

Effect of ultrasonic tip and root-end filling material on bond strength

Rodrigo Ricci Vivan¹ · Juliane Maria Guerreiro-Tanomaru¹ ·
Ricardo Affonso Bernardes¹ · José Mauricio Santos Nunes Reis¹ ·
Marco Antonio Hungaro Duarte² · Mário Tanomaru-Filho¹

Received: 1 June 2015 / Accepted: 30 December 2015 / Published online: 9 January 2016
© Springer-Verlag Berlin Heidelberg 2016

Abstract

Objectives The objective of this study was to evaluate the bond strength of three root-end filling materials (MTAA–MTA Angelus, MTAS–experimental MTA Sealer, and ZOE–zinc oxide and eugenol cement) in retrograde preparations performed with different ultrasonic tips (CVD, Trinity, and Satelec).

Materials and method Ninety 2-mm root sections from single-rooted human teeth were used. The retrograde cavities were prepared by using the ultrasonic tips, coupled to a device for position standardization. The specimens were randomly divided into nine groups: CVD MTAA; CVD MTAS; CVD ZOE; Trinity MTAA; Trinity MTAS; Trinity ZOE; Satelec MTAA; Satelec MTAS; Satelec ZOE. Each resin disc/dentin/root-end filling material was placed in the machine to perform the push-out test. The specimens were examined in a stereomicroscope to evaluate the type of failure. Data were submitted to statistical analysis using ANOVA and Tukey tests ($\alpha=0.05$).

Results The highest bond strength was observed for the CVD tip irrespective of the material used ($P<0.05$). There was no significant difference for the Trinity TU-18 diamond and S12 Satelec tips ($P>0.05$). MTAA and MTAS showed highest bond strength. The most common type of failure was adhesion between the filling material and dentin wall, except for ZOE, where mixed failure was predominant.

Conclusions The CVD tip favored higher bond strength of the root-end filling materials. MTA Angelus and experimental

MTAS presented bond strength to dentin prepared with ultrasonic tips.

Clinical relevance Root-end preparation with the CVD tip positively influences the bond strength of root-end filling materials. MTA Angelus and experimental MTAS present bond strength to be used as root-end filling materials.

Keywords Bond strength · Root-end filling materials · Ultrasonic tips

Introduction

An ideal root-end filling material should have some properties as dimensional stability, radiopacity, antimicrobial activity, biocompatibility, and ability to stimulate mineralized tissue [1]. The marginal adaptation of materials used for root canal filling or retrograde filling is important for clinical outcome after treatment. Among the physicochemical properties, the bond strength between root dentin and root-end filling should promote adaptation and decrease interface between material and dentin. Thus, the bond strength of endodontic materials has been evaluated by using the push-out tests [2].

New MTA-based root-end filling materials have been developed [3–7]. MTA Sealer is an experimental endodontic sealer composed by white Portland cement, zirconium oxide (radiopaque filler), calcium chloride (additive), and resin [3]. The addition of calcium chloride to MTA-based materials increases its capacity of releasing calcium [8]. MTA Sealer has demonstrated calcium ions release [9], proper setting time and flow for clinical use [10], and biocompatibility similar to MTA in rats [11].

Ultrasonic preparation is the most suitable technique for retrograde cavity preparation [12] promoting parallel walls with adequate retention for the filling material and reduced

✉ Mário Tanomaru-Filho
tanomaru@uol.com.br

¹ Araraquara School of Dentistry, Araraquara, São Paulo, Brazil

² Bauru School of Dentistry, Bauru, São Paulo, Brazil

exposure of dentin tubules [13]. In addition, ultrasonic preparation requires less bone removal for access to the apex [14] and allows root-end preparation according to the long axis of the root canal [15]. Different ultrasonic tips are available differing in diameter, angle, and cutting surface. The different surface characteristics can result in qualitative differences in root-end preparation [16–22] and time required to preparation. The conventional tips with a diamond-coated surface are the most widely used for root-end preparations. The conventional diamond tips are manufactured by means of galvanic soldered diamond powder, with a roughened structure and spaces between the grains [23].

