Influence of Single Cone Techniques and Continuous Wave of Obturation on the resistance of Endodontic Cements union to Radicular Dentin

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Abstract*— Endodontic obturation has the purpose to fill three-dimensional root canal system. The search for this objective resulted in the emergence of different techniques. The study proposed to evaluate, in vitro, the influence of Single Cone and Continuous Wave techniques on the adhesion of EndoSequence BC (Brasseler USA, Savannah, USA), Pulp Canal Sealer EWT (SybronEndo, Orange USA) and AH Plus (Dentsply , USA) to the dentinal walls of the root canals of extracted human teeth. Seventy-two human premolars were divided into 6 experimental groups (n = 12). The teeth were instrumented and obturated in a standardized way by means of the single cone technique or the continuous wave technique according to the specification of each group: a) EBC-OC Group: EndoSequence BC + Continuous Wave; B) PC-OC Group: Pulp Canal Sealer EWT + Continuous Wave; C) AH-OC Group: AH Plus + Continuous Wave; D) EBC-CU Group: EndoSequence BC + Single Cone; E) PC-CU Group: Pulp Canal Sealer EWT + Single Cone; F) AH-CU Group: AH Plus + Single Cone. The teeth were sectioned into approximately 1.0mm thick slices and the adhesion of the sealer to the dentin walls was measured using the push-out shear test. The failure mode was observed by visual inspection of a 12,5X magnification optics microscope. Data on union resistance by the group push-out test were submitted to statistical analysis by two-way ANOVA, post hoc and Mann-Whitney tests. There were no significant differences between the sealers when the Continuous Wave technique was employed (p=0,783); in the Single Cone technique the EndoSequence BC sealer had the highest bond strength, which was limited to the apical third, while the lowest bond strength values were attributed to the Pulp Canal Sealer EWT. The chi-square test revealed that the EndoSequence BC sealer showed an adhesive failure mode at the sealer/gutta percha interface in a proportion significantly higher than the Pulp Canal Sealer EWT, which, on the other hand, showed a predominance of adhesive failure mode at the dentin/sealer interface (p <0.05). The single cone technique showed better adhesion of the EndoSequence and AH Plus sealers when compared to the continuous wave technique.

***Keywords*— Continuous Wave, Single Cone, endodontic sealer, push-out test, bond strength.**

I. INTRODUCTION

One of the objectives of endodontic treatment is the three-dimensional filling of root canals, however, this objective is difficult to be achieved due to some variables, mainly related to the anatomical complexity of the root canals system and dentin irregularities. Various materials have been proposed for filling the intraradicular space and most techniques include a main material (commonly represented by gutta-percha) and an endodontic cement. Regardless of the choice of technique, cement is essential in filling, as it promotes sealing, thus preventing the infiltration of tissue fluids (Cohen, Hargreaves, 2011).

Among the many desirable properties for endodontic cement is the adhesive force both at the cement-dentin interface and at the cement-gutta-percha interface. The cement must also have cohesive strength to maintain the filling set (Saleh et al, 2003). According to Grossman (1976), for an endodontic cement to be ideal, it is necessary to promote a good seal, have dimensional stability, have sufficient working time, be insoluble in contact with tissues and fluids, present adhesion and be biocompatible. However, there is no endodontic cement with all the ideal physical, chemical and biological characteristics available on the market.

Endodontic cements can be classified according to their composition into cements based on zinc oxide and eugenol, based on epoxy resin, based on calcium

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hydroxide, based on silicone, based on methacrylate or based on silicate. calcium (Barbizam, 2006).

Cements based on zinc oxide and eugenol have been used for a long time (Grossman, 1976; Cohen, 2011), have good microbial activity and exhibit a long setting time. One of the cements based on zinc oxide and eugenol is the Pulp Canal Sealer EWT (SybronEndo, Orange, USA) which is widespread and commonly used among clinicians.

Presented in the form of paste, AH Plus cement (Dentsply, USA) is a resin cement, based on the epoxy amine resin. This cement has high radiopacity, low solubility, little contraction, good adaptation to the root canal walls, dimensional stability, antimicrobial activity and good biological behavior (AL-Kathar et al, 1995; Almeida, 1997).

Bioceramic cement, represented by the trademark EndoSequence BC is an endodontic cement that was launched, with calcium silicate, zirconium oxide, calcium phosphate, calcium hydroxide and thickening agents in its composition. To take prey it is necessary to have water in an environment such as the dentinal tubules. EndoSequence BC is described in the literature as having antimicrobial activity due to high pH, hydrophilicity, active diffusion of calcium hydroxide, in addition to being biocompatible (Zhou, et al. 2015). Cements based on tricalcium silicate, such as EndoSequence BC are hydrophilic, their properties are improved in the presence of moisture. A particularity of these cements is their potential to express bioactivity, with the ability to form hydroxyapatite during the setting process and, thus, join the filling material to the dentin (Loushine et al. 2011; Candeiro et al. 2012; Amir et al. 2016).

Gutta-percha, although widely used in filling the root canal system, has low adhesion and for this reason it is used with endodontic cement (Pommel et al. 2003). Modern filling techniques aim to obtain a smaller cement film and a greater amount of gutta-percha, since cement represents the fragile portion of the filling (Shilder, 2006).

The thermoplasticization of gutta-percha using the Continuous Wave technique is widely used, as this promotes the complete filling of the irregularities of the canals, in addition to practicality in the execution (DeLong et al. 2015).

The Continuous Wave technique aims to improve the filling result, as the heated gutta-percha promotes better adaptation to the canal. Its method of execution recommends the use of a single cone and a heat source, filling is performed by softening the gutta-percha and pressing with a heated presser foot, and its effectiveness can be measured by apical sealing and filling of lateral canals (Guess et al. 2003).

Viapiana et al. (2014) stated that, in addition to homogenizing the gutta-percha inside the canals, the thermoplasticization increases its density. However, when heat is applied to plasticize the main filling material, the cements are subjected to a drastic change in heat, which can alter their properties and cause damage around the dentinal tissues. Beltes et al. (2008) reported, in their research, that the increase in temperature did not affect the shear strength of a resin cement (AH26), on the other hand, observed the change in viscosity.

Few studies have evaluated the influence of the Single Cone and Continuous Wave techniques through the thermoplasticization of gutta-percha in the final result of adhesion of endodontic cements to dentinal walls. Therefore, there is a gap in the relevant literature on the subject, and it is relevant to study the issue.

