

# Effect of double antibiotic and calcium hydroxide pastes on dislodgement resistance of an epoxy resin-based and two calcium silicate-based root canal sealers

Hakan Gokturk<sup>1</sup> · Emre Bayram<sup>1</sup> · Huda Melike Bayram<sup>1</sup> · Tugrul Aslan<sup>2</sup> · Yakup Ustun<sup>2</sup>

Received: 4 August 2015 / Accepted: 6 June 2016 / Published online: 10 June 2016  
© Springer-Verlag Berlin Heidelberg 2016

## Abstract

**Objectives** The purpose of the present study was to determine the dislodgement resistance of AH Plus, MTA Fillapex, and Total Fill BC sealer to root canal dentin walls following placement of calcium hydroxide (CH) or double antibiotic paste (DAP) medicaments.

**Materials and methods** Root canals of 90 single-rooted human mandibular premolar teeth were instrumented with Reciproc rotary instruments to a size R50. The teeth were randomly divided into two experimental groups: those receiving an intracanal medicament with either CH or DAP and a control group ( $n = 30$ ). After 3 weeks, the medicaments were removed by irrigation with 5 mL of 2.5 % NaOCl, 5 mL 17 % EDTA, and 5 mL distilled water under sonic agitation. Each group was then subdivided into three subgroups ( $n = 10$ ), and the canals were filled with either AH Plus, MTA Fillapex, or Total Fill BC sealer. After 1 week, a push-out test was applied to the specimens and the results were analyzed using one-way analysis of variance (ANOVA) and post hoc Tamhane's tests. **Results** Regardless of the type of intracanal medicament used, Total Fill BC Sealer and MTA Fillapex showed the highest and lowest bond strength, respectively ( $P < 0.05$ ). The use or absence of medicaments did not significantly affect the dislodgment resistance of root canal fillings ( $P > 0.05$ ). Prior CH placement improved dislodgement resistance of all sealers

without statistical difference ( $P > 0.05$ ). Adhesive failure between core and sealer was the most frequent failure mode.

**Conclusions** Prior application of CH or DAP did not significantly affect the adhesion of the AH Plus, MTA Fillapex, and Total Fill BC Sealers.

**Clinical relevance** There is a little information about the influence of antibiotic medicaments on the bond strength of root canal sealer. These findings suggest that the use of DAP does not affect the adhesion strength of AH Plus, MTA Fillapex, and Total Fill BC Sealers.

**Keywords** Bond strength · Calcium hydroxide · Double antibiotic paste · Resin-based sealer · Calcium silicate-based sealer

## Introduction

The aim of root canal treatment is to eliminate and discharge bacteria from the root canal to prevent reinfection of the system. To achieve the objective of purging the intracanal bacterial population, cleaning and shaping of the root canal space with irrigation is often selected as the first option. But, owing to the unique chemomechanical preparation of the root canal, it has been observed that even after irrigation, 40–60 % of the system still contains cultivable bacteria [1–3]. Therefore, medicaments have been used in interappointment to increase the incidence of bacteria-free canals [1, 2, 4–6].

Calcium hydroxide (CH) is a commonly used intracanal dressing. Its antimicrobial properties as well as its ability to induce the formation of new bone are well established [5, 7] but studies have shown that even with the use of CH, it is not possible to obtain bacteria-free canal [8, 9]. Hence, new medicaments, such as antibiotic pastes, chlorhexidine gel, and

✉ Hakan Gokturk  
gokturk82@hotmail.com

<sup>1</sup> Department of Endodontics, Faculty of Dentistry, Gaziosmanpaşa University, 60100 Tokat, Turkey

<sup>2</sup> Department of Restorative Dentistry and Endodontics, Faculty of Dentistry, Erciyes University, Kayseri, Turkey

propolis, have been investigated as possible alternatives to CH [6, 10, 11].

