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The Efficacy of Adhesion of C-Point Obturation System in Retreated Root Canal Walls

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ABSTRACT

Purpose: This study assessed the adhesion of C-point filling system to retreated root canal walls. **Materials and Methods:** Eighty extracted upper incisors were prepared using Protaper Universal rotary files then the samples were distributed into 2 main groups. Group I: primary treated, Group II: retreated. Each group was further distributed into 4 subgroups; Subgroup A: Samples were filled with gutta-percha. Subgroup B: Samples were filled with gutta-percha and AH Plus sealer. Subgroup C: Samples were filled with C-point. Subgroup D: Samples were filled with C-point and BioCeramic sealer (BC). The push out test was carried out. The sealer penetration inside the dentinal tubules was evaluated using scanning electron microscope (SEM). **Results:** regarding the results of group I(primary treated) and II (retreated), at all levels, the highest mean bond strength value was recorded in primary treated samples, while the lowest value was recorded in retreated samples. Among the tested groups there was no statistically significant difference except for subgroup B(Gutta-percha/AH plus) at the middle and apical levels while in subgroup D(C-point/BC sealer) at the middle level, there was a statistical significant difference among the tested groups. SEM observation of sealer/ dentin interface revealed few traces of sealer penetration in samples retreated with C-point and BC sealer. **Conclusion:** C-Point/BC sealer showed better adhesion to the intraradicular dentin in primarily treated group compared to gutta-percha /AH Plus sealer. While the adhesion of C-point filling system to intraradicular dentin negatively affected by the retreatment procedure.

KEYWORDS

Retreatment, C-Point, BC sealer, Bond strength.

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INTRODUCTION

Debridement, disinfection and a complete three dimensional obturation are elements important for the endodontic treatment success. Gutta-percha has been used with ZOE based or Ca $(OH)_2$ based sealers for many years. However, leakage and recontamination continue to appear and cause post-treatment complications [1]. To improve the sealing and bonding of gutta-percha epoxy-resin based sealers have been developed. Example is AH plus which has good handling characteristics [2].

Attempts were made to modify the usage of gutta-percha to improve the treatment outcome. C-point system which is consists of c-point and bio-ceramic sealer has been developed. C-point has a polymeric coating which radially expands to fill the root canal system for a complete seal. The expansion is limited to the available space laterally, pressing the sealer into any canal irregularities. Bio-ceramic sealer has a crystalline structure similar to tooth where interact with the dentin surface and improve the sealing and bonding to dentin [3].

Endodontic therapy success depends on chemo-mechanical debridement. During the mechanical instrumentation smear layer formed, the smear layer removal improves the adhesion of the filling materials to the root canal dentin, this is achieved by using 2.6% NaOCl and 17% EDTA [4,5]. Retreatment may be required due to reinfection or persistent of infection. The obturation material removal is one of the essential elements in retreatment procedure to allow further cleaning, shaping and obturation. Different methods are used to remove gutta-percha mechanical, chemical, thermal or a combination of the three[6,7]. While the root canals filled with C-point can be retreated with any retreatment NiTi rotary retreatment file system, without the use of solvents[8-10].

MATERIALS AND METHODS

1. Teeth selection and preparation:

Eighty recently extracted human upper incisors with completely formed roots and no evidence of fractures or cracks were selected. The teeth were rinsed under tap water to remove tissues, blood and debris then kept until use in distilled water. Each tooth was decapitated at the cement-enamel junction (CEJ) using diamond disc (Diatech, Goltène AG, Altstätten, Switzerland) under steady water cooling. The root lengths of all teeth were 16 mm. Canal patency was done by #15 K-files (MANI Inc., Japan) and the working length was measured by subtracting 1mm from length when the tips of #15 K-file became observed at the apical foramen.

ProTaper Universal rotary NiTi files were used in a crown-down manner for root canal preparation with torque and speed adjusted according to manufacturer's recommendations for each file used. A set of seven instruments were used (SX, S1, S2, F1, F2, F3 and F4), the first three files were used for coronal 2/3 preparation and the other four files were used for apical preparation. After each instrument use, irrigation was done with a fresh preparation of 2 ml 2.6% NaOCl solution for 1 minute dispensed through a 3 ml gauge side vent irrigating needle, where the needle was inserted deeply inside the root canal without binding. Final rinse with 5ml of 17% EDTA for1 minute was used to remove the smear layer, followed by 5ml distilled water.

