Lautenschlager EP, Duncan JL. Intraorifice sealing of gutta-percha obturated root canals to prevent coronal microleakage. J Endod. 1998;24(10):659-62.
15. Khayat A, Lee S, Torabinejad M. Human saliva penetration of coronally unsealed obturated root canals. J Endod. 1993;19(9):458-61.
16. Stricker EJ, Gohring TN. Influence of different posts and cores on marginal adaptation, fracture resistance, and fracture mode of composite resin crowns on human mandibular premolars. An in vitro study. J Dent. 2006;34(5):326-35.
17. Torabinejad M, Ung B, Kettering JD. In vitro bacterial penetration of coronally unsealed endodontically treated teeth. J Endod. 1990;16(12):566-9.
18. Holland R, Cruz A, Souza V, Nery MJ, Bernabé PFE, Otoboni Filho JA, et al. Comportamiento de los tejidos periapicales frente a la exposición de la obturación endodóntica al medio oral: Estudio histológico en dientes de perros. Endodoncia. 2000;54:99-108.
19. Barbosa HG, Holland R, Souza V, Dezan E Junior, Bernabé PFE, Otoboni Filho JA, et al. Healing process of dog teeth after post space preparation and exposition of the filling material to the oral environment. Braz Dent J. 2003;14(2):103-9.
20. Holland R, Murata SS, Silva MN, Dezan E Junior, Souza V, Bernabé PFE. Influence of the sealer and a plug in coronal leakage after post space preparation. J Appl Oral Sci. 2004;12(3):223-6.
21. Holland R, Manne LN, Souza V, Murata SS, Dezan-Júnior E. Periapical tissue healing after post space preparation with or without use of a protection plug and root canal exposure to the oral environment. Study in dogs. Braz Dent J. 2007;18(4): 281-8.
22. Alves JA, Walton RE, Drake DR. Coronal leakage: Endotoxin penetration from mixed bacterial communities through obturated post-prepared root canals. J Endod. 1998;24(9):587-91.
23. Madison S, Swanson K, Chiles SA. An evaluation of coronal microleakage in endodontically treated teeth. Part II. Sealer types. J Endod. 1987;13(3):109-12.
24. Valera MC, Cia D. Impermeabilização da obturação do canal radicular após preparo para núcleo. Rev Gaúcha Odontol. 2000;48(3):157-60.
25. Pappen AF, Bravo M, Gonzalez-Lopez S, Gonzalez-Rodriguez MP. An in vitro study of coronal leakage after intraradicular preparation of cast-dowel space. J Prosthet Dent. 2005;94(3):214-8.
26. Al-Ali K. Effect of eugenol-based root canal sealers on retention of prefabricated metal posts luted with resin cement. Saudi Dent J. 2009 July;21(2):69-73.
27. Pereira JR, do Valle AL, Shiratori FK, Ghizoni JS, Bonfante EA. The effect of post material on the characteristic strength of fatigued endodontically treated teeth. J Prosthet Dent. 2014;112(5):1225-30.
28. Alfredo E, Souza ES, Marchesan MA, Paulino SM, Gariba-Silva R, Sousa-Neto MD. Effect of eugenol-based endodontic cement on the adhesion of intraradicular posts. Braz Dent J. 2006;17(2):130-3.
29. Wu MK, Pehlivan Y, Kontakiotis EG, Wesselink PR. Microleakage along apical root fillings and cemented posts. J Prosthet Dent. 1998;79(3):264-9.
30. Barthel CR, Strobach A, Briedigkeit H, Gobel UB, Roulet JF. Leakage in roots coronally sealed with different temporary fillings. J Endod. 1999;25(11):731-4.
31. Yamauchi S, Shipper G, Buttke T, Yamauchi M, Trope M. Effect of orifice plugs on periapical inflammation in dogs. J Endod. 2006;32(6):524-6.
32. Dastjerdie EV, Oskoui M, Sayanjali E, Tabatabaei FS. In-vitro comparison of the antimicrobial properties of glass ionomer cements with zinc phosphate cements. Iran J Pharm Res. 2012;11:77–82.
33. de Almeida Manzano RP, Naufal SC, Hida RY, Guarnieri LO, Nishiwaki-Dantas MC. Antibacterial analysis in vitro of ethyl-cyanoacrylate against ocular pathogens. Cornea. 2006;25(3):350-1.
34. Romero IL, Malta JBNS, Silva CB, Mimica LMJ, Soong KH, Hida RY. Antibacterial properties of cyanoacrylate tissue adhesive: Does the polymerization reaction play a role? Indian J Ophthalmol. 2009;57(5):341-4.
35. Pasquet J, Chevalier Y, Pelletier J, Couval E, Bouvier D, Bolzinger MA. The contribution of zinc ions to the antimicrobial activity of zinc oxide. Colloids Surf A. 2014;457:263-74.
36. Almoudi MM, Hussein AS, Hassan MIA, Zain NM. A systematic review on antibacterial activity of zinc against Streptococcus mutans. Saudi Dent J. 2018;30(4):283-91.
