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Article

Micro-push-out bond strength of Mineral—based root canal sealer in canals with different tapers.

Fuerza de unión por micro-expulsión del sellador de conductos radiculares a base de minerales en conductos con diferentes ahusamientos.

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Abstract: Objective: The aim of this study was to assess the micro-push-out bond strength of a mineral-based root canal sealer, BioRoot RCS in canals prepared by K3XF rotary systems of two different tapers. **Material and Methods:** Eighty caries free maxillary central incisors were used in this study. The samples were allocated into 4 groups (n=20) according to the root canal sealer and taper of the rotary instruments. The samples were obturated using single cone obturation technique. From each root 1mm thick slices at coronal, middle and apical thirds were collected using hard tissue microtome under continuous water coolant. Push-out tests were done for these sections using a Universal testing machine (INSTRON 8801) at a crosshead speed of 1mm/min. One-way analysis of variance (ANOVA) was used to compare the bond strengths within groups and Tukey's multiple post hoc analysis was used for pair-wise comparison of bond strengths. **Results:** AH Plus exhibited higher micro-push-out bond strength than BioRootRCS though they did not differ significantly (p>0.05). Preparation of root canals with 6% taper rotary instruments showed higher bond strength than 4% though they did not differ significantly (p>0.05). **Conclusion:** There was no significant difference between micro-push-out bond strength values of BioRoot RCS and AH Plus. The bond strength values were high in 6% taper canals than 4% canals though the difference was not significant statistically.

Keywords: Dentin-bonding agents; epoxy resin-based root canal sealer; dental pulp cavity; canals sealer; root canal filling materials; root canal preparation.

Resumen: Objetivo: El objetivo de este estudio fue evaluar la fuerza de unión por micro-expulsión de un sellador de conductos radiculares de base mineral, BioRoot RCS, en conductos preparados por sistemas rotativos K3XF con dos conos diferentes. **Material y Métodos:** En este estudio se utilizaron 80 incisivos centrales superiores libres de caries. Las muestras se distribuyeron en cuatro grupos (n = 20) de acuerdo al sellador del conducto radicular y al cono de los instrumentos rotativos. Las muestras se obturaron mediante la técnica de obturación de un solo cono. De cada raíz se recogieron rodajas de 1 mm de grosor en los tercios coronal, medio y apical utilizando un micrótomo de tejido duro con refrigeración continua por agua. Posteriormente, se realizó una prueba de expulsión para estas secciones utilizando una máquina de prueba universal

(INSTRON 8801) a una velocidad del cabezal transversal de 1mm/min. Se utilizó el análisis de varianza unidireccional (ANOVA) para comparar las resistencias de la unión dentro de los grupos y el análisis post hoc multiple de Tukey se utilizó para la comparación por pares de las resistencias de la unión. **Resultados:** AH Plus exhibió una fuerza de unión de micro-expulsión más alta que BioRootRCS, aunque no difirieron significativamente (p>0,05). La preparación de los conductos radiculares con instrumentos rotativos ahusados al 6% mostró una fuerza de unión superior al 4%, aunque no difirieron significativamente (p>0,05). **Conclusión:** No hubo diferencias significativas entre los valores de fuerza de unión de micro-expulsión de BioRoot RCS y AH Plus. Los valores de la fuerza de unión fueron más altos en canales cónicos al 6% que en canales al 4%, aunque la diferencia no fue significativa estadísticamente.

Palabra Clave: *Recubrimientos dentinarios; resinas epoxi; cavidad pulpar; materiales de obturación del conducto radicular; preparación del conducto radicular.*

INTRODUCTION.

Root canal sealers have been evolved to reach the ideal requirements of a root canal filling material. Epoxy resin-based root canal sealers exhibit low shrinkage during polymerization, low solubility, micro-retention to root dentin and tissue compatibility. AH Plus has been used as a gold standard by several researchers but its biocompatibility is lower.[1]

Later, sealers made of biocompatible materials were introduced, such as EndoSequence BC Sealer. It is antibacterial because of its high alkalinity and biocompatible.[2] These bioceramic sealers resulted in cell viability and higher cell migration capacity when compared with other sealers.[3]

One of the drawbacks of this BC sealer is the difficulty in its removal during retreatment procedures.[4] A more recently introduced bioceramic sealer, BioRoot RCS is a water-based sealer with a composition of tricalcium silicate and zirconium oxide.[5]