Triple antibiotic paste (TAP) is another example of an intracanal medicament. It is composed of ciprofloxacin, metronidazole, and minocycline [1]. Previous reports have shown that TAP is both biocompatible and as well as antimicrobial [1, 12] but some studies reported that the minocycline component causes visible crown discoloration [6, 13]. Due to such reports, minocycline was removed from TAP and the double antibiotic paste (DAP), consisting only ciprofloxacin and metronidazole, was started to be used [14].

Neither antibiotics nor CH pastes, when used as a medicament, can be completely eliminated from root canals [15–18]. Previous studies have shown that clinically used concentrations of TAP, DAP, and CH are cytotoxic to human dental stem cells and pulp cells of the apical papilla [19, 20] and can lead to a moderate inflammatory reaction in subcutaneous tissues [12]. Residual medicament, by acting as a physical barrier between root canal dentin and the sealer, adversely affects penetration of sealers into the root canal dentin walls [16, 21]. Akcay et al. reported that while DAP or CH placement did not affect the adhesion of ERS (AH Plus jet), the use of TAP actually improved the bond strength of the sealer [36]. Guiotti et al. showed that prior application of CH did not significantly impact the bond strength between calcium silicate-based sealers (CSSs) (MTA Fillapex and Sealapex) and the root canal dentin [21]. Amin et al. proved that while the use of intracanal CH medicament prior to final canal obturation improved the push-out bond strength of iRoot SP, it had no such effect on the MTA Fillapex and AH Plus [22].

There are limited data available in the literature about the effects of the remaining medicaments on the adhesion of sealer to root dentin and to our knowledge, there have been no previous studies on the effect of antibiotic pastes on the adhesion of CSS to root dentin.

The aim of this *in vitro* study was to investigate the effects of CH and DAP on the bond strength of one ERS and two CSSs to root canal dentin. The null hypotheses were that (1) there would be no significant difference between the medicaments in terms of the dislodgement resistance of sealers and (2) there would be no significant difference in dislodgement resistance between the sealers.

## Material and methods

The research proposal was submitted for review to the Tokat Clinical Research Ethics Committee of the Gaziosmanpaşa University of Turkey (14-KAEK-051) and the study design was approved. A total of 90 single-rooted human mandibular premolars were extracted for periodontal reasons. Preoperative digital radiographs of each root were taken from two directions (mesiodistal and buccolingual) to confirm that

the canal anatomy was composed of a single-rooted canal without calcification. A periodontal scaler was used to remove all calculus and other remnants from the surface of the teeth, and the crowns were removed using diamond discs under water cooling to acquire a standardized root length of 15 mm. The working length was established to be 1 mm short of the apex using a #10 K file. The root canals were prepared by using Reciproc R50 (VDW, Munich, Germany) file by and a torque-controlled motor (Silver Reciproc; VDW, Munich, Germany) in a reciprocating movement by the “Reciproc ALL” program. During preparation, the canals were irrigated with 5 mL 2.5 % sodium hypochlorite (NaOCl) solution (Whitedentmed, Erhan Kimya, İzmir, Turkey), using a 27-gauge irrigating needle. The smear layer was removed with 5 mL 17 % ethylenediaminetetraacetic acid (EDTA; Imicryl Ltd., Konya, Turkey) for 1 min. For final irrigation, 10 mL distilled water was used and then the root canals were dried with paper points. The specimens were randomly divided into a control group (without intracanal medicament) and two experimental groups (received intracanal medicament with either CH or DAP).

Group 1 (Control): No intracanal medicament was used before root canal filling ( $n = 30$ ).

Group 2 (CH): The intracanal medicament was prepared by mixing CH powder (Kalsin; Spot Dis Deposu AS, İzmir, Turkey) and distilled water ( $n = 30$ ).

Group 3 (DAP): The intracanal antibiotic paste was prepared by mixing equal quantities of ciprofloxacin (Biofarma, Istanbul, Turkey) and metronidazole (Eczacibasi, Istanbul, Turkey) with distilled water ( $n = 30$ ).