2. Samples' grouping:

After root canal preparation, the samples were equally distributed into two groups (I, II) (40 samples each). Group I: primary treated. Group II: re-treated. Each group was further equally distributed into four subgroups; subgroup A: samples were filled with gutta-percha subgroup B: samples were filled with gutta-percha/AH Plus sealer, subgroup C: samples were filled with C-point and subgroup D: samples were filled with C-Point/BC sealer.

3. Samples' obturation:

❖ ***Group I: (Primary treated group)***

- *Subgroup A (Gutta-percha):*

The samples were filled with ProTaper gutta-percha cones (#F4). The cones were introduced into the canal. Root canal filling was completed by cold lateral compaction using #25 finger spreader and adding accessory cones (#25, 0.02 taper). The excess gutta-percha was removed using hot instrument, then the access cavity was sealed with temporary filling. The samples were stored in incubator at 37˚C for 7 days.

- *Subgroup B (Gutta-percha /AH Plus sealer):*

The samples were filled with ProTaper gutta-percha cones (#F4) and AH Plus sealer. The canal walls were coated with sealer using the master cone which moved vertically up and down inside the canal to coat the canal wall completely by the sealer. Root canal filling was done using cold lateral compaction technique using #25 finger spreader and adding accessory cones (#25, 0.02 taper). The excess gutta-percha was removed using hot instrument, and completed as mentioned previously in subgroup A.

- *Subgroup C (C-Point):*

The samples were filled by C-Point Cones (#F4). The cones were introduced into the canal. The excess C-Point was removed to the level of the canal orifice using a cylindrical diamond stone without water, then the access cavity was sealed with temporary filling. The samples were stored in incubator at 37˚C for 7 days.

- *Subgroup D (C-Point/ BC sealer):*

The samples were filled by C-Point cones (#F4) and BC sealer. The sealer was introduced into the canal via disposable canal tip from a premixed syringe and the master cone moved vertically up and down inside the canal to ensure full coating of the canal wall by the sealer. Root canal filling was done with single cone technique. The excess C Point was removed at the canal orifice using a cylindrical diamond stone without water, and completed as mentioned previously in subgroup C.

❖ ***Group II (retreated group):***

This group was subdivided into 4 subgroups A, B, C, D and treated as group I. After obturation, all the samples were stored in incubator at 37˚C for 7 days. The filling material (core and/or core and sealer) of all subgroups were removed with Endostar retreatment rotary files and chloroform for gutta-percha (subgroup A and B) and Endostar retreatment rotary files only for C-point (subgroup C and D) used according to the manufacturer instructions. The root canals were constantly irrigated with 2.6% NaOCl (2ml after each file) during the retreatment procedures.

After complete removal of filling materials, refreshment of the root canal wall was performed using Protaper Universal rotary files size F4. Final rinse with 5ml 17% EDTA (1 minute) used to remove the smear layer, followed by 5 ml distilled water. The paper point size F4 were used to dry the canals to be ready for obturation. The 4 subgroups (A, B, C, D) were obturated following the same protocol as mentioned in group I. After retreatment all the specimens were stored in incubator at 37°C for 7 days.

4. Samples' preparation for push-out bond strength testing:

Isomet 4000 microsaw (Buehler, USA) was used to section the samples perpendicular to the root's long axis without water coolant, where three 2 mm-thickness sections were gained from coronal, middle and apical levels of each sample. Indelible marker was used to mark the apical surface of each section, and then the sections were kept in 100% humidity till testing.

Cylindrical stainless-steel plunger with diameter 0.9, 0.7 and 0.5 mm corresponding to coronal,

middle and apical sections respectively were used to load root filling of each section. The tip of the plunger was adjusted to cover the obturation material without contacting the canal wall. The plunger was connected to the universal testing machine (Instron, Norwood, MA, USA) and the applied load was directed from apical aspect to coronal aspect in order to avoid any impediments during the push-out testing because of tapering of the root canal. A 0.5 mm/min speed cross-head was conducted until debonding happened and the maximum load conducted for debonding was measured in Newton (N).

The push out bond strength value in mega-pascal (MPa) for each sample was calculated using the following equation:

Push-out bond strength (MPa) =

$$\frac{\text{Maximum load (N)}}{\text{Adhesion area of root canal filling (mm}^2\text{)}}$$

Area of root canal filling (mm²) =

$$\frac{\text{(Circumference of coronal aspect + circumference of apical aspect)}}{2} \times \text{thickness of the section}$$

5. SEM evaluation:

After the push-out test, one selected sample from each subgroup was grooved longitudinally in buccolingual direction without reaching the internal portion of the canal and sectioned with sharp chisel. The sections were examined under SEM (FEI Company, Nertherland). Under magnifications (X 2000), two photomicrographs were obtained to evaluate the amount of sealer penetrating the dentinal tubules.