The alkaline pH of BioRoot RCS results in antibacterial activity and favors apatite nucleation with gutta-percha. This improves the sealing ability due to calcium phosphate deposition at the interface. Along with a stable seal, bioceramic sealers also prevent recurrent infections by promoting periapical tissue regeneration due to prolonged release of calcium ions.[6] Zirconium oxide in BioRoot RCS helps in improving compressive strength and biological response by allowing a long and greater release of calcium ions than tricalcium silicate cements with bismuth oxide.[7,8] It exhibits very few toxic effects on cells of periodontal ligament and induces secretion of osteogenic and angiogenic growth factors indicating higher bioactivity.[9]

Effectiveness of adhesion between tooth structure and root canal sealers is assessed by bond strength tests.[10] Push-out tests are effective and reproducible.[11] Hence, the present study was designed to assess the micro-push-out bond strength of BioRoot RCS in canals prepared by K3XF rotary systems with two different tapers (4% and 6%) and obturated using matched single cone technique.

MATERIALS AND METHODS.

The study design was reviewed and approved by the research and institutional ethics committee. Eighty extracted human maxillary central incisors of similar dimensions were collected and stored for no longer than one month. The teeth were cleansed of debris and soft tissue attached to the root surfaces using an ultrasonic scaler. Teeth with defects such as caries, fractures or visible crack lines, resorption defects, malformed roots, abnormal root curvatures, calcific changes in the root canals and teeth with root filling and restorations were excluded from the study.

Specimen preparation

Radiographs were taken using digital radiography buccolingually and mesiodistally for the confirmation of single root canal. Then, decoronation of teeth was done at cemento-enamel junction, with a diamond disc, with a slow speed handpiece, under copious amounts of water. Root length was standardized to 13mm and the samples were allocated into four groups.

Grouping of specimens

Group 1, Subgroup A (1A)

The orifice was enlarged with K3XF enhanced-tapered body shapers (K3XF 10% rotary files) (Sybron-

Endo, California, USA). Then, the coronal third was prepared using 40/0.04 and 35/0.04 K3XF rotary files. The middle third of the canal was explored and prepared with 35/0.04, 30/0.04 and 25/0.04 K3XF rotary files. The apical third was explored with a #10K file and working length was determined.

The file was placed in the canal until its tip was seen at the apical foramen. From this length 1mm was subtracted to establish working length. Then, the apical third was prepared with 30/0.04 and 25/0.004 K3XF rotary files in a crown down manner. Later apical enlargement was performed until a 40/0.04 size. Irrigation of root canals was done with 10ml of 3% NaOCl (Prime Dental Products Pvt Ltd., India) per tooth with intermittent saline irrigation using side-vented irrigating needles.

Final irrigation was done with 17% EDTA. After instrumentation, canals were dried using absorbent paper points. Later single cone obturation was done using AH Plus root canal sealer and 0.04 taper gutta-percha. AH Plus sealer was mixed as per manufacturer's recommendations. Excess gutta-percha was removed, and the orifice has been sealed with glass ionomer cement of 1mm thickness.

Group 1, Subgroup B (1B)

In group 1B, K3XF 6% taper files were used. The cleaning and shaping procedure employed was similar to that of group 1A. Single cone obturation was done using AH Plus root canal sealer and 0.06 taper gutta-percha point.

Group 2, Subgroup A (2A)

In group 2A, K3XF 4% taper rotary files were used. Exploration and instrumentation were performed as in group 1A. BioRoot RCS root canal sealer and 0.04 taper gutta-percha points were used in this group. BioRoot RCS sealer was manipulated as per the manufacturer's recommendations.

Group 2, Subgroup B (2B)

Exploration and instrumentation of root canals were performed as in group 1B using K3XF 6% taper files. Root canals were obturated using BioRoot RCS sealer and 0.06 taper gutta-percha points. K3XF

Storage of the specimens

Storage of specimens was done at 37°C and humidity of 100% for seven days in an incubator, to allow the sealer to set completely.

Obtaining root sections

Root samples were placed in methacrylate resin blocks. Root slices of 1mm thickness were obtained from coronal, middle and apical thirds of each specimen using a hard tissue microtome (LEICA SP160O, Nussi-och, Germany) under water coolant.