Medicaments were placed into the root canals using a lentulo spiral. Access to the root canals was sealed with a cotton pellet and Cavit G (3M ESPE, Seefeld, Germany). The specimens were stored at 37 °C and 100 % humidity for 3 weeks. After this period, medicaments were removed by irrigation with 5 mL of 2.5 % NaOCl, 5 mL 17 % EDTA, and 5 mL of distilled water under sonic agitation (Endoactivator, Dentsply Tulsa Dental Specialties, Tulsa, OK) for 30 s at 10,000 cycles/min (medium power) with a red tip (25/04) inserted 2 mm short of the working length. The root canals were then dried using paper points. Each group was subdivided into three subgroups ( $n = 10$ ), and the canals were filled with MTA Fillapex (Angelus Soluções Odontológicas, Londrina, Parana, Brazil), Total Fill BC Sealer (Brasseler USA, Savannah, GA, USA), or AH Plus (Dentsply DeTrey, Konstanz, Germany). All sealers were prepared according to the manufacturer’s recommendations. A single gutta-percha cone (R50, VDW) that was lightly coated with the sealer was used for the single cone obturation technique. The excessive gutta-percha was removed, and coronal

access was coated with Cavit G (3M Espe, Germany). The teeth were then incubated for 1 week at 37 °C in 100 % humidity to allow the sealer to set entirely. After 1 week, each specimen was embedded in acrylic resin and sectioned perpendicular to its long axis using a precision saw (Micracut 125; Metkon, Bursa, Turkey) at a slow speed under constant cooling. Three slices, of 2 ± 0.01 mm in thickness, were obtained at 2, 7, and 11 mm distance from the coronal surface of each root (*n* = 30 slices/subgroup). Each slice was numbered, and apical and coronal surfaces were photographed under a stereomicroscope (Nikon, Tokyo, Japan) at ×35 magnification to investigate obturation quality. If any void was detected between dentin and filling material, the specimen was replaced with a fresh one. The coronal and apical diameters of each slice were calculated under stereomicroscope. Push-out tests were carried out at a cross-head speed of 0.5 mm/min in a universal testing machine (Instron Corp, Norwood, MA, USA). The diameters of stainless steel pluggers used were approximately 90 % of the diameter of the filling materials on the apical surface. Load was applied in the apical-coronal direction until the root canal filling was dislodged from the slice. In order to express the bond strength in megapascals (MPa), the load at failure recorded in Newtons was separated by the surface area of the root canal filling. The surface area of the root canal filling (*A*) for each slice was calculated as:  $A = \pi(R + r)h$ ,  $p = 3.14$ ; *R* is the larger radius of the canal space or coronal radius, *r* is the smaller radius of the canal space or apical radius, and *h* is the thickness of the slice (2 mm). After a push-out test, failure mode was investigated on both sides of the slices under a stereomicroscope at ×35 magnification. The failure modes were classified as follows: adhesive failure which is of two types: at root canal sealer-dentin (*Ad*) or at root canal sealer-core (*Ac*); and cohesive failure (*C*) which occurs within root canal sealer; and mixed failure (*M*) which is a combination of adhesive and cohesive modes.

**Statistical analysis**

All statistical analyses were performed with SPSS software (ver. 20.0; IBM Corp., Armonk, NY, USA). One-way analysis of variance (ANOVA) and the post hoc Tamhane’s test were used for the analyses of the data. For each outcome, *P* < 0.05 was considered statistically significant.

**Results**

The mean and standard deviations of the dislodgement resistance values are presented in Table 1. Without prior medication (control), Total Fill BC Sealer showed the maximum push-out bond strength (*P* < 0.05) but there was no significant difference between AH Plus and MTA Fillapex (*P* > 0.05). In prior application of CH and DAP, Total Fill BC Sealer showed

**Table 1** Dislodgement resistance values (MPa, mean ± standard deviation) of root filling materials with respect to intracanal medicaments