II. MATERIALS AND METHODS

This research was initiated after it's approval by the ethics committee, with the number CAE:55581516300005374. For this work, 72 freshly extracted human uniradicular and circular premolars were used, which were distributed in six experimental groups of 12 specimens each. This choice was based on the result of the sample calculation and power test. The lower premolars were placed in a 0.1% thymol solution that was obtained directly from the patients (who needed extractions for therapeutic reasons) by explaining the research and signing the Free and Informed Consent Form (ICF). Radiographs in the mesio-distal and buccal-lingual directions were performed to confirm the presence of a single straight circular canal. Through the 8X magnification operating microscope, the absence of cracks, fractures and external apical resorption along the entire surface of each root was confirmed.

One week before the tests, the root surfaces were scraped and smoothed with periodontal curettes to remove any remaining periodontal ligament and were subjected to prophylaxis, using Robson's brush with pumice paste and water. After cleaning, the teeth were sectioned with a double-sided diamond disc attached to a straight chuck and micromotor, cooled with air / water spray. The length of the roots was standardized at 15 mm in the apex-cervical direction with the aid of a digital caliper.

For instrumentation, visual dentometry was determined. A file type K # 15 was introduced in each canal, until its visualization in the apical foramen. The working length was determined at 0.5 mm below the apical foramen.

Instrumentation was performed using ProTaper Next rotary files attached to the X-SMART engine. The files used were X1, X2, X3, X4 and X5 in order to obtain an

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apical matrix corresponding to the diameter 50 / 0.6. The torque and speed of the rotating files were in accordance with the manufacturer's determination, with torque equal to 3.0 Ncm and speed equal to 300 min. The movement of the file was the entry and exit.

During the cleaning and shaping of the root canals, irrigation was performed at each instrument change with 2.5% NaOCl, in a total of 20 mL of solution per experimental unit, 1 mm below the working length. After instrumentation, passive ultrasonic irrigation was performed as previously described (Van der Sluis, 2010) using the Irrisonic insert (20.01), inserted at 2 mm of the working length at a frequency of 30,000 Hz. 3 cycles of 20 seconds were performed. with 2.5% NaOCl (5 mL), 3 cycles of 20 seconds with 17% liquid EDTA (5 mL), proceeding with an additional 3 20-second cycles with 2.5% NaOCl (5 mL). Then, the canals were dried with a suction cannula and capillary tip attached to a high-power suction cup and with # 50 absorbent paper tips.

The use of 3 different cements resulted in the creation of 6 experimental groups containing 12 teeth in each group (n = 12). The teeth were randomly distributed to form groups using a specific program (http://www.random.org)

a) EBC-OC Group (n = 12): EndoSequence BC Cement + Continuous Wave
b) PC-OC Group (n = 12): Cement Pulp Canal Sealer EWT + Continuous Wave
c) AH-OC Group (n = 12): AH Plus Cement + Continuous Wave
d) EBC-CU Group (n = 12): Cement EndoSequence BC + Single Cone
e) PC-CU Group (n = 12): Cement Pulp Canal Sealer EWT + Single Cone
f) AH-CU Group (n = 12): AH Plus Cement + Single Cone

The cements were spatulated or inserted into the root canal according to the manufacturer's recommendations. For the handling of the cements, a sterile glass plate and a flexible spatula number 24 were used.

EBC-OC Group: The EndoSequence BC cement was inserted with the aid of a syringe and insertion point in the channel according to the manufacturer's recommendations, a 50.06 gutta-percha cone was placed and then the portion was cut cone of the cone with the heated plugger condenser. The Continuous Wave Technique was performed following 2 steps: Downpack and Backfill (Christopher et al. 2005), for this purpose the Beta Main Device and Alpha II devices (figure 12) were used following the manufacturer's recommendations.

For the Downpack phase, which was carried out by the Alpha II device, the Plugger condenser was inserted in the thermocondenser, heating the gutta-percha until reaching a depth of 5mm below the working length at a temperature of 200 ° C (Christopher et al. 2005), it was waited for 5 seconds with a laterality movement and immediately afterwards it was removed from the interior of the canal, breaking the gutta-percha. The Condenser 40/80 instrument was used to condense the apical plug. For the Backfill phase, the Beta Main Device was used. The thermal injector left the gutta-percha preheated to 180 ° C, the 25-gauge metal tip was selected, which was 5mm from the actual working length, and the 2/3 of the canal was filled with heated gutta-percha using the gun, shortly thereafter, the heated gutta-percha was condensed with the Paiva condenser number 4.

PC-OC Group: The Pulp Canal Sealer EWT cement was handled following the manufacturer's guidelines and was inserted together with the main gutta-percha cone. The obturation technique used was the Continuous Wave already described in the EBC-OC group, using the Beta Main Device and Alpha II devices.

H-OC Group: The AH Plus cement (figure 14) was handled following the manufacturer's guidelines and was inserted together with the main gutta-percha cone. The obturation technique employed was that of Onda Continua already described in the EBC-OC and PC-OC groups, using Beta Main Device and Alpha II devices.

EBC-CU Group: The canals were filled using the Single Cone Technique, the 50.06 gutta-percha cone was used. The cement was EndoSequence BC, which has already been manipulated, according to the manufacturer's instructions, and was inserted into the mouth of the canal with the tip of the intracanal syringe, in an amount measured from one or two markings on the embolus. The gutta-percha cone was inserted slowly into the canal up to the working length, cut at the mouth of the channel with the Paiva condenser number 4 heated and condensed with the same cold instrument.

PC-CU Group: The canals were filled using the Single Cone Technique, the 50.06 gutta-percha cone (VDW, Munich - Germany) was used. The cement was the Pulp Canal Sealer EWT (SybronEndo, Orange USA) was mixed according to the manufacturer's recommendations. The cement was taken next to the main gutta-percha cone, cut at the mouth of the canal with the Paiva condenser number 4, heated and condensed with the same cold instrument.

AH-CU Group: The canals were filled using the Single Cone Technique, the 50.06 gutta-percha cone was used. The cement was AH Plus which was manipulated in equal portions of the pastes until the consistency of bullet

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wire was obtained. The cement was taken next to the main gutta-percha cone, cut at the mouth of the canal with the Paiva condenser number 4, heated and condensed with the same cold instrument.

After filling, all teeth were stored in an oven with relative humidity of the air at about 37 ° C (figure 17), for a period of 30 days, to allow the complete setting of the endodontic cement, according to the protocol of aging followed by Rios et al. 2014.

The roots were individually positioned on acrylic plates and then fixed with sticky wax in order to allow a more precise cut (Guedes Filho, 2012).