An improved type of diamond-coated tip manufactured by chemical vapor deposition (CVD) has recently been introduced [24]. Diamond surfaces are created using the CVD technique by depositing a uniform polycrystalline diamond film resulting in a single body diamond film. This surface property is the basis for the cutting capacity of CVD tips when compared to conventional diamond tips [24]. Bernardes et al. [24] observed that root-end preparations established with CVD diamond tips required less preparation time than conventional tips, with no difference in quality between the three preparation tips studied. Batista de Faria-Junior et al. [12] evaluated ErCr:YSGG laser to perform retrograde cavities and observed a longer preparation time and lower quality preparations when compared to ultrasonic tips.

The push-out mechanical test has been used to evaluate bond strength of filling materials and posts to the root dentin [23, 25–27]. Optimal adhesion of the root-end filling material minimizes the occurrence of displacement that may cause voids and cracks, resulting in failure of endodontic treatment.

The impact of the root-end preparation tip in bond strength has not been described in the literature. The aim of this investigation was to evaluate the influence of different ultrasonic tips (CVD T0F-2; Trinity diamond; Satelec S1290 L) used for root-end preparation on the bond strength and type of failure of different root-end filling materials. The null hypothesis is that different ultrasonic tips do not influence the bond strength of retrograde materials.

Material and methods

The composition and manufacturers of tips and root-end filling materials evaluated are described in Table 1.

The study was approved by the Ethics Committee of the Araraquara School of Dentistry—UNESP. The MTA Angelus cement was prepared using a 3:1 ratio by weight (powder:liquid) according to the manufacturer's instructions. The MTA Sealer was prepared using a 5:1 ratio by weight (powder:liquid) to obtain the puttylike consistency of a retrofilling material. The ZOE cement was prepared using a 5:1 ratio (powder:liquid) [28].

Ninety slices (2-mm thick) from single-rooted human teeth were stored in 0.5 % chloramine-T trihydrate solution (Formula & Action Magistral Pharmacy, São Paulo, SP) for no longer than 1 week and, thereafter, stored in distilled water in a refrigerator at 4 °C, according to ISO/TS 11405:200 standards. The slices were embedded in resin (Resina Poliéster Automotiva Natrielli–Natrielli Química Ltda., Santana do Parnaíba, São Paulo). The initial root canal preparation was performed with a 1.5-mm diameter cylindrical bur (Vortex, Produtos Odontológicos, São Paulo, SP) at a speed of 2000 rpm. Then, for the retrograde preparation, the specimens were placed in a delineator device in order to place the tip parallel to the walls of the preparation.

The tips used for retrograde preparation were CVD (CVD-Valley, São José dos Campos, São Paulo, Brazil), Trinity (Trinity, São Paulo, SP, Brazil), and Satelec (Satelec, Paris, France). All tips are diamond with 3 mm in length. The slices were randomly divided into nine groups of 10 samples each. Group CVD MTAA; Group CVD MTAS; Group CVD ZOE; Group Trinity MTAA; Group Trinity MTAS Group Trinity ZOE; Group Satelec MTAA; Group Satelec MTAS; Group Satelec ZOE.

The preparations were performed with CVD ultrasound (CVD-Vale, São José dos Campos, SP, Brazil) at 50 % power under copious irrigation with saline solution. The retropreparation tip was positioned against all the walls, providing an average increase of approximately 0.5 mm in diameter of the cavity. The preparation time was 17 s for the CVD tip [21] and 45 s for the Trinity and Satelec tips (Zuolo et al. [17]). After the preparation, the materials were placed in the cavities. The samples were kept in an incubator at 37 °C in the presence of humidity for 48 h. After this time, the excess cement was removed with scalpel blades and 220–600 grain sandpaper until the entire cement/dentin interface was observed.