	Intracanal medicaments		
	Control	CH	DAP
AH Plus	2.03 ± 1.24 <sup>a</sup>	2.58 ± 1.74 <sup>ab</sup>	2.31 ± 1.77 <sup>ab</sup>
MTA Fillapex	1.75 ± 1.07 <sup>a</sup>	1.79 ± 1.05 <sup>a</sup>	1.50 ± 0.68 <sup>a</sup>
Total Fill BC	3.80 ± 2.06 <sup>b</sup>	4.03 ± 2.14 <sup>b</sup>	2.52 ± 1.36 <sup>b</sup>
<i>P</i> value	0.005	<0.001	0.023

Different superscripted lowercase letters indicate statistically significant difference within each column (*P* < 0.05). There was no statistically significant difference within in each row (*P* > 0.05)

the highest push-out strength but there was no significant difference between Total Fill BC Sealer and AH Plus (*P* > 0.05). Regardless of the type of intracanal medicament used, the lowest dislodgement resistance was observed in MTA Fillapex (*P* < 0.05) but there was no significant difference between MTA Fillapex and AH Plus (*P* > 0.05).

The use or absence of medicaments did not significantly affect the dislodgment resistance of root canal fillings (*P* > 0.05). Prior application of CH improved the dislodgement resistance of all sealers. Prior application of DAP improved the bond strength of all sealers except for MTA Fillapex.

Table 2 shows the distribution of failure modes in the groups. Adhesive failure between core and sealer for the three sealers was predominantly observed regardless of the type of intracanal medicament used. In prior application of CH, the predominant failure modes for AH Plus, MTA Fillapex, and Total Fill were adhesive along sealer/core interface, mixed, and cohesive, respectively.

**Discussion**

An ideal root canal filling material should adhere to the root canal dentin and resist dislocating forces. To accomplish this,

**Table 2** Failure modes of the experimental groups

	Control				CH				DAP			
	Ad	Ac	C	M	Ad	Ac	C	M	Ad	Ac	C	M
AH Plus	2	9	10	9	3	15	2	10	5	15	1	9
MTA Fillapex	3	17	6	4	4	5	5	16	7	14	4	5
Total Fill BC	1	12	12	5	0	10	14	6	4	12	6	8

*Ad* adhesive failure between dentin and sealer, *Ac* adhesive failure between core and sealer, *C* cohesive, *M* mixed

the sealer should bond as much as possible with the root canal dentin [23]. For this purpose, manufacturers are continuously making efforts to develop new sealers with superior properties. Total Fill BC Sealer is one such sealer. It is a premixed bioceramic endodontic material that is equivalent to the iRoot SP sealer. The sealer is a hydrophilic CSS that is not unaffected by the presence of moisture in the radicular dentin. Composed of calcium phosphate monobasic, calcium silicates, thickening agents, zirconium oxide, and tantalum oxide [24], the total Fill BC Sealer has extremely small particle size that allows it to penetrate into all the irregular areas of the canal anatomy. The manufacturer asserts that this sealer has several ideal properties such as adhesiveness, hydrophilicity, osteoconductivity, as well as capacity to chemically bond with the intraradicular dentin [25]. MTA Fillapex is an MTA-based root canal sealer that can also be categorized as a CSS. According to the manufacturer, MTA Fillapex is designed to provide a low film thickness and high flow rate for facilitating easy penetration of accessory and lateral canals. It is composed of bismuth trioxide as a radiopacifying agent, diluting resins, nanoparticulated resin, salicylate resin, natural resin, and 40 % MTA that is significant for its biocompatibility and antimicrobial properties [26, 27]. However, the concern as to whether the use of prior antibiotic medicaments can affect the bond strength of the aforementioned sealers requires further investigations [22].

It is known that intracanal medicaments can influence the bond strength of the root filling both negatively as well as positively; it is also feasible that they have no effect whatsoever on the bond strength [36, 21, 22]. To our knowledge, there is very limited information available in the literature pertaining to the effect of antibiotic pastes on the adhesion of sealer to root dentin [36].