6. Statistical analysis:

Kolmogorov-Smirnov and Shapiro-Wilk tests were used to explore the normality of the numerical data and to check the distribution of data. Data were presented as median and range. Mann-Whitney U test was used for non- parametric data to compare between the two filling materials. Kruskal-Wallis test was used to compare between irrigants. Friedman's test was used to compare between root levels. For pair-wise comparisons Dunn's test was used. The significance level was set at $P \leq 0.05$. IBM SPSS Statistics Version 20 for Windows was utilized to carry out statistical analysis.

RESULTS

I. Push out test results:

Comparison of push out bond strength between Group I (primary treated) and group II (retreated) (Table 1) and (Fig. 1)

- **Subgroup A (Gutta-percha):**

At all levels (coronal, middle and apical), the difference between group I and group II was not statistically significant (P>0.05).

- **Subgroup B (Gutta-percha /AH Plus sealer):**

At the coronal level; the difference between group I and group II was not statistically significant (P>0.05). At the middle level and apical levels; the difference between group I and group II was statistically significant ($P \leq 0.05$), where the higher value of push out bond strength was recorded in group I (primary treated).

- **Subgroup C (C-point):**

At all levels (coronal, middle and apical), the difference between group I and group II was not statistically significant (P>0.05).

- **Subgroup D(C-Point / BC sealer):**

At the coronal and the apical levels, the difference between group I and group II was not statistically significant ($P > 0.05$). At the middle level, the difference between group I and group II was statistically significant ($P \leq 0.05$), where the higher value of push out bond strength was recorded in group I (primary treated).

Table (1): *The mean value, standard deviation (SD) and results of Mann-Whitney U test for comparison between push-out bond strength of treatment and retreatment groups (I, II).*

Obturation technique	Root level	Primary Treated (Group I)		Retreated (Group II)		*P*-value
		Mean	SD	Mean	SD	
GP (subgroup A)	Coronal	5.39	2.08	4.44	2.23	0.649
	Middle	5.30	4.40	6.02	3.03	0.448
	Apical	5.61	3.49	5.54	3.32	0.879
GP + AH Plus (subgroup B)	Coronal	6.65	2.43	5.38	0.93	0.199
	Middle	9.53	3.75	6.78	2.25	0.034*
	Apical	10.33	3.83	7.22	3.59	0.049*
C Point (subgroup C)	Coronal	3.23	0.97	2.44	1.79	0.288
	Middle	4.91	2.51	6.34	3.54	0.288
	Apical	5.71	3.51	5.02	3.74	0.879
C Point + BC Sealer (subgroup D)	Coronal	7.10	3.04	5.44	3.54	0.290
	Middle	10.89	4.02	5.25	4.02	0.013*
	Apical	11.06	4.12	6.24	4.78	0.096

*: *Significant at P ≤ 0.05*

II. Scanning electron microscopic results:

Group I (primary treated):

Tracing the sealer dentin interface in subgroup B showed traces of sealer particles penetrating dentinal tubules at all levels. Subgroup D showed few traces of sealer particles penetrating dentinal tubules at the coronal and the middle level however, at the apical level there was no evidence of sealer penetration. (Figure 2)

Group II (retreated):

Tracing the sealer dentin interface in subgroup B showed traces of sealer particles penetrating dentinal tubules at coronal level however, at the middle and apical level there was no evidence of sealer penetration. Subgroup D showed few traces of sealer particles penetrating dentinal tubules at the apical level however, at the coronal level and middle level there was no evidence of sealer penetration. (Figure 3)