Each root was sectioned perpendicularly along the long axis through the Diamond Wafering Blade High Concentration 4 ”x .012 x ½ disc (102 mm X 0.3 mm X 127 mm) that was coupled to the metallographic cutter - Isomet 1000 in order to obtain a slice of approximately 1.0mm thick of the cervical, middle and apical thirds of each root. Right after each cut, the slices were identified with overhead pens, with different colors for each third on the face facing the cervical and kept in a humid environment according to the respective group and third for 24 hours.

For the extrusion resistance test, a slice of each third was subjected to an axial compression loading. The specimens were positioned on a stainless steel metallic base containing a 2.0mm internal diameter hole in the central region. The whole set was positioned on the base of the universal testing machine EMIC DL 2000 (figure 20) with a load of 100 Kilonewton (kN). The slices were arranged so that the load was applied in an apical to coronal direction, avoiding interference imposed by the root canal taper. A metal rod with an active tip of 1.0 mm for the cervical third, and 0.5 mm in diameter for the middle and apical thirds was fixed on the machine and positioned in the center of the gutta-percha mass.

The shear strength test by extrusion was conducted at a speed of 1.0 mm / min until failure occurred. The required force was obtained in Kilogram-force (kgf) and converted to Megapascal (MPa) by dividing the force by the root canal area. The kgf values were multiplied by 0.0980655 which corresponds to the conversion factor from kgf to Newton (N) and the area will be calculated using the formula: A = π (R + r) [h2 + (R - r) 2] 0.5, where π was the constant 3.14, R was the radius of the cemented gutta-percha facing the coronal region, r was the radius of the cemented gutta-percha facing the apical region and h was the thickness of the slice. The largest, smallest radius and thickness of each slice were individually measured using a digital calibrator. The results of the values obtained were tabulated in a data collection spreadsheet and submitted to statistical interpretation.

After the mechanical shear test by extrusion (push-out), the failure mode of each slice was analyzed using an operating microscope with 12.5X magnification and they were classified as: Adhesive at the cement / dentin interface; Adhesive at the cement / gutta-percha interface; Mixed, combination of the two adhesive failures and Without cement, if no cement was found in dentin and gutta-percha.

The statistical analysis of comparisons between cements as a function of root thirds was performed using two-way analysis of variance (two-way ANOVA) and a post hoc test that allowed “two by two comparisons” between groups, where significance was found statistic (α = 0.05). To compare the two techniques used in each cement, the Mann-Whitney test was used.

III. RESULTS

Table 1. Arithmetic means, standard deviations and statistical analysis between the sample groups (MPa).

	EndoSequence BC		**Pulp Canal Sealer EWT**		**AH Plus**	
	OC	cone único	OC	cone único	OC	cone único
Cervical	0,37 ± 0,23 Aa	0,36 ± 0,29 Aa	0,45 ± 0,29 Aa	0,10 ± 0,09 Ba	0,90 ± 0,17 Aa	0,91 ± 0,20 Aa
Medium	0,43 ± 0,29 Aa	0,24 ± 0,35 Aa	0,56 ± 0,40 Aa	0,15 ± 0,17 Aab	0,95 ± 0,57 Aa	0,95 ± 0,62 Ba
Apical	0,40 ± 0,52 Aa	1,57 ± 1,07 Ab	0,47 ± 0,58 Aa	0,38 ± 0,47 Bb	0,79 ± 0,01 Aa	0,90 ± 0,18 Aa
Total	0,40 ± 0,36 Aa	0,72 ± 0,89 Ab	0,49 ± 0,43 Aa	0,21 ± 0,31 Bb	0,54 ± 0,61 Aa	0,74 ± 0,56 Ab

Obs: OC = continuous wave. Different capital letters in the totals indicate significant differences between cements, with the same technique, while different lower letters indicate statistical significance between techniques when the same cement was

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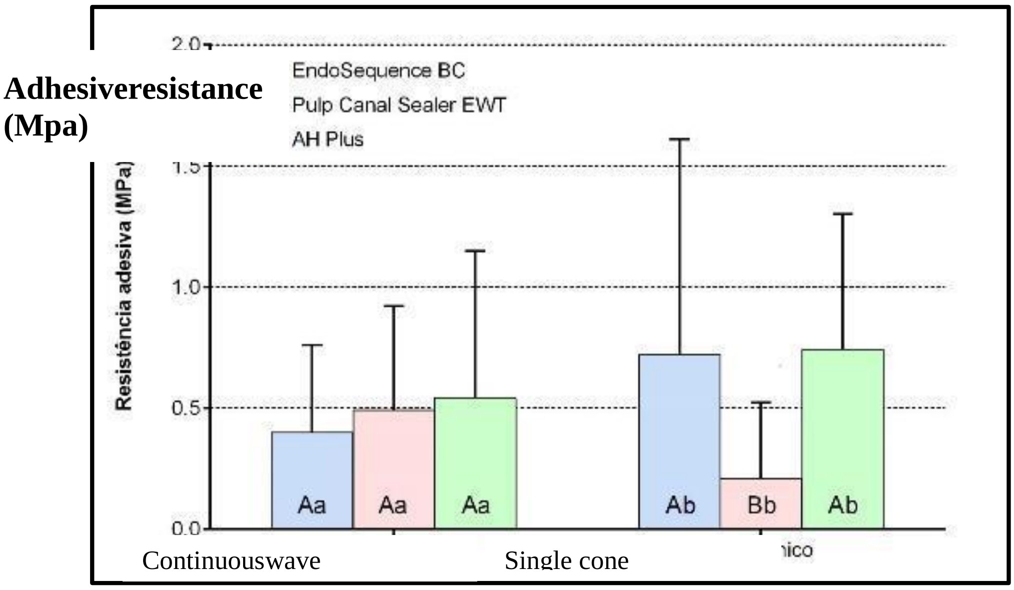
used. Different capital letters in the root thirds indicate significant differences between cements, using the same technique. Different lowercase letters in the root thirds indicate significant differences in the same cement, using the same technique.

Source: Ownauthorship.

The Kruskal-Wallis test applied to the different cements indicated that there were no significant differences between them when the continuous wave technique was used ($p = 0.783$). When the single cone technique was used, significant differences were detected ($p < 0.001$), with Dunn's multiple comparisons post hoc test revealing that Pulp Canal Sealer EWT cement had lower adhesion values than EndoSequence BC and AH Plus cements .

Between each cement, the continuous wave and single cone techniques were compared by the Mann-Whitney test, which revealed differences between them when the EndoSequence BC cement was used ($p = 0.581$). The techniques using the Pulp Canal Sealer EWT or AH Plus cements also show significant differences between them ($p = 0.001$ and $p = 0.031$, respectively). Graph 1 illustrates the results obtained for comparisons between cements and techniques.