Previous studies have shown that antibiotic medicaments are not entirely removed from root canal walls using currently available irrigation techniques [15, 16, 18]. Several investigators have reported that EDTA is the most effective agent for removal of CH from the root canals [28, 29]. In contrast, Arslan et al. have reported that passive ultrasonic irrigation with NaOCl is more effective in removing TAP from artificial grooves [16]. Based on these findings, this study employed a combination of EDTA and NaOCl along with sonic agitation as the irrigation protocol to improve the removal of medicaments. Nevertheless, a limitation of this study was not investigating the remaining medicament in the root canal after irrigation protocol. The presence of residual medicaments in the root canal should be taken into consideration when assessing the results.

The push-out test has been commonly used to evaluate the effectiveness of the adhesion of dental materials to root canal dentin [21–24, 26, 30, 34, 38, 39, 41–43]. Dislodgement resistance of root canal filling to radicular dentin prevents coronal and apical leakage and supports the dental tissue against

root fracture [31, 32] and resist dislocation of root filling during operative procedures, post space preparation, and tooth flexure [30, 33]. Previous studies have shown that a material that has high push-out test results contributes to the longevity and prognosis of root canal-treated teeth [32, 34].

The bond strength of root canal filling is affected by irregular canal anatomies such as lateral and accessory root canals, and resorption areas [35]. These irregular canal anatomies cause difference between the calculated bonding area and existing bonding area, which may lead to erroneous calculations. At the same time, previous studies have shown that the use of a medicament, before filling the root canal filling, tooth section, root filling technique, slice thickness, and final irrigation protocol, may affect the bond strength [36, 37, 39, 42].

In this study, the null hypothesis (1) that there was no influence of medicaments in terms of the dislodgement resistance of sealers was accepted. However, the null hypothesis (2) that there was no difference between the sealers was partially rejected. The maximum dislodgement resistance was observed in Total Fill BC Sealer under all tested conditions. The dislodgement resistance of Total Fill BC Sealer was significantly superior to that of AH Plus and MTA Fillapex in the control group ( $P < 0.05$ ). Similar to our results, Nagas et al. reported that iRoot SP showed the maximum bond strength as compared to MTA Fillapex, AH Plus, and Epiphany. The bond strength values obtained were as follows: MTA Fillapex  $\leq$  Epiphany  $<$  AH Plus  $<$  iRoot SP [24]. As stated in previous studies, the superior bond strength of Total Fill BC Sealer may be related to its smaller particle size, which improves the penetration of the sealer into anatomic irregularities and dentinal tubules [24, 38]. However, no significant difference between Total Fill BC Sealer and AH Plus was observed in the CH group.

While the use of CH as an intracanal medication for 3 weeks was observed to improve the dislodgement resistance of AH Plus, this improvement was not found to be statistically significant when compared with the control group. These results are similar to those obtained by Carvalho Bauer et al. who reported that CH, when used for 14 days, had a positive influence on the dislodgement resistance of AH Plus [39]. In contrast to these results, several studies have reported that the use of CH does not affect the dislodgement resistance of AH Plus [11, 22, 36], and the study conducted by Guiotti et al. reported totally contrary results, wherein significantly lower bond strengths were seen when CH was used as a medicament prior to filling with AH Plus sealer [21]. Despite inconsistent results about the influence of prior use of CH on the dislodgement resistance of AH Plus, the number of studies that have reported that CH residues have a positive effect on dislodgement resistance of calcium silicate-based materials are numerous in the literature [22, 40, 41]. This observation can be explained by the reaction of calcium silicate and calcium phosphate, which are the main components of calcium

silicate-based materials, with the remaining CH of root canal resulting in an improvement in the dislocation resistance.

In line with the present results, previous studies have shown that MTA Fillapex has low dislodgement resistance as compared to iRoot SP. The reason for the low adhesion strength of MTA Fillapex was reported to be the low adhesion property of its tag-like structures to root canal dentin [24, 26].

Akçay et al. reported that the use of DAP does not affect the adhesion strength of AH Plus [36]. In line with the finding reported by them, our study also showed that prior use of DAP does not statistically significantly affect the dislodgement resistance of AH Plus.