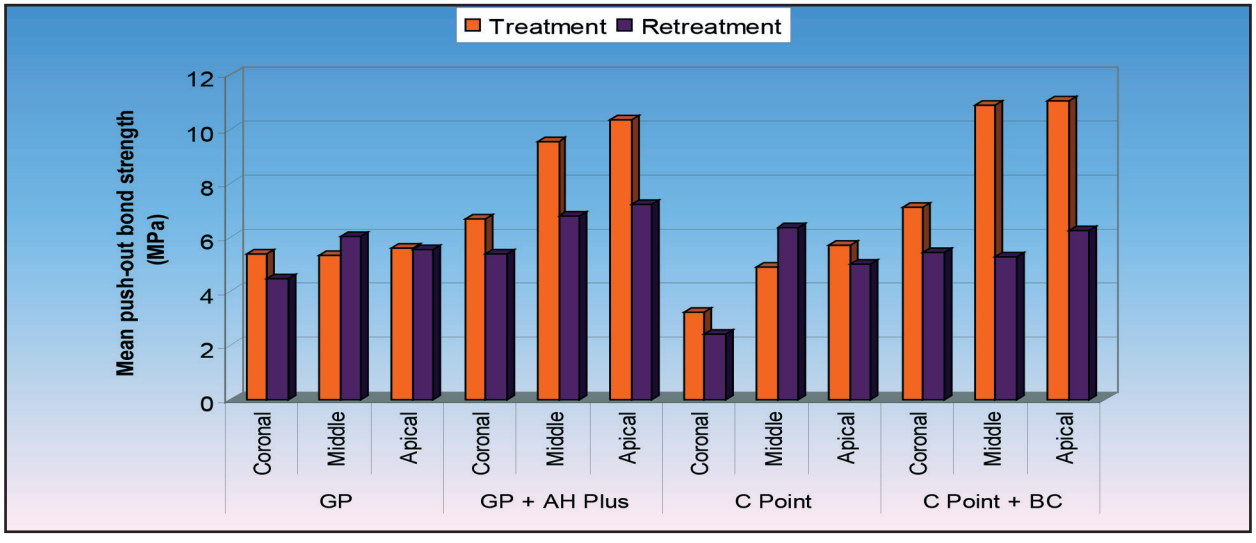

Figure (1) Bar chart representing mean values for push-out bond strength of treatment and retreatment groups at coronal, middle and apical levels.

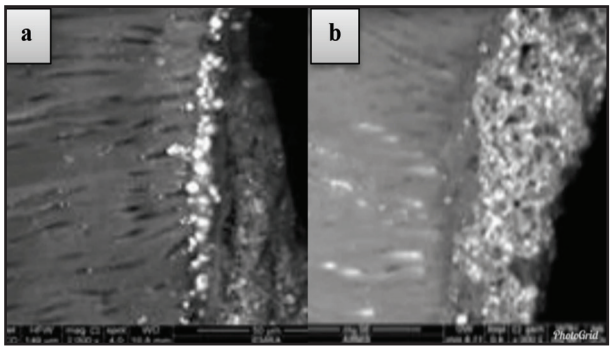

Figure (2) A scanning photomicrograph of sealer/dentin interface at the apical level of subgroup IB and the middle level of subgroup ID showing few traces of sealer particles penetrating dentinal tubules: a) Gutta-percha/AH plus, b) C-point/BC sealer (X2000).

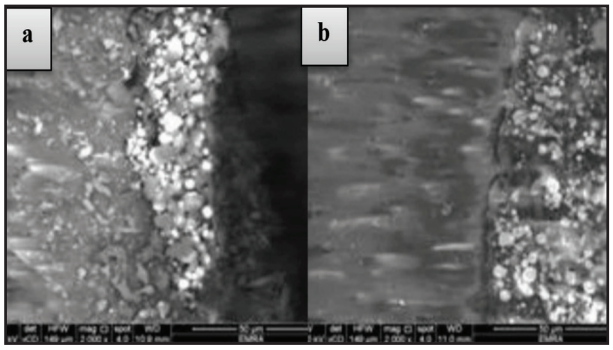

Figure (3) A scanning photomicrograph of sealer/dentin interface at the apical level of subgroup IB and the middle level of subgroup ID showing few traces of sealer particles penetrating dentinal tubules: a) Gutta-percha/AH plus, b) C-point/BC sealer (X2000).

DISCUSSION

After the completion of the root canal procedure nonsurgical retreatment may be required due to re-infection of the root canal or persistent infection from the primary treatment as a result of insufficient chemo-mechanical preparation and obturation [11-15].

In this study upper incisors were used to avoid the human variable that could be related to the coronal access cavity preparation which could affect the proposed root canal preparation and obturation techniques. The teeth were decoronated at the cervical level near cemento-enamel junction, using high speed diamond disc which allows samples standardization [16- 18].