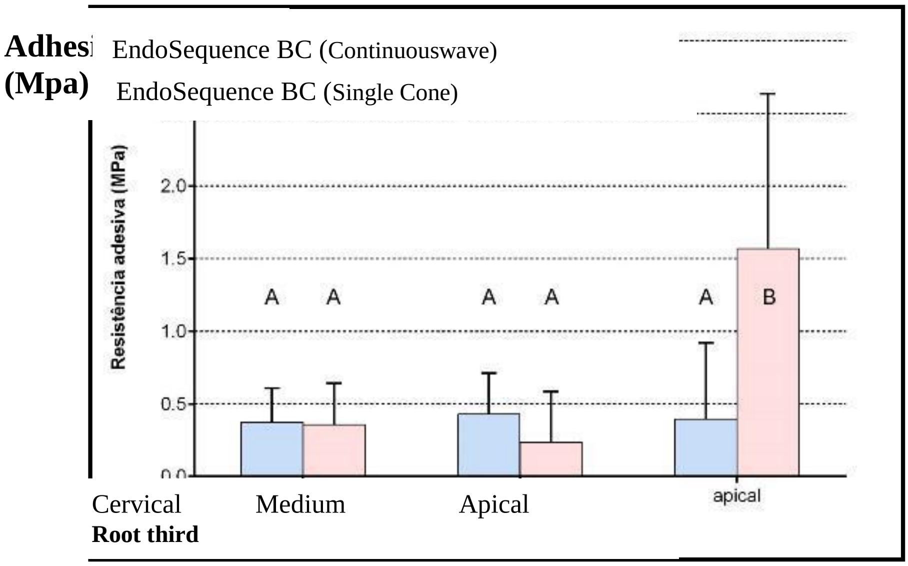
Graph 1 - Bond strength of the tested cements, using continuous wave and single cone techniques. The vertical line represents the standard deviation. Different capital letters indicate significant differences between cements. Different lowercase letters indicate Significant differences between techniques.



Source: Own authorship.

The comparison between the root thirds of the filled teeth with EndoSequence BC cement showed that there were no significant differences when the continuous wave technique was used ($p = 0.323$); when the single cone technique was used, the apical third showed greater adhesive resistance ($p < 0.001$), as shown in Graph 2.

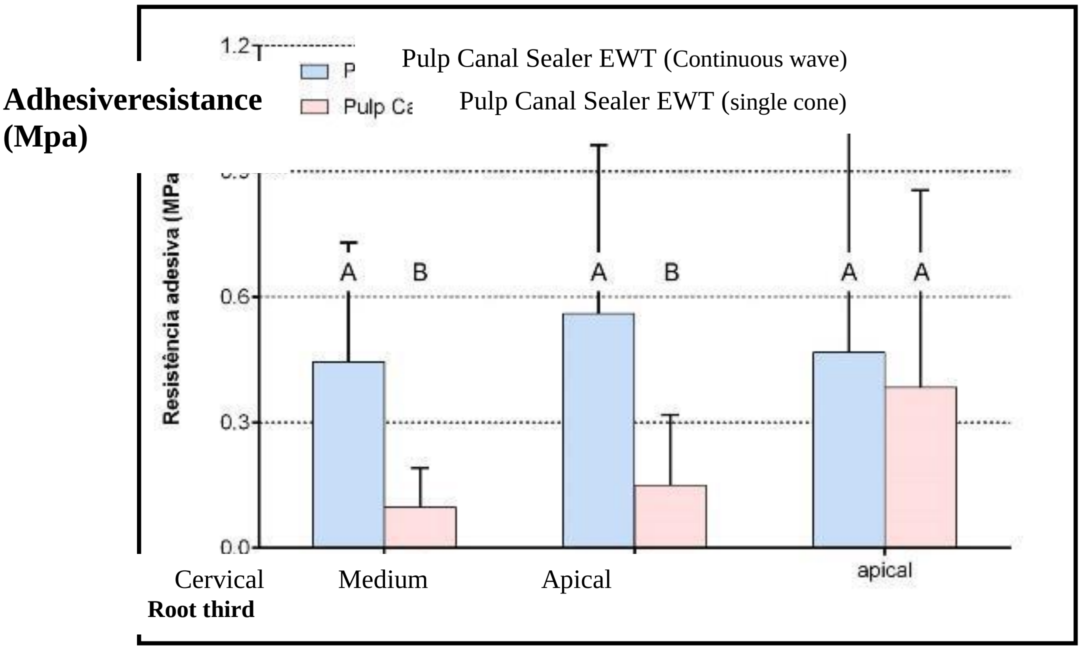
Graph 2 - Adhesive strength of EndoSequence BC cement, used in different techniques, in each root third. The vertical line represents the standard deviation. Different letters indicate a statistically significant difference.



Source: Own authorship.

The Pulp Canal Sealer EWT cement showed significant differences between the techniques in the cervical and middle thirds ($p = 0.007$), with lower values of bond strength, however, it did not show significant difference when the Continuous Wave technique was used regardless of the third ($p > 0.05$). With regard to the Single Cone technique, the apical third obtained greater results when compared to the cervical and middle thirds, as shown in Graph 3.

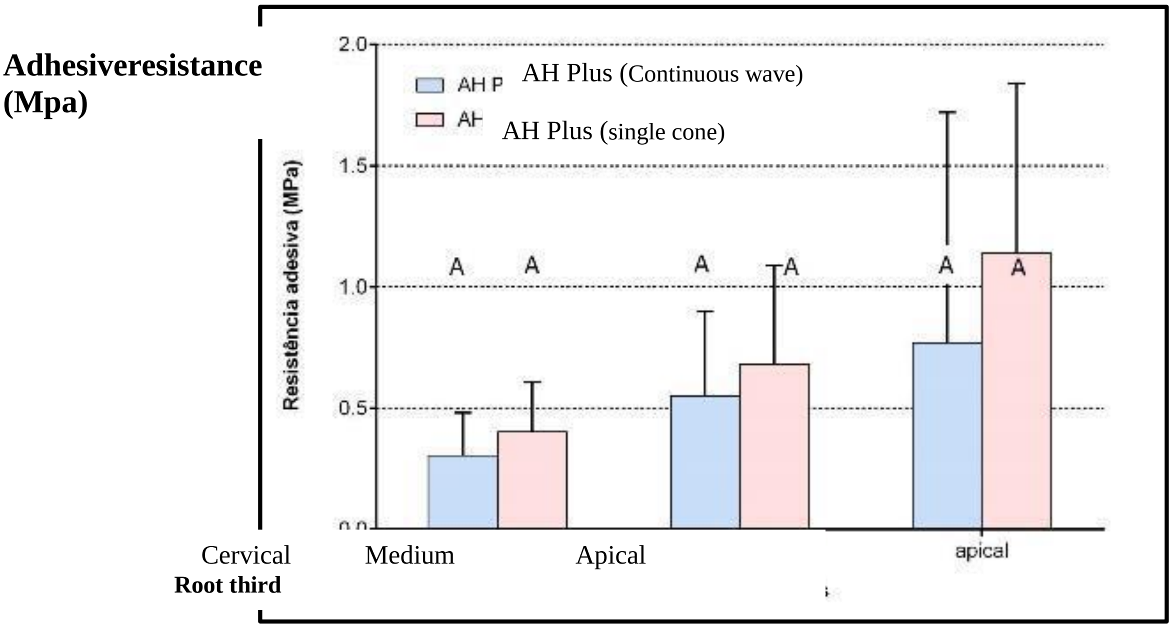
Graph 3 - Adhesive strength of Pulp Canal Sealer EWT cement, used in different techniques, in each root third. The vertical line represents the standard deviation. Different letters indicate significant differences.