Bond strength determination

Push-out test was done using a Universal testing machine (INSTRON 8801) at a crosshead speed of 1mm/min. Each section was positioned on the platform in apico-coronal direction with the apical margin facing the plunger. The plunger was aligned so that it touched precisely at the gutta-percha and application of force was done until the filling material in the root canals was dislodged. Force (in Newtons) at which the root canal filling got dislodged was noted as maximum load and was converted into MegaPascals by using the following formula:

Maximum load (N) = Push-out bond strength (MPa)/ Adhesion area of root canal filling (mm^2)

Adhesion area = $\pi (r^1+r^2) \sqrt{(r^1-r^2)^2+h^2}$ where π = 3.14, r^1 = apical radius, r^2= coronal radius, h = height of the specimen.

Diameters (D^1& D^2) of each specimen were calculated using an optical microscope and then radii (r^1 & r^2) were obtained as: r=D/2. All the sections were observed under stereomicroscope (OLYMPUS, SZX16) at 40X magnification for the evaluation of mode of failure (Figure 1).

Based on the failure mode each specimen was placed in one of the following categories (Table 1):

i. Adhesive failure (failure at dentin-sealer interface or sealer-gutta-percha interface)

ii. Cohesive failure (failure within root dentin or gutta-percha)

iii. Mixed failure (both cohesive and adhesive) Samples with adhesive failures and mixed failures with major areas involving adhesive interface were only included in the study. Samples with cohesive failures and mixed failures with major involvement of cohesive areas were excluded from the study.

Bond strength in all the three segments *i.e.* coronal, middle, and apical for each tooth was measured and their average value was taken for each sample.

Statistical analysis

The data of micro-push-out bond strength values were subjected to statistical analysis using SPSS/PC version software. Mean and standard deviation of all groups and subgroups Figure 2.

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One-way analysis of variance (ANOVA) was used to compare the bond strengths within the groups.

Tukey's multiple post hoc analysis was done for pair-wise comparison of the bond strength for the two groups and subgroups. Probability value (p-value) was set at <0.05.

Figure 1. Fractographic analysis - Adhesive, cohesive and mixed failures in AHPLUS (A, B, C) and BioRoot RCS (D, E, F).