ProTaper Universal rotary files were used for canals instrumentation, as they have a convex triangular cross-section which decreases the friction between the blade of file and the canal wall and increases its cutting efficiency. The apical patency was kept using #15 K file in between each rotary file. In addition, ProTaper gutta-percha or C-Points perfectly fit canals that have been prepared with ProTaper files, which minimizes the volume of the sealer used and thus, the sealing quality could be improved [17-20].

Sodium hypochlorite (NaOCl) in 2.6% concentration was used to simulate the clinical condition[21]. Chelating agent 17% EDTA was used for the removal of smear layer to improve tubular diffusion and enhance the sealing ability [22, 23].

To overcome the disadvantages of hydrophobic systems and to elevate the consequences of the treatment, hydrophilic obturating systems was introduced. The C-Point with BC sealer is a recently evolved root canal filling system, consisting of a single cone (C-Point) and BC bioceramic sealer. The C-Point system imparts the points with the elasticity that allows it to easily gauge around any curvatures in the biomechanically prepared canal [3, 24, 25].

Bioceramic sealer is used along with C-Points in this study, as the bioceramic particles in the sealer can bond to the outer layer of C-Points as well as to the dentinal with the formation of hydroxyapatite and water as by product. This byproduct water can be utilized by the C-Points, due to its hydrophilic property, to expand in the available space and allow sealer penetration into the lateral canals and dentinal tubules. This helps in achieving a good seal of the obturated root canal space [26, 27].

Various methods have been used to remove gutta-percha from root canal which includes the use of rotary instruments along with solvents like chloroform. In this study the obturation material in the root canal was removed with the help of rotary retreatment Ni-Ti file system (Endostar) which is less time consuming than hand instrumentation [28].

Chloroform is an organic solvent, which is effective in dissolving gutta-percha / AH plus sealer but it affect the mineral content of root dentine so it can decrease bond strength when used for more than 5 minutes [19]. Accordingly, it was used for 45-60 seconds in the current study. C-point was removed by rotary retreatment Ni-Ti file system (Endostar) as there is no solvents is available to help in removing C-point and BC sealer [29].

Paper points were used to effectively dry the canal then obturated in subgroup IA (gutta-percha), IB (gutta-percha/AH plus sealer), IIA (gutta-percha) and IIB (gutta-percha / AH plus) using lateral compaction technique .The obturation was considered to be complete when no spreader could enter more than 3mm into the obturation material [16].While in subgroup IC (C-point), subgroup ID (C-point/BC sealer), subgroup IIC (C-point) and subgroup IID (C-point / BC sealer) were obturated using single cone obturation technique as a C-point cone can expand in the canal space in the presence of moisture in the canals and the sealer, to achieve a complete seal of the canal system [22,30,31].

The present study was designed to evaluate adhesion of C-point and BC sealer with conventional root canal filling using AH plus (epoxy resin sealer) and gutta-percha on human root dentin in both primary treated and retreated root canal wall using the push-out test and samples evaluation using SEM. The push-out bond strength test was used in this study which is better than conventional shear in evaluating the bond strength [32].

Samples were sectioned perpendicular to the long axis of the root without water coolant, due to the hydrophilic nature of C-Point. Moreover, a pilot study was done to determine the effect of cutting with or without water coolant on the push-out bond strength and the highest results was obtained by cutting without coolant irrespective of the filling material used. Therefore, cutting without water coolant was done in samples filled with gutta-percha/ AH-Plus sealer as well as in samples obturated with C-Point/ BC sealer for standardization purpose [33].

Push-out bond strength evaluation:

1. Effect of filling material on the push out bond strength:

The findings of the current study showed that the highest mean value of the bond strength was obtained in subgroup ID (C-point/BC sealer). This subgroup was statistically different in bond strength from subgroup IB (Gutta-Percha / AH plus sealer). This could be due to the hydrophilic nature of BC sealer which cause more intimate contact with the canal walls than the AH Plus sealer which is hydrophobic. Furthermore, it could be due to the slow expansion of the C-Point when exposed to moisture with the slow-setting of the BC sealer .This pushed the sealer into places that lateral compaction with AH plus sealer could not reach, this result corroborates other studies [33,34]. However, the results of the current study disagree with previous study which showed that the highest push out bond strength value was recorded in the root canals filled with gutta-percha/AH Plus sealer, whereas the lowest strength was noted in canals filled with C-point/ BC sealer [35]. This could be attributed to the use of larger tip diameter of C-point (F4) in the current study. Where in larger sizes of C-Points, there was higher amount of polymer, higher lateral expansion, which decrease gaps and enhance sealer penetration and adaptation in dentin.