Source: Own authorship.

The AH Plus cement did not present significant differences between the techniques studied, in any of the root thirds ($p > 0.05$). Graph 4 shows these data.

Graph 4 - Adhesive strength of AH Plus cement, used in different techniques, in each root third. The vertical line represents the standard deviation. Equal letters indicate that there is no statistical difference.



Source: Own authorship.

Failure Mode Analysis after Push-out Test

The analysis using the chi-square test revealed significant differences between the experimental groups (p <0.001), indicated in Table 2.

Table 2. Failure mode distribution

Group	Dentin/CementAdhesive	gutta-percha /Cement Adhesive	Mixed	Withoutcement
EBC-OC	0 Aa	8Aa	19Aa	12Aa
PC-OC	12Ba	6Aa	4Ba	16Aa
AH-OC	5Aa	5Aa	13Aa	16Aa
EBC-CU	0Aa	28Ab	6Ab	0Ab
PC-CU	13Ba	5Ba	20Bb	0Ab
AH-CU	5Aa	11Cb	23Bb	0Ab

EBC - Endosequence BC; PC - Pulp Canal Sealer; AH - AH Plus; OC - continuous wave; CU - single cone. Different capital letters denote significant differences between cements using the same filling technique, while lower case letters indicate differences between filling techniques in the same cement.

Source: Own authorship.

Between different cements

The frequencies of each occurrence observed for the different cements are recorded in Table 3.

Table 3. Absolute (relative) frequencies of each occurrence observed for the different cements tested

	Failure mode				
	Without cement	Adhesive dentin / cement	Adhesive cement / gutta-percha	Mixed	Total
EndoSequence BC	12 (5,7%)	0 (0,0%)	32 (15,3%)	23 (11,0%)	67 (32,1%)

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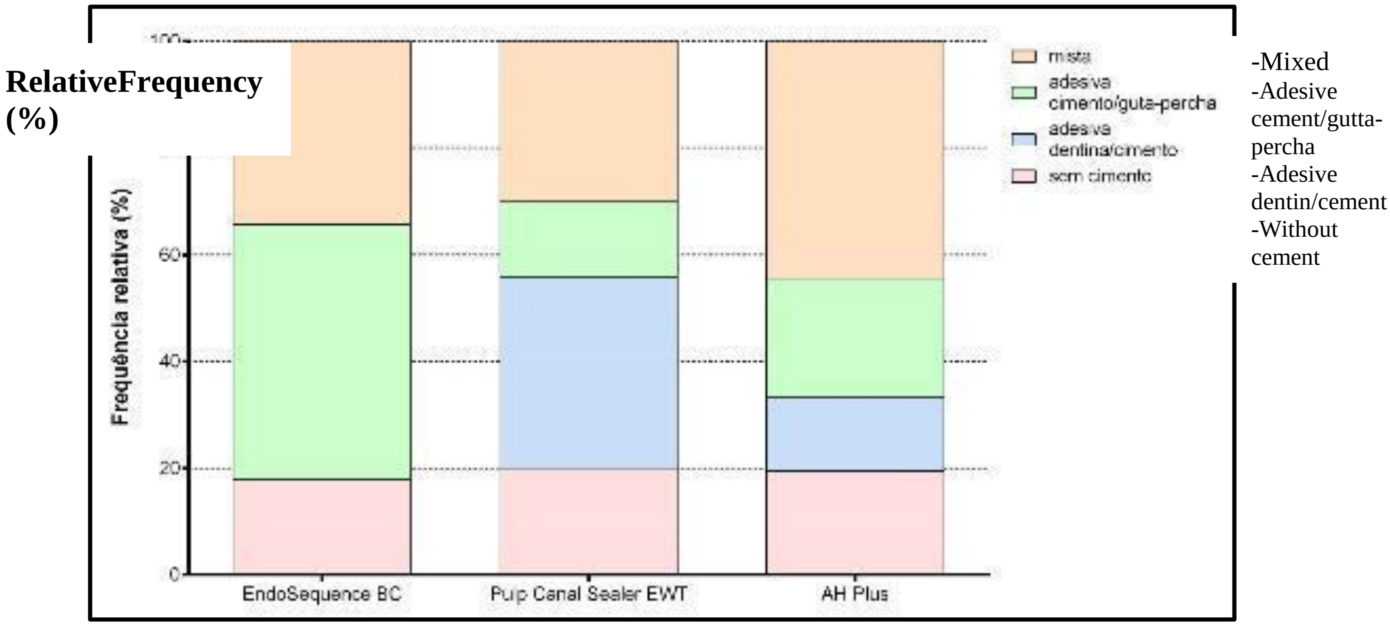
Pulp Canal Sealer	14 (6,7%)	25 (12,0%)	10 (4,8%)	21 (10,0%)	70 (33,5%)
AH Plus	14 (6,7%)	10 (4,8%)	16 (7,7%)	32 (15,3%)	72 (34,4%)
Total	40 (19,1%)	35 (16,7%)	58 (27,8%)	76 (36,4%)	209 (100,0%)

Source: Own authorship.

The distribution of these occurrences, separated by cements, is illustrated in Graph 5.

Graph 5 - Relative frequencies of each occurrence observed for the different cements tested.



Source: Own authorship.

The analysis using the chi-square test revealed that the EndoSequence BC cement showed an adhesive failure mode at the cement / gutta-percha interface in a significantly higher proportion than the Pulp Canal Sealer EWT cement, which in contrast presented more adhesive failure mode at the dentin interface / cement ($p < 0.05$).