For the mechanical test, each resin disc/dentin/retrofilling material was placed in the testing machine (EMIC DL 2000, São José dos Pinhais, PR, Brazil) with a 5-kN load cell. The progressive compression test was carried out at a speed of 1 mm/min from the contact until the displacement of the sealer from the root canal walls was observed. The apparatus had a cylindrical tip with a diameter of 1.3 mm and was positioned so that during charging, the contact only occurred with the cement. The values were obtained in N and transformed to MPa. The recorded value was divided by the surface adhesion filling area, calculated by the following formula: $2\pi rh$, where r is the radius of the root canal and h is the thickness of the dentin.

The sample specimens were examined under a stereomicroscope to analyze the type of failure. After tabulating the data, they were analyzed for normality using the Shapiro–Wilk test, where a normal distribution of the data was observed. Data were submitted to the parametric ANOVA

Table 1 Root-end filling materials, compositions, ultrasonic tips, and manufacturers

Material	Composition	Manufacturer	Ultrasonic tip	Manufacturer
MTA Angelus	SiO ₂ ; K ₂ O; Al ₂ O ₃ ; Na ₂ O; Fe ₂ O ₃ ; SO ₃ ; CaO; Bi ₂ O ₃ ; MgO; and insoluble residue (silica crystals, calcium oxide, potassium sulfate, and sodium sulfate)	Angelus Indústria de Produtos Odontológicos Ltda., Londrina, PR, Brasil	CVD T0F-2	CVD-Vale, São José dos Campos, SP, Brazil
MTA Sealer	White Portland cement; resin; calcium chloride; zirconium oxide (radiopacifier)	FOAr–UNESP, Araraquara, Brazil	Trinity diamond	Trinity, São Paulo, SP, Brazil
ZOE	Powder: zinc oxide; hydrogenated resin; bismuth subcarbonate; barium sulfate; and sodium borate Liquid: eugenol and sweet almond oil	S.S.White, Rio de Janeiro, Brasil	Satelec S1290 L	Satelec, Paris, France

statistical test and to Tukey multiple comparison test, with significance level set at 5 %.

Results

The mean and standard deviation (push-out) mechanical testing are shown in Table 2 (values in MPa). In the analysis of the effect of ultrasonic tip on the bond strength, the CVD tip promoted a significantly greater bond strength than the Satelec and Trinity tips ($P < 0.05$). When the effect of the root filling material was analyzed, independent of the ultrasonic tip used in the retropreparation, ZOE demonstrated significantly less bond strength ($P < 0.05$) when compared to the other tested materials.

The most common mode of failure was adhesive failure, with the exception of the groups obturated with ZOE, in which mixed failure predominated.

Discussion

The push-out test is the most widely used to evaluate the bond strength between the dentin and root-end filling materials [25, 27, 29, 30]. The tip diameter may influence the results of the push-out test [31, 32]. In the present study, a device with approximately 1.3-mm tip diameter was used [33–35].

The most widely used method for performing root-end preparations is ultrasonic preparation [13], which has contributed to the increase in success rate of endodontic

surgery [14]. Paz et al. [36] investigated the cutting efficiency of two ultrasonic units with two different tips, Satelec and Spartan, and observed the former to be more effective for dentin removal than the latter. The present study evaluated the influence of retropreparation tips with different manufacturing methods in the bond strength of retrofilling materials. The results showed that irrespective of the filling material, the CVD T0F-2 tip showed the highest bond strength values. The characteristics and arrangement of the surface of the CVD diamond tip can be correlated to the obtained results [21]. The Satelec and Trinity ultrasonic tips have small diamond crystals embedded as if they were incorporated into a solid material. Both tips showed loss of total diamond after use, and the loss was higher for the Satelec tip [21]. In the present study, the lost diamond particles could have remained in the dentin surface and interfered with the adhesion of the materials.