Topcuoglu et al. investigated the effect of CH and antibiotic pastes on the dislodgement resistance of MTA in simulated immature teeth root canal dentin [42]. Their results showed that the application of DAP as an intracanal medicament reduced the dislocation resistance of MTA to root dentin. Similar to these findings, Nagas et al. reported that prior application of antibiotic pastes (TAP or Augmentin) decreased the dislodgement resistance of calcium silicate cements (ProRoot MTA or Biodentin) [41]. In the present study, DAP negatively affected the dislodgement resistance of MTA Fillapex but the result was not statistically significant. One possible explanation for this result may be that residual antibiotic pastes act as a physical barrier thereby preventing chemical bonding between dentin and MTA Fillapex.

Adhesive failure between sealer and core was the most frequent type of failure in the control group. This result is in line with that of Nagas et al., wherein the adhesive failure of the sealer/core material interface was observed more frequently for AH Plus, iRoots SP, and MTA Fillapex under normal moisture condition [24]. Similarly, Akçay et al. found adhesive failure as the most frequent type of failure [36].

Although use of a core material in root canal filling has some disadvantages, such as voids between sealer and core material, and lack of homogeneity in the filling [23], we still used gutta-percha (R50, VDW) as the main core material due to the reason that root canals are commonly filled with a core material and sealer in contemporary endodontics. According to previous studies, root canal sealers significantly lower dislocation resistance values when used in main core rather than in bulk-filled form [23, 43]. As stated in a previous study, deformation of the gutta-percha during the push-out test may lead incorrect measurements [44]. Furthermore, the dislodgement resistance of sealer in a thin film may also be different from its resistance in bulk. Therefore, to confirm the results of the present study, a further investigation needs to be undertaken for bulk-filling sealers with placements of different medicaments.

## Conclusion

Prior application of CH or DAP does not significantly affect the adhesion of AH Plus, MTA Fillapex, and Total Fill BC Sealer, when a matching-taper single-cone technique is used.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Funding** None.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

## References

- McGurkin-Smith R, Trope M, Caplan D, Sigurdsson A (2005) Reduction of intracanal bacteria using GT rotary instrumentation, 5.25% NaOCl, EDTA, and Ca(OH)<sub>2</sub>. *J Endod* 31:359–363
- Siqueira JF Jr, Magalhaes KM, Rocas IN (2007c) Bacterial reduction in infected root canals treated with 2.5% NaOCl as an irrigant and calcium hydroxide/camphorated paramonochlorophenol paste as an intracanal dressing. *J Endod* 33:667–672
- Siqueira JF Jr, Rocas IN, Paiva SS, Guimaraes-Pinto T, Magalhaes KM, Lima KC (2007a) Bacteriologic investigation of the effects of sodium hypochlorite and chlorhexidine during the endodontic treatment of teeth with apical periodontitis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 104:122–130
- Siqueira JF Jr, Paiva SS, Rocas IN (2007d) Reduction in the cultivable bacterial populations in infected root canals by a chlorhexidine-based antimicrobial protocol. *J Endod* 33:541–547
- Siqueira JF Jr, Guimaraes-Pinto T, Rocas IN (2007b) Effects of chemomechanical preparation with 2.5% sodium hypochlorite and intracanal medication with calcium hydroxide on cultivable bacteria in infected root canals. *J Endod* 33:800–805
- Miller EK, Lee JY, Tawil PZ, Teixeira FB, Vann WF Jr (2012) Emerging therapies for the management of traumatized immature permanent incisors. *Pediatr Dent* 34:66–69
- Mohammadi Z, Dummer PM (2011) Properties and applications of calcium hydroxide in endodontics and dental traumatology. *Int Endod J* 44:697–730
- Kvist T, Molander A, Dahlen G, Reit C (2004) Microbiological evaluation of one- and two-visit endodontic treatment of teeth with apical periodontitis: a randomized, clinical trial. *J Endod* 30:572–576
- Chavez De Paz LE, Dahlen G, Molander A, Moller A, Bergenholtz G (2003) Bacteria recovered from teeth with apical periodontitis after antimicrobial endodontic treatment. *Int Endod J* 36:500–508
- Barbizam JV, Trope M, Teixeira EC, Tanomaru-Filho M, Teixeira FB (2008) Effect of calcium hydroxide intracanal dressing on the bond strength of a resin-based endodontic sealer. *Braz Dent J* 19: 224–227