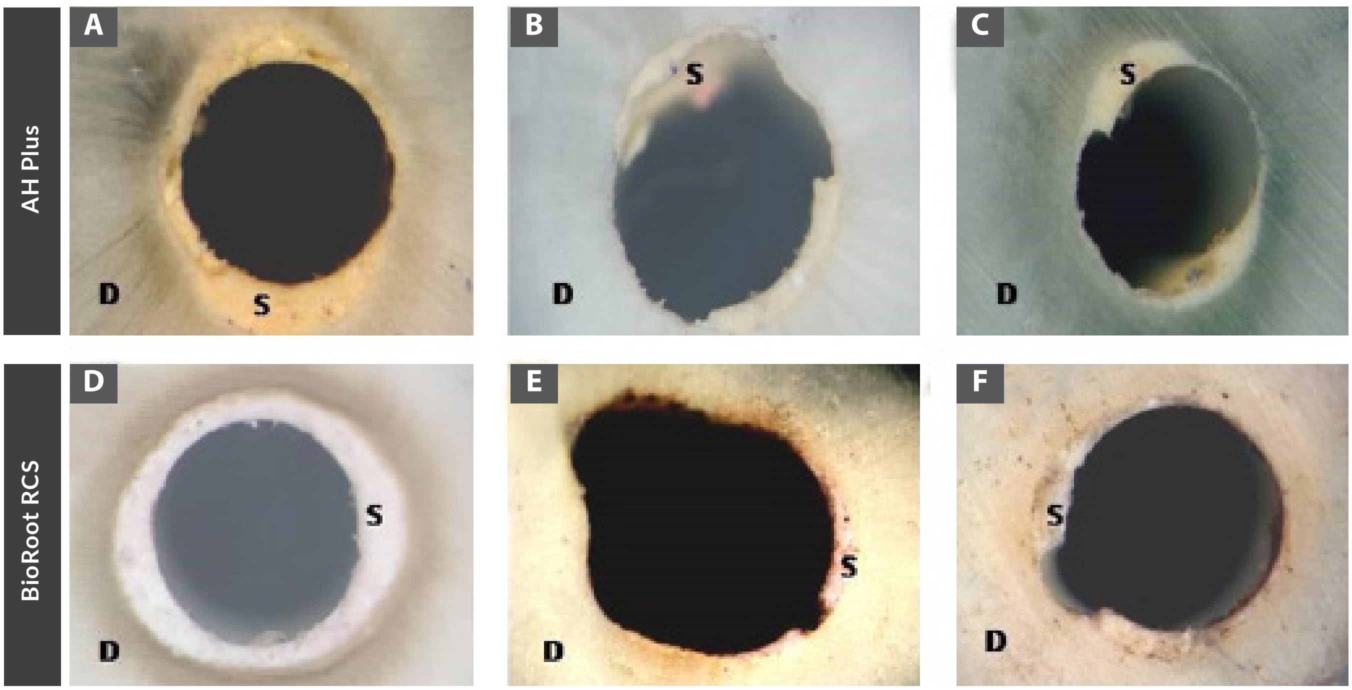

Figure 2. Mean values and standard deviation (SD) of micro-push-out bond strength of the study groups.

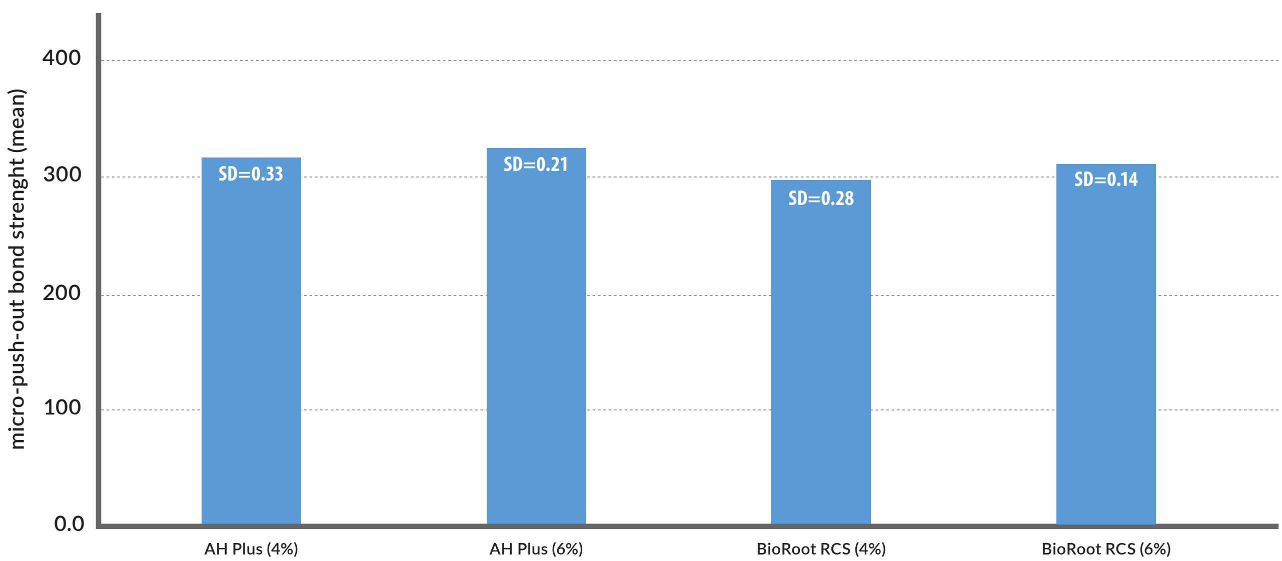

Table 1. Distribution of failure modes: adhesive, cohesive, mixed with major adhesive, and mixed with major cohesive.

Groups and sub-groups			Adhesive	Cohesive	Mixed major adhesive	Mixed major cohesive	Specimens lost during testing
Group 1A	AH Plus	(4%)	14	-	5	-	1
Group 1B	AH Plus	(6%)	17	1	-	1	1
Group 2A	BioRoot	(4%)	16	1	2	1	-
Group 2B	BioRoot	(6%)	17	-	2	1	-

Table 2. Pair-wise comparison of groups with respect to micro-push-out bond strength (MPa) by Tukey's multiple post hoc analysis.

Groups	Subgroup A (4%)	Subgroup B (6%)
1. AH Plus	3.10 (0.33)A^{a}	3.23 (0.21)A^{a}
2. BioRoot RCS	2.94 (0.28)A^{a}	3.09 (0.14)A^{a}

*: Same superscripts in capital letters indicate no significant difference in columns and rows.