The CVD tips were manufactured using chemical vapor deposition, applying a thick layer of pure diamond, forming a single stone on the entire surface of the tip. Perhaps, because of the manufacturing technique, the tip retained its shape after use, thus maintaining the cutting power for a longer time (Bernardes et al. [21]), which may explain the better results of the CVD tip observed in the present study. Bernardes et al. [21] did not find any significant difference in the quality of the root-end preparation, but they observed more regular root-end preparations for the Satelec and Trinity tips than for the CVD tip. This increased irregular root-end preparation by the CVD tip may have generated greater attrition and retention areas between the material and root canal wall.

Table 2 Mean (MPa) and standard deviation of bond strength values (MPa)

Push-out	CVD-MTAA	CDV-MTAS	CVD-ZOE	Trin-MTAA	Trin-MTAS	Trin-ZOE	Sat-MTAA	Sat-MTAS	Sat-ZOE
Mean	19.18a	19.13a	9.50a	6.05b	6.32b	4.71b	6.64b	7.56b	4.19b
Standard deviation	4.70	2.65	3.73	1.81	2.33	0.81	1.69	3.93	1.92

Different letters after mean value indicate significant statistical difference ($P < 0.05$)

CVD CVDentus, Trin Trinity, Sat Satelec, MTAA MTA Angelus, MTAS MTA Sealer, ZOE zinc oxide and eugenol

The results from the present study show that the MTA Angelus and MTA Sealer produced the highest bond strength values irrespective of the ultrasonic tip used in the root-end preparation. Hong et al. [37] reported similar values without using ultrasonic preparation. MTA-based materials undergo expansion after setting, which can explain the results [38]. The MTA Sealer, besides the resin, contains white Portland cement which could increase the mechanical strength through the expansion [38].

After retrograde cavity preparation, the use of EDTA has not been recommended to prevent exposure of a greater amount of dentinal in the apical region after apicoectomy. Also, according Celik et al. [39], irrigation regimes using EDTA have no effect on the push-out bond strength of the calcium silicate cements. The most probable reason for the MTA bond strength is related to the friction effect, since MTA has volumetric expansion, which can promote higher bond strength [40, 41]. Sluyk et al. [40] showed that the presence of some moisture after perforation sealing using MTA does not influence the MTA retention. Storm et al. [41] suggested that the possible reason for the sealing ability of mineral trioxide aggregate (MTA) is its slight expansion upon setting.

The ZOE cement had the lowest values independent of the ultrasonic tip used. In the present study, the consistency used was greater than that for the root canal filling (5:1, powder:liquid) and the results can be explained by the presence of zinc ions from the zinc oxide, which can affect the mineral component of the dentin [42].

Regarding the type of failure, adhesive failure predominated, agreeing with the results of Shokouhinejad et al. [42], with the exception of the groups where the material was the ZOE in which mixed failure predominated. The type of adhesive failure in this study may be related to the storage time before the push-out test, which was 3 days. Other authors [42, 43] used periods of 4 and 7 days. The longer time may have favored higher material adhesion to the dentinal walls.

Conclusion

The results of this study demonstrate that the root-end preparation with the CVD tip positively influences the bond strength of root-end filling materials. MTA Angelus and experimental MTAS presented bond strength to dentin prepared with ultrasonic tips.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