The lower push out bond strength results of IID (C-point/BC sealer) which was statistically different in bond strength from subgroup IIB (gutta-percha/ AH plus) which corroborates other study [29]. This could be due to the hydrophilic nature of C-point which leads to expansion laterally. This expansion pushes the associated BC sealer into the lateral canals and dentinal tubules increasing the physical adhesion of the material. Moreover, the BC sealer forms chemical bond with the root canals by the production of hydroxyapatite and water, and the nanoparticle size of the BC sealer allows to deeper penetration into the canal irregularities and dentinal tubules. This probably causes difficulty for removal

of C-point and BC sealer from canal wall and presence of remnants of filling material which reduced the adhesion during retreatment [29].

2. Effect of the root level on the push out bond:

Gutta-percha in subgroup IA showed slight increase in mean value from coronal to apical without significant difference. This could be related to the use of gutta-percha taper 6% which is more fitted apically with less axillaries. In subgroup IB (gutta-percha/AH plus) the mean value increased from coronal to apical where the coronal was significantly lower compared to middle and apical levels. This might be due to the use of gutta-percha taper 6% which is more fitted apically in addition to the use of axillaries and AH plus sealer especially for the middle level.

C-point in subgroup IC showed increase in bond strength from coronal to apical without significant difference. The lower value of the coronal level may be due to its accessibility to be dried compared to the apical level. Accordingly less expansion is expected. Moreover, the use of F4 points which has large diameter with high lateral expansion may decrease gaps and increase its adaptation to dentin[30,35].

In Subgroup IIA (gutta-percha) the middle level showed higher mean value compared to the apical and coronal levels without significant difference. This could be due to the better accessibility of the irrigating solution and EDTA which has been used 2 times lead to better interaction of the material with dentin surface [36]. Furthermore the remnants of filling material probably were less than the other levels.

Gutta-percha/AH Plus in subgroup IIB showed increase in bond strength from coronal to apical without significant difference. This could be due to the reasons have been mentioned previously in subgroup IB (Gutta-percha/AH plus)

In subgroup IIC (C-point) the middle level showed higher mean value compared to the apical and coronal levels without significant difference. This could be due to the accessibility of the irrigating solution and the adhesion of the material with dentin surface are better at the middle region and C-point absorbs water from dentinal tubules and expands better than the apical and coronal third [36].

The mean value of subgroup IID (C-point/ BC sealer) increased from coronal to apical without significant difference. The lowest value of the coronal level may be due to its accessibility to be dried compared to the apical. Accordingly less expansion is expected.

3. Effect of primary treatment and retreatment groups on the push out bond strength:

The mean value of bond strength of subgroup ID (C-point /BC sealer) was higher than subgroup IID (C-point/BC sealer). This could be due to the hydrophilic nature of C-point which leads to expansion laterally. This expansion pushes the associated BC sealer into the lateral canals and dentinal tubules increasing the physical adhesion of the material. Moreover, the BC sealer forms chemical bond with the root canals by the production of hydroxyapatite and water, and the nanoparticle size of the BC sealer allows to deeper penetration into the canal irregularities and dentinal tubules. This probably causes difficulty for removal of C-point and BC sealer from canal wall and presence of remnants of filling material which reduced the adhesion during retreatment [35].

Subgroup IB (Gutta-percha/AH plus) was higher in bond strength compared to subgroup IIB (Gutta-percha/AH plus) this might be related to residual filling material on the canal walls that affect the bond strength of filling material in retreated canal. Moreover, the decrease in push out bond strength due to the use of chloroform solvent which change the chemical structure of dentin and the Ca/P ratio of dentin surfaces when used for 5 minutes [19], however, in the current study used for 45-60 seconds. The results of the current study was in disagreement

with previous study which showed that the highest push out bond strength value was recorded in re-treated root canals (gutta-percha/AH Plus sealer), whereas the lowest strength was noted in primary treated canals (gutta-percha/ AH Plus). Probably attributed to the storage of samples for only 72 hours which is not enough for complete setting of the sealer so its removal was easier and may be due to the use of both Gates-Glidden and H files to remove gutta-percha [17].

Subgroup IC (C-point) showed increase in bond strength value compared to subgroup IIC (C-point) this could be related to difficulty of removal of C-Point and presence of residual filling material on the canal walls. However, subgroup IIA (Gutta-percha) showed increase in bond strength value compared to subgroup IA (Gutta-percha) this could be due to the removal of smear layer 2 times during (primary treatment and retreatment) which may increase the adaptation of Gutta-percha into dentinal wall.