11. Ustun Y, Arslan S, Aslan T (2013) Effects of calcium hydroxide and propolis intracanal medicaments on bond strength of resin-based endodontic sealer as assessed by push-out test. *Dent Mater J* 32: 913–919
12. Gomes-Filho JE, Duarte PC, de Oliveira CB, Watanabe S, Lodi CS, Cintra LT, Bernabe PF (2012) Tissue reaction to a triantibiotic paste used for endodontic tissue self-regeneration of nonvital immature permanent teeth. *J Endod* 38:91–94
13. Akcay M, Arslan H, Yasa B, Kavrik F, Yasa E (2014a) Spectrophotometric analysis of crown discoloration induced by various antibiotic pastes used in revascularization. *J Endod* 40: 845–848
14. Hargreaves KM, Diogenes A, Teixeira FB (2013) Treatment options: biological basis of regenerative endodontic procedures. *J Endod* 39:30–43
15. Arslan H, Akcay M, Capar ID, Ertas H, Ok E, Uysal B (2014b) Efficacy of needle irrigation, EndoActivator, and photon-initiated photoacoustic streaming technique on removal of double and triple antibiotic pastes. *J Endod* 40:1439–1442
16. Arslan H, Capar ID, Saygili G, Uysal B, Gok T, Ertas H, Topcuoglu HS (2014a) Efficacy of various irrigation protocols on the removal of triple antibiotic paste. *Int Endod J* 47:594–599
17. Chou K, George R, Walsh LJ (2014) Effectiveness of different intracanal irrigation techniques in removing intracanal paste medicaments. *Aust Endod J* 40:21–25
18. Berkhoff JA, Chen PB, Teixeira FB, Diogenes A (2014) Evaluation of triple antibiotic paste removal by different irrigation procedures. *J Endod* 40:1172–1177
19. Ruparel NB, Teixeira FB, Ferraz CC, Diogenes A (2012) Direct effect of intracanal medicaments on survival of stem cells of the apical papilla. *J Endod* 38:1372–1375
20. Labban N, Yassen GH, Windsor LJ, Platt JA (2014) The direct cytotoxic effects of medicaments used in endodontic regeneration on human dental pulp cells. *Dent Traumatol* 30:429–434
21. Guiotti FA, Kuga MC, Duarte MA, Sant’Anna AJ, Faria G (2014) Effect of calcium hydroxide dressing on push-out bond strength of endodontic sealers to root canal dentin. *Braz Oral Res* 28:1
22. Amin SA, Seyam RS, El-Samman MA (2012) The effect of prior calcium hydroxide intracanal placement on the bond strength of two calcium silicate-based and an epoxy resin-based endodontic sealer. *J Endod* 38:696–699
23. Jainena A, Palamara JE, Messer HH (2007) Push-out bond strengths of the dentine-sealer interface with and without a main cone. *Int Endod J* 40:882–890
24. Nagas E, Uyanik MO, Eymirli A, Cehreli ZC, Vallittu PK, Lassila LV, Durmaz V (2012) Dentin moisture conditions affect the adhesion of root canal sealers. *J Endod* 38:240–244
25. Total Fill (2015) [http://www.fkg.ch/sites/default/files/fkg\\_totalfill\\_brochure\\_en.pdf](http://www.fkg.ch/sites/default/files/fkg_totalfill_brochure_en.pdf). Accessed 8 July 2015
26. Sagsen B, Ustun Y, Demirbuga S, Pala K (2011) Push-out bond strength of two new calcium silicate-based endodontic sealers to root canal dentine. *Int Endod J* 44:1088–1091
27. MTA Fillapex (2015) [http://angelusdental.com/img/arquivos/mta\\_fillapex\\_technical\\_profile\\_download.pdf](http://angelusdental.com/img/arquivos/mta_fillapex_technical_profile_download.pdf) Accessed 8 July 2015