37. Grillo JPF, Uzeda M, Alves FRF, Gonçalves LS. Temporary coronary dental sealers: determination of in vitro antimicrobial activity. Rev Assoc Paul Cir Dent. 2013;67(2):136-40.

38. Domingos HB, Gonçalves LS, de Uzeda M. Antimicrobial activity of a temporary sealant used in endodontic treatment: An in vitro study. Eur J Dent. 2015;9(3):411-4.
39. Milani S, Seraj B, Heidari A, Mirdamadi A, Shahrabi M. Coronal sealing capacity of temporary restorative materials in pediatric dentistry: a comparative study. Int J Clin Pediatr Dent. 2017;10(2):115-8.
40. Estrela C, Estrada-Bernabé PF, de Almeida-Decurcio D, Almeida-Silva J, Rodrigues-Araújo-Estrela C, Poli-Figueiredo JA. Microbial leakage of MTA, Portland cement, Sealapex and zinc oxide-eugenol as root-end-filling materials. Med Oral Patol Oral Cir Bucal. 2011;16(3):418-24.
41. Valera MC, Camargo CH, Carvalho AS, Gama ER. In Vitro Evaluation of apical microleakage using different root-end filling materials. J Appl Oral Sci. 2006;14(1):49-52.
42. Daleprane B, Pereira CNB, Bueno AC, Ferreira RC, Moreira AN, Magalhães CS. Bond strength of fiber posts to the root canal: Effects of anatomic root levels and resin cements. J Prosthet Dent. 2016;116(3):416-24.
43. Machado MB, Morgan LA, Gomes GM, Vasconcellos WA, Cardoso FP, Albuquerque R. Effects of immediate and delayed intraradicular preparation on bond strength of fiber posts. Indian J Dent Res. 2015;26(3):244-7.
44. Cecchin D, Farina AP, Guerreiro CAM, Carlini-Junior B. Fracture resistance of roots prosthetically restored with intra-radicular posts of different lengths. J Oral Rehab. 2010;37(2):116-22.
45. Vargas JW, Liewehr FR, Joyce AP, Runner RR. A comparison of the in vitro retentive strength of glass-ionomer cement, zinc-phosphate cement, and mineral trioxide aggregate for the retention of prefabricated posts in bovine incisors. J Endod. 2004;30(11):775-7.
46. Camargo CH, Siviero M, Camargo SE, de Oliveira SH, Carvalho CA, Valera MC. Topographical, diametral, and quantitative analysis of dentin tubules in the root canals of human and bovine teeth. J Endod. 2007;33(4):422-6.
47. Portell FR, Bernier WE, Lorton L, Peters DD. The effect of immediate versus delayed dowel space preparation on the integrity of the apical seal. J Endod. 1982;8(4):154-60.
48. Braga NMA, Paulino SM, Alfredo E, Sousa-Neto MD, Vansan LP. Removal resistance of glass-fiber and metallic cast posts with different lengths. J Oral Sci. 2006;48(1):15-20.
49. Zarone F, Sorrentino R, Apicella D, Valentino B, Ferrari M, Aversa R, et al. Evaluation of the biomechanical behavior of maxillary central incisors restored by means of endocrowns compared to a natural tooth: a 3D static linear finite elements analysis. Dent Mat. 2006;22(11):1035-44.
50. Figueiredo FE, Martins-Filho PR, Faria-e-Silva AL. Do metal post-retained restorations result in more root fractures than fiber post-retained restorations? A systematic review and meta-analysis. J Endod. 2015;41(3):309-16.
51. Soares NS, Santana LLP. Estudo comparativo entre pino de fibra de vidro e pino metálico fundido: uma revisão de literatura. Id on Line Rev Mult Psic. 2018;12(42):996-1005.
52. Verri FR, Okumura MHT, Lemos CAA, Almeida DAF, Batista VES, Cruz RS, et al. Three-dimensional finite element analysis of glass fiber and cast metal posts with different alloys for reconstruction of teeth without ferrule. J Med Eng Technol. 2017;41(8):644-51.
53. Morgano SM, Milot P. Clinical success of cast metal posts and cores. J Prosthet Dent. 1993;70(1):11-6.
54. Izadi A, Azarsina M, Kasraei S. Effect of eugenol-containing sealer and post diameter on the retention of fiber reinforced composite posts. J Conserv Dent. 2013;16(1):61-4.
55. Habib B, von Fraunhofer JA, Driscoll CF. Comparison of two luting agents used for the retention of cast dowel and cores. J Prosthodont. 2005;14(3):164-9.
56. Coltosol Data Sheet. 2019. [Access in: 2019 Jan 20]. Available from: https://www.dhpionline.com/msds/204-C5935.pdf
57. Jabri M, Mejdoubi E, El Gadi M, Hammouti B. Optimisation of hardness and setting time of dental zinc phosphate cement using a design of experiments. Arab J Chem. 2012;5(3):347-51.