Scanning electron microscope evaluation:

In this study SEM examination of the specimens corroborate the bond strength results in all subgroups. Sealer are present in the dentinal tubules opening in subgroup IB, IIB, ID and IID, however the sealer become more in subgroup ID and IIB which corroborates the bond strength test results. This result agreed with previous studies reported that regardless of the retreatment techniques and instrumentation system used filling materials remnants still found in the root canal walls [17, 29, 37].

CONCLUSION

- Retreatment procedure did not improve the adhesion of C-Point/BC sealer or gutta-percha/AH Plus sealer to the root canal walls.
- The innovated system (C-Point/BC sealer) showed better adhesion to the intraradicular dentin in primarily treated group compared to gutta-percha /AH Plus sealer.
- The adhesion of C-point filling system to intraradicular dentin negatively affected by the retreatment procedure.

REFERENCES

1. Mordohai N, Reshad M, Jivraj S, Chee W. Factors that affect individual tooth prognosis and choices in contemporary treatment planning. Br Dent J. 2007; 202: 63–72.
2. Ng YL, Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature—part 1: effects of study characteristics on probability of success. J Endod. 2007; 40: 921–39.
3. Hegde V, Arora S. Fracture resistance of roots obturated with novel hydrophilic obturation systems. J Conserv Dent. 2016; 18: 261-4.
4. Mitchell L, Walls AW. Survival analysis in practice. Dent update. 1991; 18:125–8.
5. Gordon MP. The removal of gutta-percha and root canal sealers from root canals. N Z Dent J. 2005; 101:44-52.
6. Baig AR, Ali SN, Saoji H. Smart seal: Unique obturation system in dentistry. Int J Appl Dent Sci. 2016; 2:1-2.
7. Riis A, Taschieri S , Del Fabbro M & Kvist T. Tooth survival after surgical or nonsurgical endodontic retreatment: long-term follow-up of a randomized clinical trial. J Endod.2018; 13:57–83.
8. Paik S, Sechrist C, Torabinejad M. Levels of evidence for the outcomes of endodontic retreatment. J Endod 2004; 30: 745–50.
9. De Vasconcelos BC. An ex vivo comparison of root canal length determination by three electronic apex locators at positions short of the apical foramen. Oral Surg Oral Med Oral Pathol Oral Radiol Endod.2010; 110:57- 61.
10. Ho ES, Chang, JW, Cheung GS. Quality of root canal fillings using three gutta-percha obturation techniques. Res Dent Endod. 2016; 41: 22-8.
11. Chercoles-Ruiz A, Sanchez-Torres A, Gay-Escoda C. Endodontics, endodontic retreatment, and apical surgery versus tooth extraction and implant placement: a systematic review. J Endod 2017; 43:679–86.
12. Landys Boren D, Jonasson P, Kvist T. Long-term survival of endodontically treated teeth at a public dental specialist clinic. J Endod 2015; 41:176–81.
13. Gorni F, Gagliani M. The Outcome of Endodontic Retreatment: A 2-yr Follow-up. J Endod, 2004; 30: 1–4.