Between different techniques

The frequencies of each occurrence observed for the different techniques are recorded in Table 4.

Table 4 - Absolute (relative) frequencies of each occurrence observed for the different techniques tested

	Failure mode				
	Without cement	Adhesive dentin / cement	Adhesive gutta-percha / cement	Mixed	Total
ContinuousWave	40 (19,1%)	17 (8,1%)	18 (8,6%)	32 (15,3%)	107 (51,2%)
Single Cone	0 (0,0%)	18 (8,6%)	40 (19,1%)	44 (21,1%)	102 (48,8%)
Total	40 (19,1%)	35 (16,7%)	58 (27,8%)	76 (36,4%)	209 (100,0%)

Source: Own authorship

The distribution of these occurrences, separated by filling techniques, is illustrated in Graph 6

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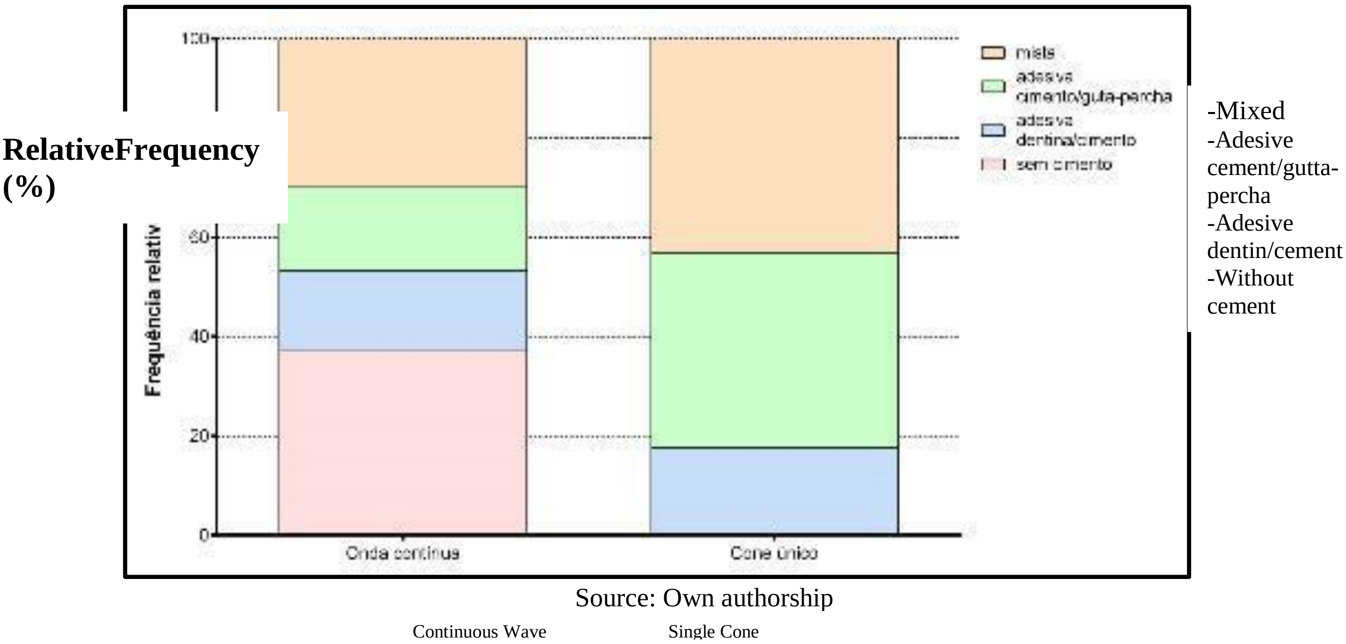
Graph 6 - Relative frequencies of each occurrence observed for the different techniques tested.



Source: Own authorship

The analysis using the chi-square test revealed that the techniques have significantly different failure modes (p <0.001).

Between different thirds

The frequencies of each occurrence observed for the different thirds are recorded in Table 5.

Table 5. Absolute (relative) frequencies of each occurrence observed for the different thirds.

	Failure mode				
	Without cement	Adhesive dentin / cement	Adhesive gutta-percha / cement	Mixed	Total
Cervical	18 (8,6%)	11 (5,3%)	23 (11,0%)	18 (8,6%)	70 (33,5%)
Medium	18 (8,6%)	11 (5,3%)	14 (6,7%)	28 (13,4%)	71 (34,0%)
Apical	4 (1,9%)	13 (6,2%)	21 (10,0%)	30 (14,4%)	68 (32,5%)
Total	40 (19,1%)	35 (16,7%)	58 (27,8%)	76 (36,4%)	209 (100,0%)

Source: Own authorship

The distribution of these occurrences, separated by thirds, is illustrated in Graph 7.

Graph 7 - Relative frequencies of each occurrence observed for the different thirds.

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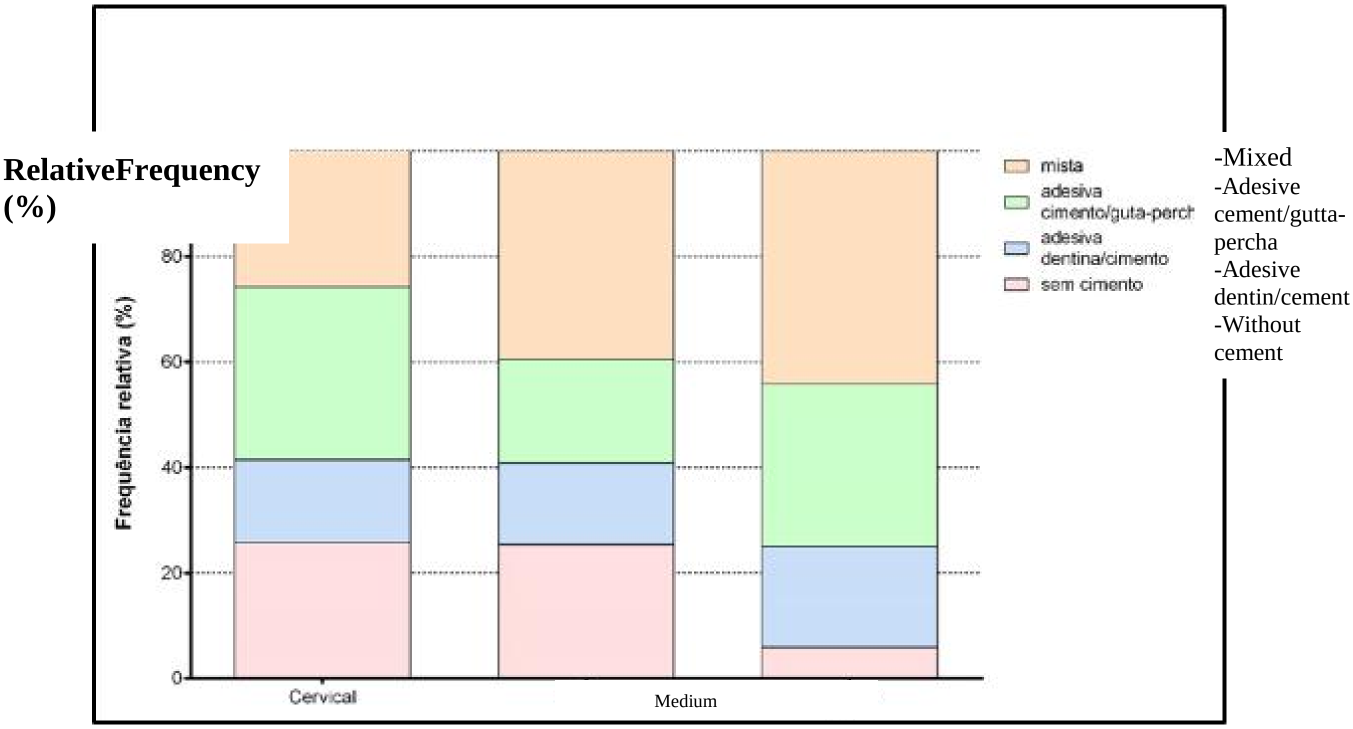