28. da Silva JM, Silveira A, Santos E, Prado L, Pessoa OF (2011) Efficacy of sodium hypochlorite, ethylenediaminetetraacetic acid, citric acid and phosphoric acid in calcium hydroxide removal from the root canal: a microscopic cleanliness evaluation. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 112:820–824
29. Rodig T, Vogel S, Zapf A, Hulsmann M (2010) Efficacy of different irrigants in the removal of calcium hydroxide from root canals. *Int Endod J* 43:519–527
30. 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
31. Shipper G, Ørstavik D, Teixeira FB, Trope M (2004) An evaluation of microbial leakage in roots filled with thermoplastic synthetic polymer-based root canal filling material (Resilon). *J Endod* 30: 342–347
32. Ulusoy OI, Genç O, Arslan S, Alaçam T, Gorgul G (2007) Fracture resistance of roots obturated with three different materials. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 104:705–708
33. Panitvisai P, Messer HH (1995) Cuspal deflection in molars in relation to endodontic and restorative procedures. *J Endod* 21:57–61
34. Huffman BP, Mai S, Pinna L, Weller RN, Primus CM, Gutmann JL, Pashley DH, Tay FR (2009) Dislocation resistance of ProRoot Endo Sealer, a calcium silicate-based root canal sealer, from radicular dentine. *Int Endod J* 42:34–46
35. Mjor IA, Smith MR, Ferrari M, Mannocci F (2001) The structure of dentine in the apical region of human teeth. *Int Endod J* 34:346–353
36. Akcay M, Arslan H, Topcuoglu HS, Tuncay O (2014b) Effect of calcium hydroxide and double and triple antibiotic pastes on the bond strength of epoxy resin-based sealer to root canal dentin. *J Endod* 40:1663–1667
37. Collares FM, Portella FF, Rodrigues SB, Celeste RK, Leitune VC, Samuel SM (2015) The influence of methodological variables on the push-out resistance to dislodgement of root filling materials: a meta-regression analysis. *Int Endod J*. doi:10.1111/iej.12539
38. Shokouhinejad N, Gorjestani H, Nasseh AA, Hoseini A, Mohammadi M, Shamshiri AR (2013) Push-out bond strength of gutta-percha with a new bioceramic sealer in the presence or absence of smear layer. *Aust Endod J* 39:102–106
39. Carvalho CN, Bauer J, Ferrari PH, Souza SF, Soares SP, Loguercio AD, Bombana AC (2013) Influence of calcium hydroxide intracanal medication on bond strength of two endodontic resin-based sealers assessed by micropush-out test. *Dent Traumatol* 29: 73–76
40. Felipe WT, Felipe MC, Rocha MJ (2006) The effect of mineral trioxide aggregate on the apexification and periapical healing of teeth with incomplete root formation. *Int Endod J* 39:2–9
41. Nagas E, Cehreli ZC, Uyanik MO, Vallittu PK, Lassila LV (2015) Effect of several intracanal medicaments on the push-out bond strength of ProRoot MTA and Biodentine. *Int Endod J*. doi:10.1111/iej.12433
42. Topcuoglu HS, Arslan H, Akcay M, Saygili G, Cakici F, Topcuoglu G (2014) The effect of medicaments used in endodontic regeneration technique on the dislocation resistance of mineral trioxide aggregate to root canal dentin. *J Endod* 40:2041–2044
43. Nagas E, Cehreli Z, Uyanik MO, Durmaz V (2014) Bond strength of a calcium silicate-based sealer tested in bulk or with different main core materials. *Braz Oral Res* 28:1
44. Williams C, Loushine RJ, Weller RN, Pashley DH, Tay FR (2006) A comparison of cohesive strength and stiffness of Resilon and gutta-percha. *J Endod* 32:553–555