14. Rödig T, Wagner J, Wiegand A, Rizk M. Efficacy of the ProTaper retreatment system in removing Thermafil, GuttaCore or vertically compacted gutta-percha from curved root canals assessed by micro-CT. J Endod; 2018; 51:808–15.
15. Yuruker S, Gorduysus M, Kucukkaya S, Uzunoglu E, Ilgin C, Gulen O. Efficacy of combined use of different nickel–titanium files on removing root canal filling materials. J Endod 2016; 42:487–92.
16. Gade VJ, Belsare LD , Patil S, Bhede R, Gade JR. Evaluation of push-out bond strength of endosequence BC sealer with lateral condensation and thermoplasticized technique: An in vitro study. J Conserv. Dent. 2015; 18: 124–7.
17. Muatafa H, Fawzy MI, Nour El-Den MM. Efficacy of adhesion of resin based obturation system in treated and retreated root canal wall. Master thesis submitted to the Faculty of Dental Medicine for Girls, Al-Azhar University.2009.
18. Nibras Kh, Maan M. Bond Strength of Endosequence Bioceramic Sealer to Root Canal Dentine Irrigated with Different Solutions. J Endod.2015; 136-9.
19. Topçuoğlu H, Demirbuga S, Tuncay Ö, Arslan H, Kesim B, Yaşa B. The bond strength of endodontic sealers to root dentine exposed to different gutta-percha solvents. J Endod. 2014; 47:1100–6.
20. Hegde V, Arora S. Effect of advanced irrigation protocols on self-expanding Smart-Seal obturation system: A scanning electron microscopic push-out bond strength study. Contemp Clin Dent. 2018; 6: 26–30.
21. Razmi H, Bolhari B, Dashti NK, Fazlyab M. The Effect of Canal Dryness on Bond Strength of Bioceramic and Epoxy-resin Sealers after Irrigation with Sodium Hypochlorite or Chlorhexidine. Iran Endod J. 2016; 11: 129–33.
22. Economides N. An ex vivo comparison of the push-out bond strength of a new endodontic filling system (Smartseal) and various gutta-percha filling techniques. Odontology. 2016; 100:187-91.
23. Aydin Z , Özyürek T, Keskin B, Baran T. Effect of chitosan nanoparticle, QMix, and EDTA on Total Fill BC sealers dentinal tubule penetration: a confocal laser scanning microscopy study. Odontology.2018; 36:512-4.
24. Hegde V, Murkey LS. Microgap Evaluation of Novel Hydrophilic and Hydrophobic Obturating System: A Scanning Electron Microscope Study. J Clin Diagn Res . 2017; 11:75-8.
25. Eid A. In Vitro Biocompatibility Evaluation of a Root Canal. Filling Material That Expands on Water Sorption. J Endod. 2016; 39:883-8.
26. Jain P, Ranjan M. The Rise of Bioceramics in Endodontic: A Review. Int J Pharm Bio Sci. 2015; 6:416 - 22.
27. Janavathi, Basavanagowda N, Reddy G, Praveen M. Apical Sealing Ability of Four Different Root Canal Sealers: An In Vitro Study. J Int Oral Health. 2016; 7:47-50.
28. Kesim B, Aslan T, Üstün Y, Topçuoğlu H, Şahin S, Ulusan Ö. Efficacy of Manual and Mechanical Instrumentation Techniques forRemoval of Overextended Root Canal Filling Material. J Endod. 2017; 20:92-76.
29. Prasad A, Nair RS, Angelo JM, Mathai V, Vineet R V, Christopher SR. A comparative evaluation of retrievability of Guttapercha, Resilon and CPoints for retreatment, using two different rotary retrieval systems - An ex vivo study. Saudi Endod J. 2018; 8:87-92.
30. Hassan N, Diab A, Ahmed G. Bond Degradation Resistance and Interface Characterization of a Water-Expandable Endodontic Obturation Point. MJ Dent. 2016; 1:16-22.
31. Hegde V. Microgap Evaluation of Novel Hydrophilic and Hydrophobic Obturating System: A Scanning Electron Microscope Study. J Clin Diagn Res. 2017; 18: 62-5.
32. Jainaen A, Palamara JE, Messer HH. Push-out bond strengths of the dentine-sealer interface with and without a main cone. J Endod. 2007; 40:882-90.
33. Pawar AM, Pawar S, Kfir A, Pawar M, Kokate S. Push-out bond strength of root fillings made with C-Point and BC sealer versus gutta-percha and AH Plus after the instrumentation of oval canals with the Self-Adjusting File versus WaveOne. J Endod .2015; 49: 374–81.
34. Sinhal TM, Shah RP, Jais PS. An In vitro Comparison and Evaluation of Sealing Ability of Newly Introduced C-point System, Cold Lateral Condensation, and Thermoplasticized Gutta-Percha Obturating Technique: A Dye Extraction Study. Contemp Clin Dent. 2018; 9: 164–9.
35. Abdelaziz SE, Fawzy MI, Bastawy HA. Effect of different chelating agents on bond strength of C-point obturation system to radicular dentin. Master thesis submitted to Faculty of Dental Medicine for Girls, Al-Azhar University.2019.
36. Marques J, Silva-Sousa Y, Rached-Junior F. New methodology to evaluate bond strength of root-end filling materials. Braz Dent J, 2015; 26: 288–91.
37. Kim H, Kim E, Lee S, Shin S. Comparisons of the Retreatment Efficacy of Calcium Silicate and Epoxy Resin–based Sealers and Residual Sealer in Dentinal Tubules. J Endod. 2015; 41: 2025–30.