Source: Own authorship

The analysis using the chi-square test revealed that the thirds have a significantly different failure mode (p <0.016), with the cervical third different from the apical third.

IV. DISCUSSION

The aim of this study was to evaluate the influence of the Single Cone and Continuous Wave techniques on the adhesion of the EndoSequence BC, Pulp Canal Sealer EWT and AH Plus cements to the dentinal walls of the root canals of human teeth extracted through the push-out test. Good adhesion of the filling material is an indication of a better filling of the root canal (De-Deus et al. 2009). Grossman (1976) pointed out that most endodontic cements have this characteristic, however, there is a difference in the degree of adhesion from one cement to another.

According to the results presented, the null hypothesis was rejected, as there was a significant difference between the techniques of single cone filling and continuous wave.

The teeth chosen for this research were lower premolars, which according to Goldberg et al. (2002) the use of extracted teeth in experimental work better simulates clinical conditions. These teeth are found in greater quantity, because in some situations, their extraction is indicated for orthodontic reasons. In this study, the choice of lower premolar teeth followed a pre-established criterion: newly extracted, single and straight canal, absence of cracks, absence of fractures and absence of external resorption.

The chemical-mechanical preparation was performed using rotary instrumentation in a standardized way with the Protaper Next files, in order to obtain an apical preparation corresponding to the X5 instrument (50.06) that was used as a final file in the enlargement of the lower premolars, with the purpose of obtaining an apical preparation corresponding to the diameter of the punch pin of the EMIC test machine, used during the push-out test, the diameter of the punch pin used in the apical third was 0.5mm. The use of nickel-titanium rotary instruments with different tips and tapers, provides a more conical modeling of the root canal, in addition to the ease and agility in the execution of the technique (Pommel et al. 2003; Lea et al. 2005; Delong et al. 2015).

In addition to exerting antibacterial activity, irrigants serve as lubricants during instrumentation and influence the sealing and adhesion of filling materials, the most used protocols in the literature recommend the use of the substance Sodium Hypochlorite (Neelakantan et al. 2015), in this research it was 2.5% sodium hypochlorite was used.

The presence of the smear layer on the dentinal walls can impair the adhesion of the cements and favor marginal infiltration, therefore, its removal is recommended in order to facilitate the penetration of endodontic cements, promoting a greater mechanical embryo between the filling material and the root dentin. To achieve this goal the use of 17% EDTA is considered to be quite effective (Alfredo et al. 2008; Nunes et al. 2008; Haragushiku et al. 2010), for the research 17% EDTA was used, together with ultrasonic activation to enhance the smear layer removal, following the protocol of (Van der Sluis et al. 2010).

Van der Sluis et al. (2010) emphasizes in his study the importance of using passive ultrasonic irrigation (PUI), as it results in increasing the temperature of the irrigant, improving the tissue dissolution capacity, the removal of pulp tissue, bacteria and smear layer when the Sodium hypochlorite is used as an irrigant. Sodium hypochlorite is a highly alkaline compound and its pH value contributes to the stability of the solution (Beltz et al. 2003; Vianna et al. 2004).

More concentrated sodium hypochlorite solutions have been shown to be more effective compared to less concentrated solutions, as long as their pH is kept constant (Lopes and Siqueira, 2010). In the present study, the PUI protocol was used, with HELSE's Irrisonic ultrasonic insert, as an irrigating solution, sodium hypochlorite was used at a concentration of 2.5%. The use of PUI in sodium hypochlorite and EDTA solutions may have contributed to the removal of the smear layer, obtaining a better mechanical embryo of the filling material with the dentinal wall.

According to Trope et al. 2015, gutta-percha is still the main choice for filling, but due to its low adhesion to dentin, it requires a cement to obtain better long-term results.

Researchers studying the adhesion of endodontic cement (Grossman 1976; Tagger et al. 2002; Tagger et al. 2003; Pommel et al. 2003; Beltes et al. 2008; De-Deus et al. 2009) are unanimous in emphasizing the importance of this property for the filling material to fulfill its purpose of generating an adhesive interface between the filling material and the dentinal wall. Endodontic cements must have good adhesive and sealing properties (Saleh et al. 2003).

AH Plus cement is considered the gold standard in the literature and has high flow, good setting time and viscosity. The good adhesion results obtained with this cement are based on the possibility of creating a covalent chemical bond between an open epoxy ring and some amine group exposed in the collagen present in the root dentin (De-Deus et al. 2009; Candeiro et al. 2012).

EndoSequence BC endodontic cement was recently launched and presents a new perspective on filling the canals. It is a pre-manipulated bioceramic cement, which was designed to take prey only when exposed to a humid environment, with the ideal humidity present inside the dentinal tubules. Among the EndoSequence BC properties, there is the potential to develop bioactivity with dentin, which is the formation of mineral tags when in contact with the humidity of dentinal tissues, generating more adhesive potential (Loushine et al. 2011; Candeiro et al. 2012; Xuereb 2015).