References

- Gartner AH, Dorn SO (1992) Advances in endodontic surgery. *Dent Clin North Am* 36:357–378
- Akçay M, Arslan H, Mese M, Sahin NN (2015) The effect of photon-initiated photoacoustic streaming, ultrasonically and sonically irrigation techniques on the push-out bond strength of a resin sealer to the root dentin. *Clin Oral Investig* 19:1055–1061
- Massi S, Tanomaru-Filho M, Silva GF et al (2011) pH, calcium ion release, and setting time of an experimental mineral trioxide aggregate-based root canal sealer. *J Endod* 37:844–846
- Jacobovitz M, Vianna ME, Pandolfelli VC et al (2009) Root canal filling with cements based on mineral aggregates: an in vitro analysis of bacterial microleakage. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 108:140–144
- Santos AD, Moraes JC, Araujo EB et al (2005) Physico-chemical properties of MTA and a novel experimental cement. *Int Endod J* 38:443–447
- Asgary S, Eghbal MJ, Parirokh M et al (2008) A comparative study of histologic response to different pulp capping materials and a novel endodontic cement. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 106:609–614
- Asgary S, Eghbal MJ, Parirokh M et al (2009) Comparison of mineral trioxide aggregate's composition with Portland cements and a new endodontic cement. *J Endod* 35:243–250
- Tanomaru-Filho M, Chaves Faleiros FB, Sacaki JN, Hungaro Duarte MA, Guerreiro-Tanomaru JM (2009) Evaluation of pH and calcium ion release of root-end filling materials containing calcium hydroxide or mineral trioxide aggregate. *J Endod* 35:1418–1421
- Zhou HM, Shen Y, Zheng W, Li L, Zheng YF, Haapasalo M (2013) Physical properties of 5 root canal sealers. *J Endod* 39:1281–1286
- Viapiana R, Flumignan DL, Guerreiro-Tanomaru JM, Camilleri J, Tanomaru-Filho M (2014) Physicochemical and mechanical properties of zirconium oxide and niobium oxide modified Portland cement-based experimental endodontic sealers. *Int Endod J* 47:437–448
- Viola NV, Guerreiro-Tanomaru JM, da Silva GF, Sasso-Cerri E, Tanomaru-Filho M, Cerri PS (2012) Biocompatibility of an experimental MTA sealer implanted in the rat subcutaneous: quantitative and immunohistochemical evaluation. *J Biomed Mater Res B Appl Biomater* 100:1773–1781
- Batista de Faria-Junior N, Tanomaru-Filho M, Guerreiro-Tanomaru JM et al (2009) Evaluation of ultrasonic and ErCr:YSGG laser retrograde cavity preparation. *J Endod* 35:741–744
- Wuchenich G, Meadows D, Torabinejad M (1994) A comparison between two root end preparation techniques in human cadavers. *J Endod* 20:279–282
- Kim S, Kratchman S (2006) Modern endodontic surgery concepts and practice: a review. *J Endod* 32:601–623
- Carr GB (1997) Ultrasonic root end preparation. *Dent Clin North Am* 41:541–554
- Brent P, Morgan L, Marshall J (1999) Evaluation of diamond coated ultrasonic instruments for root-end preparation. *J Endod* 25:672–675
- Zuolo ML, Perin FR, Ferreira MO et al (1999) Ultrasonic root-end preparation with smooth and diamond-coated tips. *Endod Dent Traumatol* 15:265–268
- Peters CI, Peters OA, Barbakow F (2001) An in vitro study comparing root-end cavities prepared by diamond coated and stainless steel ultrasonic retreaters. *Int Endod J* 34:142–148
- Navarre SW, Steiman HR (2002) Root-end fracture during retropreparation: a comparison between zirconium nitride-coated