Table 3. Intra-group comparison of micro-push-out bond strengths in all groups and sub-groups by Tukey's Post Hoc analysis

Group		Coronal third	Middle third	Apical third
AH Plus	4%	3.74 $(0.38)^{A}$	3.27 $(0.43)^{B}$	2.24 $(0.36)^{C}$
AH Plus	6%	3.88 $(0.27)^{A}$	3.43 $(0.39)^{B}$	2.41 $(0.22)^{C}$
BioRoot RCS	4%	3.59 $(0.29)^{A}$	3.13 $(0.41)^{B}$	2.07 $(0.17)^{C}$
BioRoot RCS	6%	3.69 $(0.26)^{A}$	3.16 $(0.22)^{B}$	2.41 $(0.33)^{C}$

*: Same superscripts in capital letters indicate no significant difference in columns. Different superscripts in capital letters indicate significant difference in rows.

RESULTS.

Based on the results depicted in Table 2, AH Plus showed higher micro-push-out (MPO) bond strength than BioRoot RCS, however they did not differ significantly ($p>0.05$). Root canals prepared with 6% taper rotary instruments showed higher bond strength than canals prepared with 4% taper instruments though they did not differ significantly ($p>0.05$).

Thus, null hypothesis was accepted in both conditions. MPO bond strength values are higher for coronal third followed by middle third and apical third across the entire groups (Table 3).

DISCUSSION.

The results revealed that BioRoot RCS exhibited slightly lower bond strength than AH Plus sealer and the difference was not significant. Thus, the null hypothesis was accepted. This was in accordance to previous studies where AH Plus was compared with other bioceramic sealers like EndoSequence BC sealer and iRoot SP.[12,16]

The higher bond strength achieved with the AH Plus sealer can be attributed to its low shrinkage during setting, and also due to its long-term dimensional stability[17] AH Plus expands in a humid environment.[18] It exhibited better bond strength because of formation

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of a chemical bond between the open epoxide rings and amino groups that get exposed in the collagen of dentin.[19] In spite of the desirable features of AH Plus, the difference between AH Plus and BioRoot RCS was not significant statistically.

In contrast, a recent study[20] reported higher bond strength value for TotalFill, a bioceramic sealer, when compared with AH Plus. The difference in results could be due to the difference in gutta-percha cones. Bio-ceramic coated cones were used in their study whereas normal gutta-percha cones were used in this study. Another difference is TotalFill was employed in their study and BioRoot RCS was used in this study. The compositional difference between the two sealers is the presence of calcium phosphate in TotalFil and water soluble polymer in BioRoot RCS. In bioceramic sealers, tricalcium silicate helps in minimizing shrinkage during setting of the sealer.[21] Smaller particle size and lower viscosity enhances its flow into dentinal tubules which improves its bonding efficiency to dentin and results in increased dislocation resistance.[22]

Root canals prepared with 6% tapered instruments showed higher bond strengths than 4% tapered instruments, though they did not differ significantly. This could be due to the increased linear resistance as more surface area is available for chemical bonding to root dentin in canals prepared with 6% tapered instruments.[23] In all the groups, coronal-third specimens exhibited higher values than middle-third specimens and middle-third specimens exhibited higher bond strength than apical-third specimens, with a statistically significant difference. The above findings are in agreement with other studies where bond strength values were lower in a corono-apical direction.[17,24-26]

Physiologic changes in the root dentin, such as tubular sclerosis or intratubular calcifications may have an impact on the permeability of root dentin.[27] Dentinal tubules in the apical third are fewer, less patent and in some areas of apical-third irregular dentin is seen without dentinal tubules. Consequently, there will be less resin tag formation. There is a difficulty in applying uniform sealer and moisture removal in the apical area.[28]

Another reason for low bond strength in the apical third is ineffective bonding due to the presence of more smear layer than in coronal and middle thirds. Dentinal tubule openings are wider in coronal and middle thirds than in the apical third, which allows the irrigants to act more effectively in the coronal and middle thirds.[29]

Further studies are required to establish the adhesive nature of these mineral-based bioceramic sealers. Clinical performance of this mineral-based sealer needs to be studied to establish its bioactive benefits.

CONCLUSION.

BioRoot RCS exhibited comparable bond strength to AH Plus. Micro-push-out bond strength of 6% taper canals is higher than 4% taper canals though the difference is not significant statistically. Bond strength in the coronal third of root canals is highest and apical third is lowest in all the groups.

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