Cements based on zinc oxide and eugenol have a history of successful use. They exhibit a long setting time, can stain the tooth structure and contract when taking prey. An advantage of cements based on zinc oxide and eugenol is their antimicrobial activity (Hargreaves, Cohen. 2011). Pulp Canal Sealer EWT cement was formulated to avoid the problem of too fast setting, due to high temperature and humidity, after mixing, this cement allows a working time between 6 and 8 hours. The increase in working time is due to the incorporation of essential oils in the liquid component. It can be used in hot and cold condensation techniques (Kaplowitz 1994; Tagger et al. 2003; Hargreaves, Cohen. 2011). This research was concerned with investigating these three modalities of endodontic cements given their clinical importance and scientific support.

The obturation phase of the root canals aims to fill the root canals three-dimensionally so that there are no spaces in the filling material, contributing to possible microleakage (Pommel et al. 2001; Guess at al. 2003; Collins et al. 2006).

The techniques that use heat for the plasticization of gutta-percha, such as the Continuous Wave Technique, were developed in order to better fill irregularities when compared to cold techniques, such as the single cone technique (Tonamaru et al. 2012; Viapina et al. 2014; Viapiana et al. 2015). According to Souza et al. (2009), in general terms, gutta-percha compaction techniques are preferable, as they maximize the amount of gutta-percha, resulting in a thin layer of cement on the root canal walls.

During the Continuous Wave technique, the penetration of a heated plugger is important for the success of this technique, the penetration recommendations are between 5 to 7mm of the working length, which facilitates the heating of the gutta-percha and its adaptation to the walls of the root canal (Guess et al. 2003; DeLong et al. 2015). In this study, the penetration of the plugger was 5 mm from the working length.

On the other hand, an advantage of the technique in which only a cone is used that approximates the geometry of mechanized instrumentation systems, however, the use of a cement with good adhesive and flow properties is necessary (Monticelli et al. 2007). For this research, the use of the 50.06 cone was standardized in all elements of the groups.

The use of a universal testing machine for tests of adhesion of dental materials to the dental structure was emphasized by Grossman et al. 1976, being used by several researchers (De Deus et al. 2009; Carneiro et al. 2013; Gurgel-Filho et al. 2014; Stelzer et al. 2014; Neelakantan et al. 2015; Scelza et al. 2015). In the present study, in order to assess the adhesion of endodontic cements, the Push-out test was used.

The Push-out test determines the degree of retention of the root canal filling material, which reflects the quality standard of adhesion achieved between the filling material and the root dentin. However, this test has some limitations, such as the non-uniform creation of tensions over the union interfaces (Pane et al. 2013; Chen et al. 2013).

During the study, some measures were taken to minimize these limitations produced by the test, dental elements with similar internal anatomy were selected, the thickness of the slices was around 1mm, the diameter of the perforator was standardized in the cervical, medium thirds (1mm in diameter) and apical (0.5mm in diameter), in addition to standardization of the chemical-mechanical preparation and the main cone of gutta-percha.

The results obtained by means of the mechanical push-out test, indicated that there were no significant differences between the cements when the Continuous Wave technique was used, as shown in Graph 1. It is inferred that this finding was probably due to the partial removal of endodontic cement of the cervical and middle thirds of the root canal during the Downpack phase of the Continuous Wave technique, promoting similar adhesion for these groups. These findings are similar to the study by DeLong et al. (2015) in which the authors also evaluated the adhesiveness of EndoSequence BC and AH Plus cements.

Still, it is possible that the Continuous Wave Technique has altered the adhesive properties of cements. The heat source mechanically removed the cement, reducing or eliminating it from the canal. This may explain the high frequency of failure mode without cement in the groups in which the Continuous Wave technique was used. The application of heat can also affect the properties of cements, thus affecting their adhesion forces (Viapiana et al. 2015).

Failure modes were consistent with other studies that showed adhesive and mixed failures (Shokouhinejad et al. 2013; Formosa et al. 2014; DeLong et al. 2015). No single cement sample was found in the Single Cone technique, which indicates that the filling technique employed is the reason for these findings, due to the greater amount of cement for the execution of the technique. When analyzing the failure modes of the EndoSequence BC cement, it did not present any adhesive failure at the dentin / cement interface, which can be explained by the bioactivity property that this cement develops in the presence of moisture (Loushine et al. 2011; Candeiro et al. 2012; Xuereb 2015). The Pulp Canal Sealer EWT cement presented a higher frequency of occurrence in the adhesive failure mode at the dentin / cement interface, which can be explained due to the lower result achieved in the bond strength when compared to the EndoSequence BC and AH Plus cements.

Cements based on Tricalcium Silicate, as an example, EndoSequence BC are nanoparticles and develop bioactivity in the presence of moisture. To do this, they must be used with the filling technique without the application of heat, as the presence of heat can cause evaporation of the moisture present in the dentinal tubules. Which explains the best results of this cement when the Single Cone technique was used, according to graph 2 (Khalil et al. 2016; Almeida et al. 2017).

The bioactivity that the EndoSequence BC cement promotes refers to the production of an apatite layer, which when in contact with tissue fluids reduces the flaws in the contact interfaces, increasing their bond strength (Silva et al. 2016; Almeida et al. 2017). In the study, it was observed that the EndoSequence BC cement showed statistically greater bond strength in the apical third, when the Single Cone technique was applied, according to graph 2. These results can be explained due to the use of a thin layer of cement and the application of the technique, where it is necessary to lock the cone, the force generated by the gutta-percha cone in the cement, allows greater flow to the dentinal tubules and consequently greater mechanical embryo.

In general, the Pulp Canal Sealer EWT cement presented the lowest bond strength results when compared to EndoSequence BC and AH Plus cements. According to the authors (Tagger et al. 2002; Zhou, et al. 2015; Silva et al. 2016; Almeida et al. 2017), bioceramic cements and epoxy resin cements show superiority in the dentin adhesion property, forming a strong connection with the root dentin. According to the analysis of graph 3, the Pulp Canal Sealer EWT cement showed significant differences between the filling techniques in the cervical and middle thirds, presenting the best results when the Continuous Wave technique was used, these findings indicate that the use of gutta - melted and compacted filler for filling root canals promotes greater adaptation to irregularities and recesses (Lee et al. 2002).

New studies, with technological innovations should be carried out in order to research filling techniques and filling materials, in order to improve the efficiency of

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this operative stage and obtain better clinical success rates for endodontic therapy.

V. CONCLUSION

It can be concluded according to the results presented that the Single Cone Technique showed better adhesiveness of the EndoSequence BC and AH Plus cements when compared to the Continuous Wave Technique.

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