- and stainless steel microsurgical ultrasonic instruments. *J Endod* 28:330–332
20. Ishikawa H, Sawada N, Kobayashi C et al (2003) Evaluation of root-end cavity preparation using ultrasonic retrotips. *Int Endod J* 36:586–590
 21. Bernardes RA, de Moraes IG, Garcia RB et al (2007) Evaluation of apical cavity preparation with a new type of ultrasonic diamond tip. *J Endod* 33:484–487
 22. Bernardes RA, de Souza Junior JV, Duarte MA et al (2009) Ultrasonic chemical vapor deposition-coated tip versus high- and low-speed carbide burs for apicoectomy: time required for resection and scanning electron microscopy analysis of the root-end surfaces. *J Endod* 35:265–268
 23. Pane ES, Palamara JE, Messer HH (2013) Critical evaluation of the push-out test for root canal filling materials. *J Endod* 39:669–673
 24. Predebon JC, Flório FM, Basting RT (2006) Use of CVDentUS diamond tips for ultrasound in cavity preparation. *J Contemp Dent Pract* 7:50–58
 25. Almeida J, Felipe MCS, Bortoluzzi EA, Teixeira CS, Felipe WT (2014) Influence of the exposure of MTA with and without calcium chloride to phosphate-buffered saline on the push-out bond strength to dentine. *Int Endod J* 47:449–453
 26. Scelza MZ, da Silva D, Scelza P, et al. (2014) Influence of a new push-out test method on the bond strength of three resin-based sealers. *Int Endod J*. <http://onlinelibrary.wiley.com/doi/10.1111/iej.12378/abstract>. Accessed 28 may 2015
 27. Moinzadeh AT, Moinzadeh H, Hensbergen IAM, Wesselink PR, Shemesh H (2015) The correlation between fluid transport and push-out strength in root canals filled with a methacrylate-based filling material. *Int Endod J* 48:193–198
 28. Silva GF, Guerreiro-Tanomaru JM, Sasso-Cerri E et al (2011) Histological and histomorphometrical evaluation of furcation perforations filled with MTA, CPM and ZOE. *Int Endod J* 44:100–110
 29. Saghiri MA, Shokouhinejad N, Lotfi M et al (2010) Push-out bond strength of mineral trioxide aggregate in the presence of alkaline pH. *J Endod* 36:1856–1859
 30. Goracci C, Tavares AU, Fabianelli A et al (2004) The adhesion between fiber posts and root canal walls: comparison between microtensile and push-out bond strength measurements. *Eur J Oral Sci* 112:353–361
 31. Stiegemeier D, Baumgartner JC, Ferracane J (2010) Comparison of push-out bond strengths of Resilon with three different sealers. *J Endod* 36:318–321
 32. Nagas E, Uyanik O, Durmaz V et al (2011) Effect of plunger diameter on the push-out bond values of different root filling materials. *Int Endod J* 44:950–955
 33. Sly MM, Moore BK, Platt JA et al (2007) Push-out bond strength of a new endodontic obturation system (Resilon/Epiphany). *J Endod* 33:160–162
 34. Vilanova WV, Carvalho-Junior JR, Alfredo E et al (2011) Effect of intracanal irrigants on the bond strength of epoxy resin-based and methacrylate resin-based sealers to root canal walls. *Int Endod J* 45:42–48
 35. Formosa LM, Mallia B, Camilleri J (2014) Push-out bond strength of MTA with antiwashout gel or resins. *Int Endod J* 47:454–462
 36. Paz E, Satovsky J, Moldauer I (2005) Comparison of the cutting efficiency of two ultrasonic units utilizing two different tips at two different power settings. *J Endod* 31:824–826
 37. Hong ST, Bae KS, Baek SH, Kum KY, Shon WJ, Lee W (2010) Effects of root canal irrigants on the push-out strength and hydration behavior of accelerated mineral trioxide aggregate in its early setting phase. *J Endod* 36:1995–1999
 38. Sarkar NK, Caicedo R, Ritwik P, Moiseyeva R, Kawashima I (2005) Physicochemical basis of the biologic properties of mineral trioxide aggregate. *J Endod* 31:97–100
 39. Celik D, Er K, Serper A, Taşdemir T, Ceyhanlı KT (2014) Push-out bond strength of three calcium silicate cements to root canal dentine after two different irrigation regimes. *Clin Oral Investig* 18:1141–1146
 40. Sluyk SR, Moon PC, Hartwell GR (1998) Evaluation of setting properties and retention characteristics of mineral trioxide aggregate when used as a furcation perforation repair material. *J Endod* 24(11):768–771
 41. Storm B, Eichmiller FC, Tordik PA, Goodell G (2008) Setting expansion of gray and white mineral trioxide aggregate and Portland cement. *J Endod* 34:80–82
 42. Shokouhinejad N, Sabeti MA, Hasheminasab M, Shafiei F, Shamshiri AR (2010) Push-out bond strength of Resilon/Epiphany self-etch to intraradicular dentin after retreatment: a preliminary study. *J Endod* 36:493–496
 43. Vanderweele RA, Schwartz SA, Beeson TJ (2006) Effect of blood contamination on retention characteristics of MTA when mixed with different liquids. *J Endod* 32:421–424